Faulting history and segmentation of the Tokamachi Fault Zone in Niigata Prefecture, Central Japan

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Tokamachi basin, which located in the southern part of Niigata Prefecture, is bounded by active faults along both of east and west sides of its basin. Those faults are called as Tokamachi Fault Zone, which is divided into two parts, the eastern and the western segments by HERP (2005). In their fault map, the western segment distributes along the western margin of basin from north to south, then after crossing the Shinano river, it continues to the Tsunan and Miyanohara faults with direction of NE-SW to N-E on the another side of the Shinano river. HERP (2010) evaluated the timing of faulting events on both segments of Tokamachi Fault Zone, though there was no data about Tsunan and Miyanohara faults. We will present new data of activities of these faults based on geomorphological and geological surveys as well as discussion on segmentation of Tokamachi Fault Zone deduced from the paleoseismological data of this fault zone and the geological structure of this region.

On Tsunan fault, we excavated all core borings and a pit along two lines across the fault scarplet at Himizo, Tokamachi city. Fault cuts Holocene fluvial terrace with direction of NE-SW and produces east-facing-scarplet with height between 2-5 meters. We excavated boring of depth with 4-5 meters at 4 sites along the southern line and 3 sites along the north line. A pit with 7 meters in length and 2 meters in depth, was excavated on the north line.

On Miyanohara fault, which is located on the late Pleistocene fluvial terrace near the prefecture boundary between Niigata and Nagano, we excavated all core boring at Kameoka, Tsunan town. Borings with depth of 10 meters were excavated at 5 sites across the south-facing fault scarp with 5 m height and an extra-boring with depth of 21 meters on the down-thrown side of the fault scarp.

We also conducted trenching surveys on the eastern segment of Tokamachi Fault Zone at 2 sites, Otajima and Baba. One of results from Otajima will be presented by another presentation in this session (Taniguchi *et al.*, 2016). About another result at Baba, we could not find any faults on the trench walls, meaning the scarplet produced not by faulting but by erosion of a blanch stream of the Shinano river.

In our presentation, we will present the history of the fault activities and slip-rates of these faults by using the results of 14 dating and tephra analysis. And, we will discuss the segmentation model of Tokamachi Fault Zone, based on comparison with those data in Tokamachi basin area and difference of geological structure both side of basin.

The contents of this presentation is a part of the result of the Complementary Survey Project of Active Fault by HERP in 2015 FY.

Keywords: active fault, Tohkamachi Fault Zone, faulting history, segmentation of fault, trenching survey, Niigata Prefecture

Dating of marine terraces based on arrayed boring cores in Chikura Lowland, Southern Boso Peninsula, and restriction of history of Kanto earthquakes

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It is well known that along the Sagami Trough, located in the south of Kanto region, central Japan, two great earthquakes occurred as the 1703, M 8.2, “Genroku” Kanto earthquake and the 1923, M7.9 “Taisho” Kanto earthquake. To increase our ability to forecast such megathrust earthquakes, it is important to paleo-seismologically estimate the history of past events from geological evidences along the coast. The recurrence intervals of these earthquakes have been deduced from 14C age of the shell fossils picked from marine terraces considered that were emerged at the time of the past Kanto earthquakes. Based on these measurements, the recurrence intervals of so-called Genroku type, which is the larger one, have been considered to be ~2,000 to ~2,700 years from these evidences (Nakata et al., 1980). However, some recent studies on paleoseismology (Uno et al., 2007; Shishikura, 2014) and geodesy (Sagiya, 2004) have provided new evidences contradict to such construction, leading to the need for reevaluating the history of the past earthquakes there. In this study, we aim to reexamine the emergence history of the marine terraces in the Chikura lowland, located on the eastern side of the southernmost part of Boso Peninsula based on the arrayed drilling core samples newly obtained by an AIST/GSJ project.
We used the drilling cores obtained from four steps of marine terraces which are named Numa I, II, III, IV, (Nakata, 1980), and identified in Chikura lowland along the two observation lines. We inferred and interpreted the sedimentary environment of the strata of each depth and collected shell fossils for dating marine terraces. We could obtain the fossil samples from strata probably deposited in shoreface suggesting nearly the timing of uplift as inferred from the lithofacies and habitat environment of the shells. The radiocarbon dating was conducted by using accelerator mass spectrometry (AMS) deployed in the Atmosphere and Ocean Research Institute, University of Tokyo, which enabled the highly accurate measurement of approximately 30 years of the measurement error. From the result of radiocarbon dating, it is deduced that the highest terrace (Numa I) in Chikura lowland was emerged at ~6,300 cal yBP, the second (Numa II) was after ~3,000 yBP and the third (Numa III) was after ~2,000 yBP. These dates show the later ages than previously well-accepted data: Numa I was ~7,200 cal yBP, Numa II was ~5,000 cal yBP, Numa III was ~3,000 cal yBP. We considered newly examined the amount of the ocean reservoir effect, $\Delta R = 60 \pm 31$ years.
Compared with the previous results obtained in the other areas in the southernmost part of Boso Peninsula, it is reasonable to consider that the terrace previously regarded as Numa II in Chikura actually corresponds to Numa III terrace of the western coast. Then, it comes to show the existence of some discontinuity of marine terraces between eastern and western coast of the southernmost part of Boso Peninsula. As a result of investigation on the physically constrained fault model, it seemed to be unreasonable to consider the existence of earthquakes, which produced significant gap in the amount of uplift between the eastern and western coasts of the southernmost Boso Peninsula (See the presentation by Komori et al., 2016, this meeting). Thus, the revealed inconsistency in the age of marine terraces may be discussed more in-depth from the viewpoint of the problem in identification of marine terraces or certainty of radiocarbon dating including those for the other areas done in previous studies. We will conduct the similar surveys for the other areas of this region to reexamine the history of the Kanto earthquakes.

Keywords: Kanto earthquake, Marine terrace, paleo-seismology

Did the east-ward migration of the Amur Plate cause the series of inland large earthquakes from central Honshu to eastern Kyushu during late 16 th century ?

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A series of large inland earthquakes including the 1586 Tensho earthquake (M7.8+/-0.1) and the 1596 Keicho earthquake (M7.5+/-0.25) occurred in the central to western part of Japan arc during late 16 th century. The source faults of these earthquakes are active faults in central Honshu Island (Shogawa fault zone, Atera fault zone and Yoro-Kuwana-Yokkaichi fault zone) and the Median Tectonic Line active fault zone in Shikoku Island and eastern Kyushu Island. These source faults locate along the south-eastern marginal area of the Amur Plate demonstrated by Tamaki and Honza (1985) and Taira (2001). The source faults in the central Honshu Island can be projected on the N10W direction line which is normal to the motion of the Amur Plate and strike of the Median Tectonic Line in Shikoku and eastern Kyushu Island with a little gaps and a little overlaps except for the southern-most part (Arima-Takatsuki fault zone). Toda (2011) calculated static Coulomb stress changes by movement of one of the source fault of the Tensho earthquake source faults, and he made clear only little stree change caused on the other source faults. These two facts suggest that the east-ward migration of the Amur Plate is a major factor of series of major inland earthquakes in late 16th century. This hypothesis would support that southeastern margin of the Amur Plate makes broad collisional plate boundary in central Honshu Island (Komatsubara, 2015), and huge earthquake sequence which total seismic moment is compatible with the plate boundary earthquake would occur.

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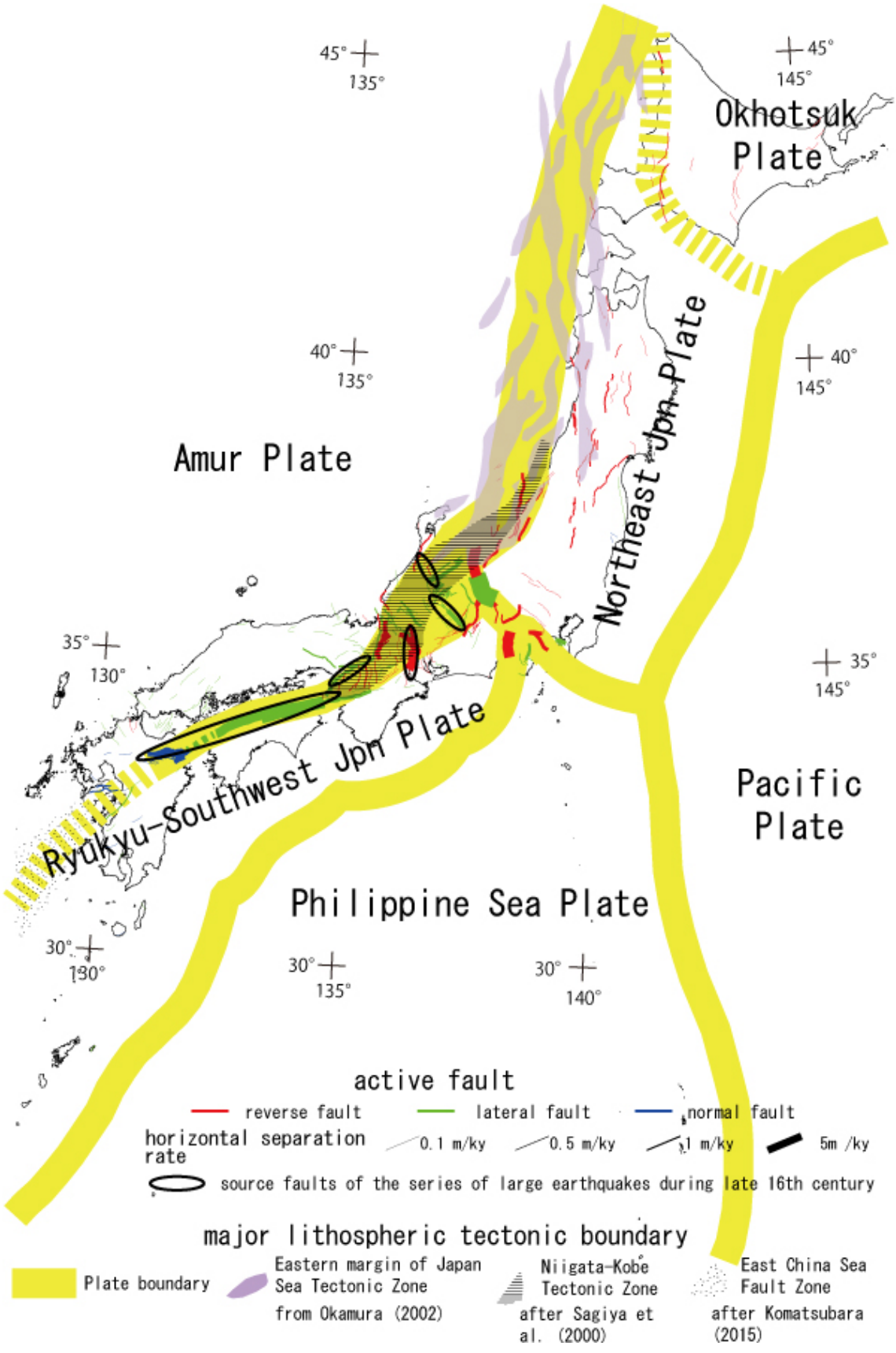
Keywords: historical earthquake, huge inland earthquake, Amur plate, collision boundary, central Honshu



Application of Dating Method by Free Iron Oxides Analysis for loess sediments (Red-Brown soil Layer) of Matsue Area, Japan

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As an alternative to soil dating method by using widespread tephras, it is proposed dating method based on free iron oxides analysis by Nagatsuka (1973).
In the Matsue area, tephras from Sanbe volcanoes (SK, about 105ka) and Daisen volcanoes (DMP, about 130ka) are preserved. In this study, the authors examined the applicability of dating method by free iron oxides analysis for loess sediments (Red-Brown soil layer) below the DMP.
As a result, loess sediments below the DMP is classified red soils by Nagatsuka (1973).
Sasaki(2011) proved that it would take about 125ka for red soils to develop. The age is most consistent with tephra stratigraphy and chronology.
It shows that this method can be a good index of the degree of soil development.

Keywords: Free iron oxides analysis, Crystallinity ratio, Soil age, Loess sediments, Red soil, Matsue area

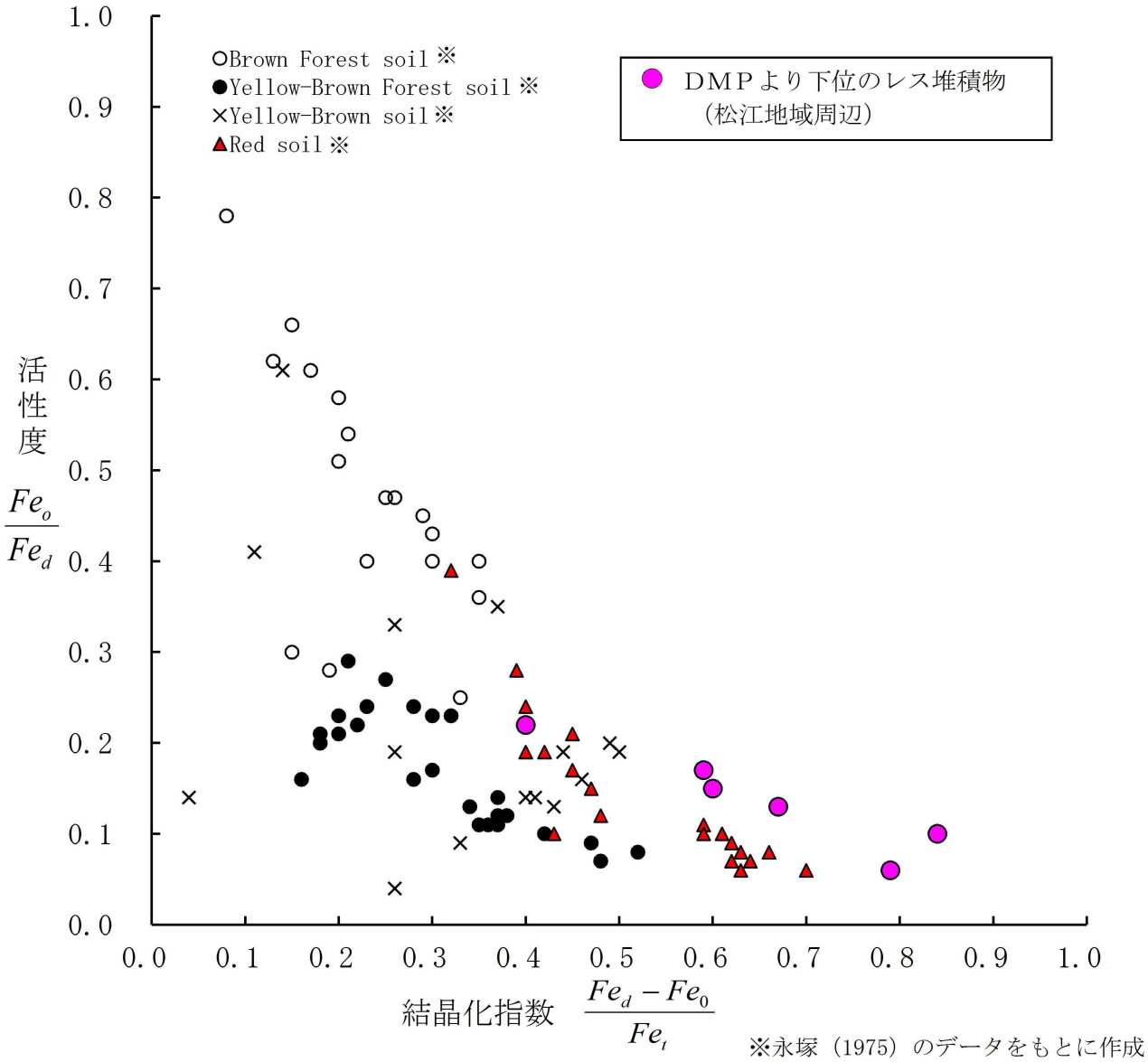

図　DMPより下位のレス堆積物における活性度－結晶化指数の関係

Paleoseimological study of the Midorikawa fault zone in Kyushu Island, Japan

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Midorikawa fault zone is distributed between Yamato town and Misato town, Kumamoto prefecture, Kyushu Island, Japan which has ENE-WSW direction. This fault consists of clear geological boundary at the northern margin of Kyushu Mountains and it is partially overlaps with Usuki-Yatsushiro Tectonic line which divide Inner and Outer zones of the Southwest Japan (Saito et al., 2005, 2010). Therefore, Midorikawa fault is a part of an important tectonic line at the geotechnical subdivision in the Southwest Japan.

The Headquarters For Earthquake Research Promotion released the long term estimation for the Midorikawa fault zone on February 2015, and the fault zone shows normal fault with dextral strike-slip and the dipping angle is about 70-90 degree to the north direction. Average recurrence interval was estimated about 34,000-68,000, if the dextral movement was negligible. However, no trench and boring investigation has ever done for the Midorikawa fault zone and the specific paleoseismological data has not been obtained. Thus the AIST accepted the contracted study in 2015 from the Ministry of Education, Culture, Sports, Science and Technology and did the investigation for the paleoseismic record.

Our field work is done at the Kariya, Yamato town where is located Kamano fault which is the the eastern margin of the Midorikawa fault zone (Chida, 1980), graben structure is developed in this area. Four boring research were done before the trench and all core consist of Aso-4 pyroclastic deposit, loam, humic silt, orange-colored pumice layer, loam and humic silt from bottom to top. An orange-colored pumice layer is overlaying the humic silt, thus it is possibly the Kusasenri-gahama pumice (Kpfa, 31ka) layer (Miyabuchi et al., 2003). The trench was dig across the southern edge of the graben and it size is around 16m×4m×2.5m. Loam, Kpfa, humic silt, loam and black soil was exposed from the bottom to the top. There is a clear fault which displace the Kpfa and dipping to the north direction, This indicated that Kamano fault is activated after the Kpfa. There are another few displacement is recognized therefore few events is suggested at the hanging wall side.

We will discuss the paleoseismic record with the carbon dating data in detail.

Keywords: Midorikawa fault zone, active fault, paleoseismology

Elucidation of activity history on Yatsushiro-sea submarine fault group-Challenge to the Seismic Trenching using high-resolution seismic survey-

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[Background]
In the survey for the offshore active faults, generally seismic exploration is used. However, in seismic explorations, these are emphasis on the grasp widely geological structure with survey lines of several 100 meters or several kilometers interval. So, estimation of faulting with high -precision has not yet at offshore area.
[Purpose]
In this study, we aim to clarify the subsurface deformation of fault using high-resolution seismic survey with 20-50 meters interval survey lines.
Target area is Yatsushiro-sea which is located Midwest of Kyushu. Yatsushiro-sea is the south part of Hinagu Fault Zone. Hinagu Fault Zone is extending from Aso volcano to Yatsushiro-sea. In the Yatsushiro-Sea, some seismic explorations were carried out so far.
[Results of seismic survey]
1) Distribution of faults
A-FA1 fault with NE-SW direction is distributed in central part of survey area. And A-FA1 extends to the NNE direction (based on Kagohara et al., 2011). In west side of A-FA1, we observed some faults which is extends to NE-SW direction and curves clockwise. Three faults extend to NW-SE and oblique to A-FA1 with high angle.
2) Acoustic stratigraphy and activity history
We recognized 7 depositional sequences (A1, A2, A3, B1, B2, C, D layers from the top) based on reflection patterns. Result of piston coring, we estimate formed period of some unconformity,1) reflector R1 (between D and C layers) is Last glacial maximum erosion surface,2) reflector R2 (between C and B2 layers) is Post-glacial erosion surface,3) reflector R5 (between B1 and A3 layers) is about 3,000 yBP. Central part of A area, we identified at least 5 paleoseismic events. And the latest paleoseismic event is occurred between 1,700y BP and 1,000 y BP.

Keywords: Hinagu Fault Zone, Yatsushiro-sea submarine fault group, Strike-slip fault, Seismic Trenching

Tsunami deposits of the 863 (Jogan 5) earthquake in Junicho Lagoon Swamp, along the western Toyama Bay, central Japan

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No large earthquake tsunami has not been recorded in recent years in Toyama Bay. However, earthquake tsunamis have sometimes occurred in the eastern margin of Japan Sea and the most recent historical example attacked the Toyama Bay is the 1-2 m tsunami in Himi City, which was raised by the source fault of the 1833 offshore Yamagata Prefecture earthquake. In order to search for the pre-historical evidences for tsunamis, marine event deposits (tsunami deposits) transported by the earthquake tsunami were deciphered.
Firstly, we analyzed core samples from the southern Toyama Bay coast of the former Houjozu Lagoon and discovered benthic foraminiferal shell in tsunami deposits. From microscopic observations, it became clear that sample No. 5-2 from the Hojozu Lagoon is a tsunami deposit and that the tsunami hit after 2974-2834 calBC and before 1910-1754 calBC. Sedimentological characteristics of sample No. 5-2 indicate that tsunami deposits arond Toyama Bay, might offer an index evidence for determining tsunami deposits. The major features are aggregated sand, allochthonous shells, and benthic characteristic foraminiferal shells derived from greater depth [*Ammonia ketienziensis* (Ishizaki)], and abundant coastal benthic foraminiferal shells (*Ammonia beccarii*).
Along the western Toyama Bay coast, a layer of strange event-deposits containing miscellaneous materials (fossil shells, wood and earthen ware pieces, etc) derived from both land and sea were found in the Junicho Lagoon Swamp in Himi City. The strange assemblage in the deposits was already reported by Matsushima (1981) who pointed out that an earthquake and/or paleocurrent from tsunami could be responsible. In order to identify the factor responsible for these event deposits, the University of Toyama Tsunami Mitigation project carried out drilling surveys at Kubo and Iseomachi in Himi City where core samples (sampleNo.901-1) and (sampleNo.145) respectively were collected. As a result, it was found that the event deposits consist of coarse sand layer which apparently corresponds to the above the Junicho deposits.
This study aimed to make the description and correlation of the core samples, and to reveal the factors and timing of formation of these event deposits. In order to determine the formation age of the event deposits recovered from drilling point of sample No.145, analyses of benthic foraminiferal shells using stereoscopic microscope were conducted as well as radiocarbon dating and an appraisal of pottery pieces.
From the results, the event deposit has been established to be in a marine origin, although no foraminiferal shells of deep-sea origin was detected yet. Based on the dating data, the stratigraphy of the Junicho event deposits was correlated to that of the drill-core sample No.145 and the marine event was found to have been occurred at a time between 1700 BP (calendar year AD315) from 826 BP (AD1190). As for the historical records during this period, the only earthquake tsunami that might bring a great damage to the ancient Toyama was found to correspond to the Jogan 5 (July 10 AD863) Etchu and Echigo earthquake.
As future challenges, it is necessary to find any benthic foraminiferal shells derived from the deep-sea bottom of Toyama Bay to exclude the probability of tidal swell origin for marine event deposits.

Keywords: earthquake tsunami, Toyama Bay, event deposits

Re-examination of scaling relations for crustal earthquakes.

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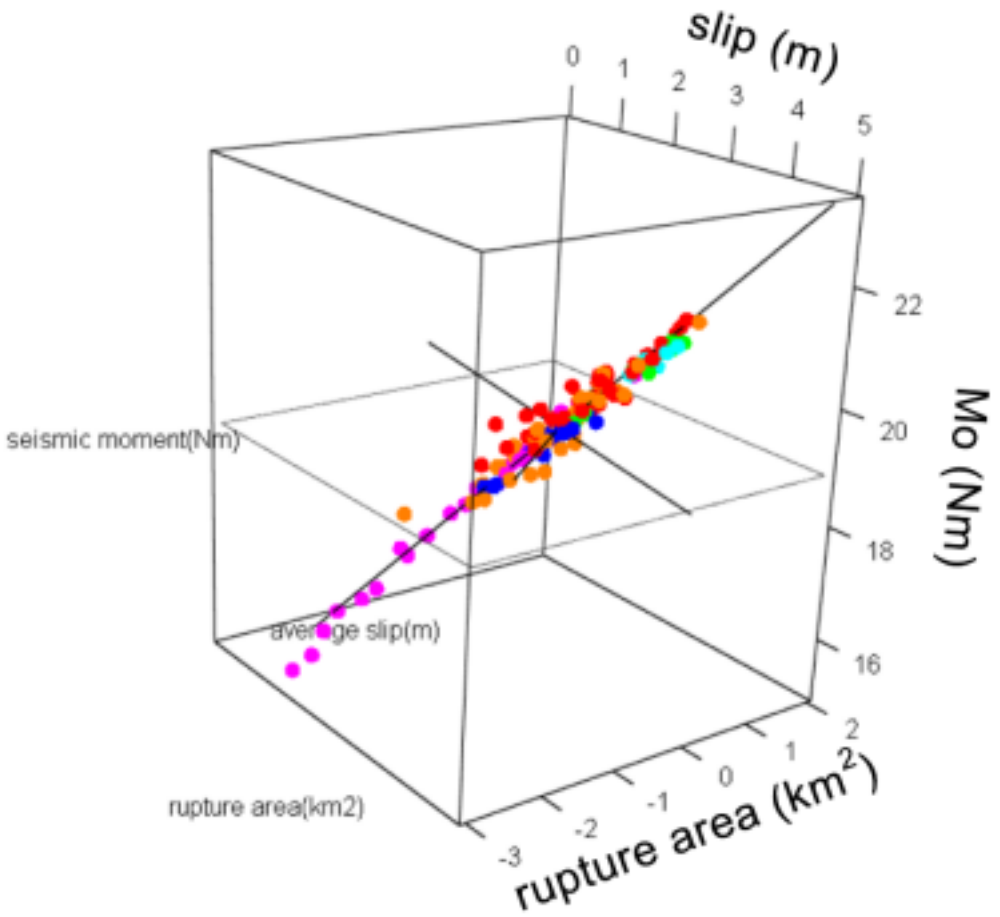
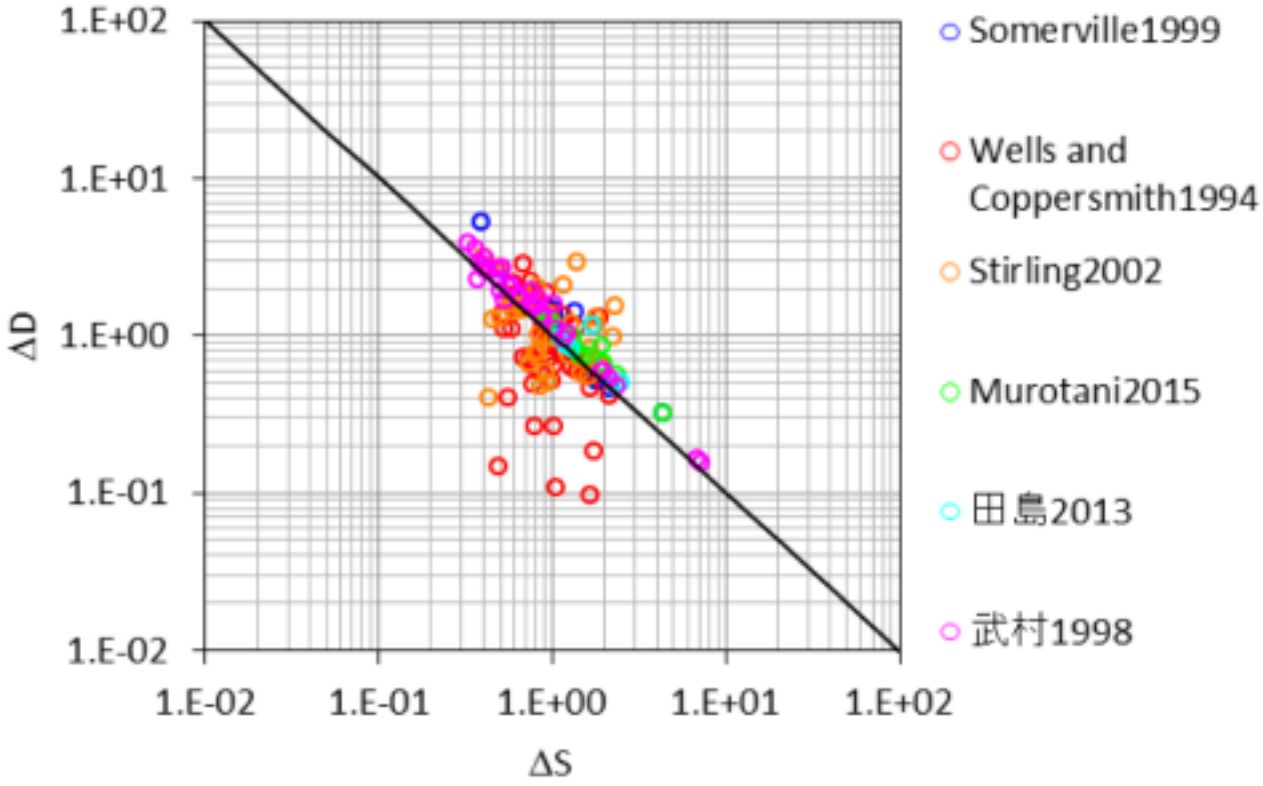
Some of the scaling formula have been already proposed for crustal earthquakes (e.g. Matsuda (1975), Takemura (1998), Irikura and Miyake (2001), Tajima addition (2013) and Murotani et al. (2015)). Matsuda (1975) and Takemura (1998) showed scaling relations between fault length L and magnitude of earthquakes. Also, Irikura and Miyake (2001), Tajima et al. (2013) and Murotani et al. (2015) proposed scaling relations between fault area S and magnitude or seismic moment.
1) Matsuda (1975) : $\log L=0.6M_j-2.9$
2) Takemura (1998) : $\log L=0.75M_w-3.77$ $(6.8\leq M_w)$
3) Irikura and Miyake (2001) : $M_0=(S/4.24\times10^5)^2\times10^{-7}$ $(6.5\leq M_w<7.4)$
4) Tajima et al. (2013) : $M_0=0.877\times S\times10^{11}$ $(7.5\leq M_w)$
5) Murotani et al. (2015) : $M_0=1.0\times S\times10^{11}$ $(7.4\leq M_w)$
These scaling formulas indicate relation between one variable parameter (i.e. fault length L or fault area S) and the seismic moment or magnitude. When we calculate seismic moment with these scaling formulas and slip amount using the formulas, Mo=μDS and S=LW, the resulting slip amounts vary from formula to formula. When we assume a fault with L=50km and W=20km, we obtain Mw=7.10 and average slip D=1.64 by Irikura and Miyake (2001) and Mw=7.29 and average slip D=3.21 by Takemura (1998). Such differnces would significantly affect the results of seismic hazard assessments.
In this study we proposed a scaling relation of seismic moment with two variables parameters, fault area S and average slip D. We used the same earthquake data used in Irikura and Miyake (2001) and Takemura (1998). We obtained regression line with principal component analysis. The relation between the residual of slip ΔD and the residual of area ΔS could be expressed by $\log\Delta D = -\log\Delta S$ ($\Delta D * \Delta S = 1$), which indicates that fault area S and the average slip D are not independent parameters on earthquake data used in this study.

Keywords: scaling relation, crustal earthquake, earthquake source model, earthquake hazard assessment





A Bayesian prediction for active faults using spatial similarity of variation of recurence intervals

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We propose a new Bayesian method of probability prediction for recurrent earthquakes of inland active faults in Japan. Renewal processes with the Brownian Passage Time (BPT) distribution are applied for over a half of active faults in Japan by the Headquarters for Earthquake Research Promotion (HERP) of Japan. Long-term forecast with the BPT distribution needs two parameters; the mean and coefficient of variation (COV) for recurrence intervals. The HERP applies a common COV parameter for all of these faults because most of them have very few specified paleoseismic events, which is not enough to estimate reliable COV values for respective faults. However, different COV estimates are proposed for the same paleoseismic catalog by some related works. It can make critical difference in forecast to apply different COV estimates and so COV should be carefully selected for individual faults.
Recurrence intervals on a fault are, on the average, determined by the long-term slip rate caused by the tectonic motion but fluctuated by nearby seismicities which influence surrounding stress field. The COVs of recurrence intervals depend on such stress perturbation and so have spatial trends due to the heterogeneity of tectonic motion and seismicity. Thus we introduce a spatial structure on its COV parameter by Bayesian modeling with a Gaussian process prior. The COVs on active faults are correlated and take similar values for closely located faults. It is found that the spatial trends in the estimated COV values coincide with the density of active faults in Japan. We also show Bayesian forecasts by the proposed model using Markov chain Monte Carlo method. Our forecasts are different from HERP’s forecast especially on the active faults where HERP's forecasts are very high or low.

Keywords: earthquake recurrence interval, BPT distribution, Coefficient of variation

On the differences of source areas between 1703 Genroku earthquake and 1923 Taisho Kanto earthquake from the detailed examination of seismic intensities

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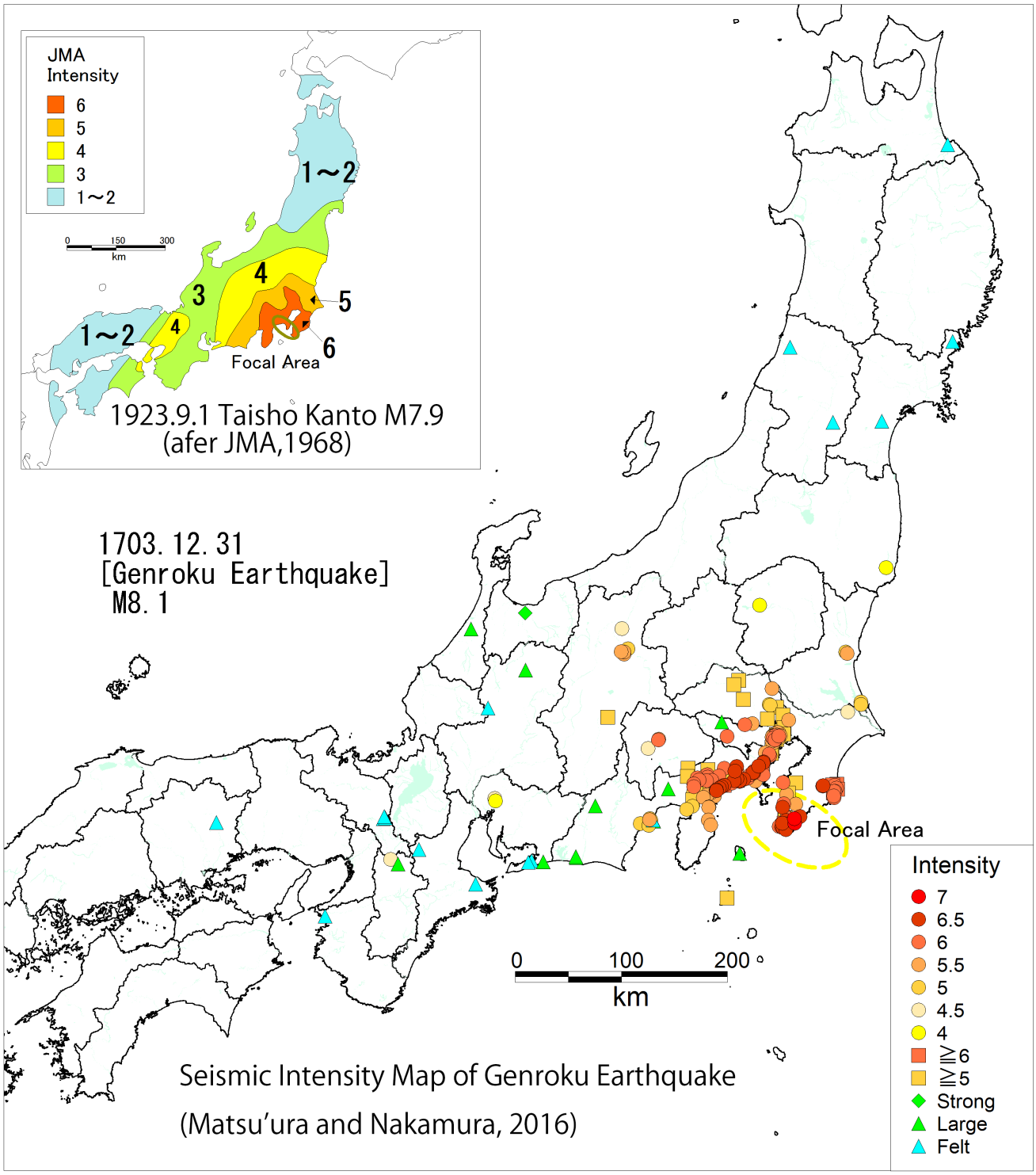
We have examined the whole known historical documents on the Genroku earthquake, other than those related to small houses of bannermen in Edo city. The M8.1 Genroku earthquake occurred at the midnight on December 31, 1703 on the plate boundary along the Sagami Trough. It has been widely believed that the Taisho Kanto earthquake at noon on September 1, 1923 of M7.9, occurred in the western part of the source area of the Genroku earthquake. However, we found that the westernmost part of the 1923 Taisho Kanto focal area, where the Izu peninsula is colliding to the Honshu Island, did not move at the time of Genroku. The seismic intensities of the Genroku earthquake are evidently smaller than those of the Taisho earthquake in the western Japan (Fig. 1). This feature is also apparent even in the existing intensity maps of the both events.
At the time of 1923 event, in Osaka branch of the Bank of Japan, piled up money boxes fell down to the floor. The intensity at the Osaka Meteorological Observatory was 4 at the time of Taisho. However, we have not yet found a historical material, which shows that the Genroku event was felt in Osaka. The 1923 event was followed by many M7-class aftershocks, including the large intra-plate earthquake in 1924 at Tanzawa. After the Genroku event, historical materials only recorded a conflagration in Edo city a few days later, but no strong aftershocks were noted.
The source area of the Taisho Kanto earthquake consists of the plate-boundary type part, which is the western half area of the Genroku earthquake, and the intra-plate type in the westernmost part in Kanagawa Prefecture, which generated strong short-period waves. Taisho event was felt strong in the western Japan. In the Genroku earthquake, the area off the southeastern part of Boso peninsula moved and caused the devastating tsunami disaster along the Sotobo area in Chiba Prefecture. Not only the tsunamis but also the strong motions of both earthquakes are very different from each other. These are not the similar events, nor the characteristic earthquakes. We should mind these differences to plan the disaster mitigation for the next large earthquake in the southern Kanto district.

Keywords: Genroku earthquake, Taisho Kanto earthquake, Sagami trough, Collision of the Izu Peninsula, detailed analysis of historical materials



A description of a tsunami in the essay "Kyu-ai Zuihitsu" written by To-u Momoi (? - 1792)

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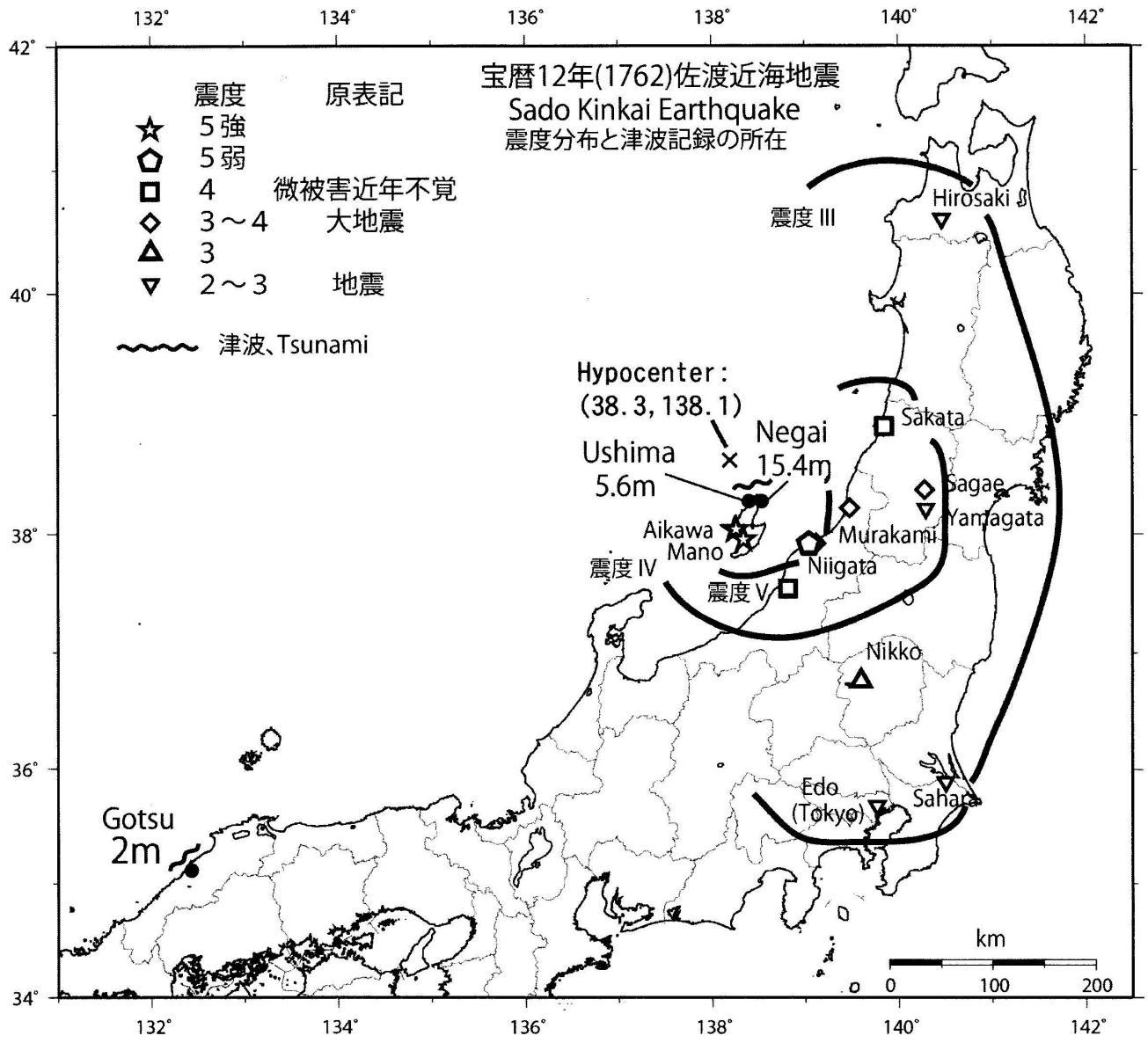
In the end of 18th century, To-u Momoi, who was a son of a rich merchant in Kyoto wrote an essay called "Kyuu-ai zuihitsu". He sent a life of long travels. He began travel in 1758 and finished travels by the end of 1788. He visited almost all part of the Japanese countries, and recorded many episodes experienced in his travel in his essay. But unfortunately, he seldom wrote year of each episode. He mentioned in a section on a tsunami which hit the Japan Sea coast of the mouth of Gonogawa river, Shimane prefecture, Western part of Honshu Island. Unfortunately he did not write the year of the Tsunami. He saw this tsunami from afternoon to the night, and he wrote "it was September and full moon night". We check the tsunami catalog written by Watanabe(1998), and found out that the Sado Kinkai earthquake of October 31, 1762 (September 15, the 12th year of the Horeki Era in Japanese calender).
Acknowledgement: The present study was achieved as a part of the commissioned research on disaster prevention for nuclear facilities named “Study on the historical tsunamis in Japan Sea (2015)” proposed by the Nuclear Regulation Authority, Japan.

Keywords: a tsunami in Japan Sea, a historical tsunami, the 1762 Sado-Kinkai earthquake



Examination of the damage description in Kyushu by the large earthquake on June 30th, 1498 on a war chronicle

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On June 30th, 1498, ground shaking was widely recorded in western Japan. Court nobles in Kyoto (the then capital city of Japan) described on diaries strong shaking there in *Saru-no-koku* (3:00-5:00 p.m.) although they did not mention any damage by this earthquake. According to the historical books and chronicles compiled in Edo Period, felt area of this earthquake extends from Osumi region (Kagoshima Pref. at present) in Kyushu Island to Koshu region in Honshu (Yamanashi Pref. at present). Large earthquake in *Mi-no-koku* (10:00-12:00 a.m.) on the same day and serious damage in Kyushu are described on the war chronicle *Kyushu-gunki* which was written in the early 1600s. Although this war chronicle is one of the popular literatures which was written more than 100 years after the 1498 event, the damage descriptions have been accepted by many seismologists without evaluating the reliability, and considered to be important information on the location of this earthquake.
Usami (1987) regarded the earthquake in *Mi-no-koku* as an M~7 event in the Hyuga-Nada Sea on the east side of Kyushu Island along Nankai Trough, while he commented that credibility of *Kyushu-gunki* is low. Tsuji and Ueda (1997) and Tsuji (1999) interpreted a part of the damage descriptions in Kyushu as a tsunami and claimed that the 1498 event was an unknown great Nankai earthquake based on the tsunami around Kyushu and extensive felt area in western Japan. Ishibashi (1998, 2002, 2014), however, pointed out that the 1498 event could not be a great Nankai earthquake because the damage descriptions in Kyushu were doubtful and the interpretation by Tsuji and Ueda (1997) and Tsuji (1999) was unreasonable. Incidentally, Ishibashi (2002, 2014) suggested that the 1498 event was possibly an M~7 intra-slab earthquake beneath Kyushu Island like the 1909 earthquake of M7.6. As mentioned above, the location of the 1498 earthquake has been controversial and it is important to reveal whether serious damage in Kyushu was real or not.
In this study, in order to assess whether the descriptions were credible or not, we carefully examined the damage descriptions in Kyushu on the *Kyushu-gunki*. As a result, they are very suspicious because of following reasons: (1) Damage descriptions in Kyushu were generic without location information. (2) Some major earthquakes in the 1200s and 1400s are listed following the damage description, which clearly indicates that the writers had knowledge of the past major earthquakes. Thus, the descriptions of the 1498 earthquake could also have been taken from historical documents and not original. (3) Origin time (*Mi-no-koku*) of the 1498 event is close to that of the great Tokai earthquake on Sep. 11th, 1498. Therefore, the writers possibly confuse the damage of these two earthquakes. (4) Serious famine in Kyushu in 1503 and pains of people by many disasters are also written in the chapter of the earthquake damage, making this chapter a stage setting for later stories. Therefore, the earthquake damage could be a fictitious story. (5) Since *Kyushu-gunki* was completed in 1607, writers should have experienced the 1596 large destructive earthquake in Kyushu when writing the war chronicle. Thus, this experience might have influenced the description of earthquake damage.
Acknowledgement: This study was supported by the MEXT's "New disaster mitigation research project on Mega thrust earthquakes around Nankai/Ryukyu subduction zones".

Keywords: June 30th, 1498 earthquake, war chronicle "kyushu-gunki", serious damage in Kyushu, Hyuga-Nada earthquake, Meio-Tokai earthquake

Paleoseismic study on the Kamishiro Fault, the northern segment of the Itaigawa-Shizuoka Tectonic Line, Japan

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The Mj 6.8 (M_w 6.2) Nagano (Japan) earthquake of 22 November 2014 produced a 9.3-km-long surface rupture zone with a thrust-dominated displacement of up to 1.5 m, that duplicated the preexisting Kamishiro Fault along the Itoigawa–Shizuoka Tectonic Line (ISTL), the plate-boundary between the Eurasian and North American plates, in the northern Nagano Prefecture, central Japan. To better understand the nature of the seismogenic fault zone, we carried out paleoseismic study on the Kamishiro Fault. Field investigations and trench excavations reveal that seven morphogenic earthquakes (E1~E7) prior to the 2014 M_w 6.2 Nagano earthquake have occurred on the Kamishiro Fault during the past ~6000 years, in which the timings of three recent events (E1~E3) corresponding to historical-recorded earthquakes occurred in the past ~1200 years are well constrained, suggesting an average recurrence interval of ~300–500 years on the seismogenic fault of the 2014 Kamishiro earthquake. The most recent event (E1) prior to the 2014 earthquake occurred within the past 200 yr, and corresponds to the 1918 M 6.5. The penultimate faulting event (E2) occurred in the period between AD1800 and AD 1400 and is probably associated with the 1791 M 6.8 earthquake. The antepenultimate faulting event (E3) is inferred to have occurred in the period between AD ~700 and AD ~1000, corresponding to the AD 841 M 6.5 earthquake. The oldest faulting event (E7) is identified to be occurred in the period during ~5600–6000 yr BP in this study area. The vertical slip rate during the early Holocene is estimated to be 1.2–3.3 mm/yr with an average of 2.2 mm/yr. When compared with the active intraplate faults of Honshu Island, Japan, the relatively high slip rates and short recurrence intervals for morphogenic earthquakes within the Kamishiro Fault developed along the ISTL indicate that the present activity of this fault is closely related to seismic faulting along the plate boundary between the Eurasian and North American plates.
Keywords: 2014 M_w 6.2 Nagano earthquake, paleoseismicity, Kamishiro Fault, recurrence interval, morphogenic earthquake, plate boundary

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Keywords: Kamishiro Fault, paleoseismicity, 2014 Mw 6.2 Nagano earthquake, Itoigawa-Shizuoka Tectonic Line active fault system

Seismic cycle of the Kamishiro fault (northern part of the Itoigawa-Shizuoka Tectonic Line active fault system) revealed by tectonic geomorphology at Warabidaira, Hakuba Village, central Japan

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An Mj=6.7 (Mw=6.2) earthquake occurred the northern part of the Itoigawa-Shizuoka Tectonic line active fault system. The surface rupture appeared in association with the earthquake along the previously mapped Kamishiro fault. The maximum vertical displacement of the surface rupture is about 1 m.Long-term Kamishiro fault slip rate estimated of 3-4 mm/yr by drilling survey and tectonic geomorphology. It has believed that recurrence interval of the Kamishiro fault estimates of 1,250 to 1,500 years for the large quakes by trench survey. In this case, average vertical displacement per event estimates of 3 to 4 m.

The magnitude of the 2014 event is smaller than predicted magnitude along the Kamishiro fault. Our aim is to clarify the crustal deformation system in Kamishiro area and therefore investigated it to clarify paleoseismology and the tectonic geomorphology on the surface rupture at Warabidaira in Hakuba village.

We defied five Holocene terraces as Lc2 terrace, Lc1 terrace, Lb2 terrace, Lb1 terrace, La terrace in order of young on the landform classification. The amounts of vertical offset of the Lc2, Lc1, Lb2, Lb1, and La terrace surface are 0.3-0.4m, 0.5m, 1.1m, 1.6m, and 1.5m respectively. The amounts of left-lateral offset of Lc1/Lc2 terrace, Lb2/Lc1 terrace,Lb1/Lb2 terrace,and La/Lb1 terrace are about 1.0m,1.0m 5.0m,and 7.5m, respectively. The Lc2, Lc1, Lb2, Lb1 and La terrace emerged at modern, modern, 1695-1535 Cal.BP, 1530-1355 Cal.BP and 2055-1900 Cal.BP, respectively. The vertical and left lateral average slip rate is calculated to be 0.8mm/yr, and 3.5mm/yr, respectively. The average recurrence interval is 586-880 year.

Keywords: 2014 Kamishiro fault earthquake, surface rupture, trench excavation, left-lateral offset

Vertical slip rate estimated from young lacustrine sediment core samples across the Kamishiro fault, Itoigawa-Shizuoka Tectonic Line, central Japan

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We conducted drilling survey to re-examine a rate of the vertical deformation on the Kamishiro fault, northern part of the Itoigawa-Shizuoka tectonic line active fault system, central Japan. Exacted two cores, obtained on the hanging wall of the Kamishiro fault, consist of paleo-lacustrine sediments (alternation of sand-mud and sand-gravel layers). In the KMS-1 core, closer to the fault trace, extracted strata shallower than a depth of 3.2 m from the surface are horizontally laminated. The core extracted from depths from 3.20 m to 16.20 m exposes inclined strata with apparent dips of 20° to 30°, whereas upstanding strata were recovered from the core depth of 16.20 m to 28.60 m. We encountered horizontaly laminated sand and mud layers again deeper than the sharp boundary at a depth of 28.65 m, In the KMS-2 core, farther from the fault trace, sediments shallower than a depth of 4.20 m are horizontally laminated. At depths from 4.20 m to 38.30 m, inclined strata with dips of 20 to 30 degree was extracted, whereas upstanding strata were recovered with shear planes at depths of 38.30 to 42.17 m. Across the sharp boundary at the core depth of 42.17 m, sand and mud layers return to be horizontally laminated.
We interpret that the sudden lithofacies change from overlying inclined strata to underlying horizontally-laminated strata, commonly shown in the both cores, is penetrating the Kamishiro fault. This interpretation is supported by ^{14}C ages of the two cores. Thus, ^{14}C age is younger (ca. 16,000 yr BP in the KMS-1 core, ca. 24,000 yr BP in the KMS-2 core) just below the horizon shown by the sharp boundary than that above the boundary (ca. 30,000 yr BP in the KMS-1 core, older than 50,000 yr BP in the KMS-2 core). On the basis of altitude of facies boundaries and over fifty radiocarbon ages, cumulative vertical displacements are 12–14 m at 9,000 yr BP, 16–17 m at 11,000 yr BP, ≥41 m at 21,000–24,000 yr BP, respectively. These vertical separations and ages indicate that average rates of vertical displacement in the study area are 1.2–1.4 mm/yr during the past 10 ka, and higher than 1.6 mm/yr during the past 25 to 30 ka, respectively. It implies that a coseismic vertical slip of 0.3–0.5 m at the 2014 earthquake released a strain accumulated during the past 210 to 420 years.

Keywords: Itoigawa-Shizuoka Tectonic Line, Kamishiro fault, vertical slip rate, sediment core, radiocarbon dating

Trench excavation survey across the 2014 rupture zone along Kamishiro fault, Itoigawa-Shizuoka Tectonic Line

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The Mw=6.2 Nagano-ken-hokubu earthquake, central Japan, on November 22, 2014 was accompanied by an ~9-km-long NS-trending surface rupture zone along the pre-existing scarp of the Kamishiro fault, a part of the Itoigawa-Shizuoka Tectonic Line active fault system. This earthquake was the first surface-breaking earthquake to have occurred on one of the 110 major inland active faults prioritized for evaluation by the Headquarters for Earthquake Research Promotion that was launched in 1995 after the 1995 Kobe earthquake. To furnish more paleoseismic data to retrospectively evaluate the seismic hazard and to validate pervasive characteristic earthquake model, we excavated paleoseismic trenches across the 2014 rupture zone at two sites, Oide (northern site) and Iida (southern site). Trench walls at both sites exposed evidence for the penultimate surface-rupturing event that had occurred sometime between ~400 cal. B.P. and present. Together with the documented local damages similar to the ones in 2014, we interpret that the 1714 Otari earthquake of M 6 1/4 would have been the penultimate surface-breaking earthquake along the Kamishiro fault. At Oide, we found three or four paleoseismic events during the past 15 ka whose movements accumulated four-to-six-meter high hill-facing fault scarp. The penultimate event, possibly at the Otari earthquake, could have formed larger coseismic vertical separation comparing to < 1m ground tilt at the 2014 earthquake. At Iida, despite a paucity of sediments and unique deformation as a transverse fault, we found five paleoseismic events during the past 53 ka, which is roughly consistent with the result reported by Okumura et al. (1998), except the penultimate event occurred sometime after about 1700 A.D. that is well constrained from an earthenware fragment yielded from a younger unit.
Acknowledgements: This study was performed as a part of “Additional surveys of the comprehensive study of the Itoigawa-Shizuoka Tectonic Line active fault system, Ministry of Education, Culture, Sports, Science and Technology (MEXT)”.

Keywords: Nagano-ken-hokubu earthquake, active fault, paleo-earthquake, surface rupture

Surface rupture and coseismic deformation associated with the 2014 Nagano-ken-hokubu earthquake revealed from differential LiDAR analysis

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The Nagano-ken-hokubu earthquake occurred on November 22, 2014, along the Kamishiro fault, one of the segments of the Itoigawa-Shizuoka Tectonic Line active fault system. A 9-km-long surface rupture associated with the earthquake indicates a N-NW trending, east dipping fault extended to the hyponcentral depth. We mapped the surface rupture and measured the amounts of vertical and horizontal displacements (Okada et al., 2015; Ishimura et al., 2015). However, due to the limited time allowance until winter snowfall starting from December, we could not homogeneously observe ground deformation along the Kamishiro fault. We thus employ differential LiDAR analysis to reveal precise location of surface rupture and coseismic displacement.

The data sets we used for the analyses are 1 m mesh DTM (Digital Terrain Model) data measured in 2009 (pre-event), 2014 (5 days later from the event), and 2015 (about 1 year later from the event). We applied the particle image velocimetry method to obtain 3-D vectors of coseismic deformation (Mukoyama, 2011). The precision of this method is ~0.1 m.

The result shows a clear contrast of vertical displacements and horizontal vector directions between hanging wall and foot wall sides. The locations of these contrasts are corresponding with our field observations (Okada et al., 2015; Ishimura et al., 2015) and let us know missed surface ruptures. From these results, we confirmed the surface ruptures composing of two or three bow-shaped traces. Vertical displacements at some points are larger than the field measurements, indicating underestimates at the field due to wide warping zone. Horizontal displacement was detected at the extending part of the surface rupture, corresponding with InSAR results.

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This study was carried out as a part of “Additional surveys of the comprehensive study of the Itoigawa-Shizuoka Tectonic Line active fault system, Ministry of Education, Culture, Sports, Science and Technology (MEXT)”.

Keywords: the 22 November 2014 Nagano-ken-hokubu earthquake, Itoigawa-Shizuoka Tectonic Line, Kamishiro fault, surface rupture, LiDAR

Fault displacement distribution of the 2014 Nagano-ken Hokubu earthquake based on a differential analysis of multi LiDAR-DEM data

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The author shows 3-D fault displacement distribution of the 2014 Nagano-ken Hokubu earthquake using LiDAR-DEM data acquired before and after the earthquake.

Keywords: Nagano-ken Hokubu earthquake, Kamishiro fault, LiDAR-DEM, fault displacement

Interpretation of SAR interferograms on the ground deformation associated with the Northern Nagano Prefecture earthquake in 2014

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Detailed ground deformation associated with the Northern Nagano Prefecture earthquake in 2014 was well recorded in the interferograms of ALOS-2 "Daichi-2" SAR. We focused on the local interferometric patterns considered to be the reflection of local characteristics of surface displacement, and interpreted them to identify the subsurface structure and motion of rupture of the earthquake fault, with references to the results of ground-penetrating radar profiling and trench excavation survey.

Keywords: SAR interferogram, Northern Nagano Prefecture earthquake in 2014, subsurface rupture structure

Fault geometry on Miura-hanto fault group presumed by comparison of various seismic reflection records

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Miura-hanto fault group (MHFG) mainly appeared at the land area of Miura Peninsula, southern part of Kanto district and are consist from main and southern parts, both showing right-lateral slip with vertical displacement. The main part of the MHFG is divided into two parallel faults whose strikes are WNW-ESE, i.e. Kinugasa-Kitatake fault (north side) and Takeyama fault (southern side).
In a land area and a seaward extension of these faults, several seismic reflection surveys were conducted to elucidate fault geometries and those activities. Further long seismic survey line was set crossing at high angle with the trend of the MHFG from Sagami bay to Tokyo bay to reveal the geometry of the Philippine Sea plate's upper surface.
Since spatial resolutions of these surveys arranged from several centimeter to several hundred meter order, it makes us possible to discuss a detailed fault geometry of MHFG from the sea bottom to the depth of the PHS plate boundary by careful comparing between these seismic profiles.
Then we estimated the location of Takeyama fault from the shallow to the deep by using a high-resolution chirp sonar image, a fine singe-channel profile, middle range multi-channel profiles and other previous seismic profiles derived in the study region.
As a result of careful examination on the seismic reflection profiles, bending of the sea floor and kink-like deformation structures of strata are recognized, implying the existence of a fault. In addition, the fault at the deeper depth is also configured from single and multi-channel profiles as reflection discontinuities. The location of this fault is correlated to the seaward extension of the Takeyama fault, and therefore, we judged the fault as the Takeyama fault. . This fault has the northward dipping, changing inclination angle from steep to gentle as increasing depth. In contrast, there are tilted reflections derived from the Philippine Sea plate (Ministry of education, Culture, sports, Science and Technology 2003). Based on the spatial relationship between Takeyama fault derived in this study and the deeper reflector, there is a possibility that these two faults might continue. However, since we can't continually encompass all the reflections compared to the depth direction, we are planning on discussing it including the comparison with the velocity structure.

Keywords: Miura-hanto fault group, Sea area, Active fault, Seismic reflection survey

Electrical resistivity survey of subsurface structure of an active fault - A case study of the Gomura fault in Kyotango, Kyoto -

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The relationship between earthquake magnitude and displacement accompanying an earthquake was first proposed by Matsuda (1975) for Japanese Inlands. This formula has been widely used to estimate the magnitude of a large earthquake which will occur at a given fault-segment. However, many papers recently pointed out the generation of earthquakes with larger magnitudes than the estimated ones. Revealing subsurface structure of an active fault is not only an important key to overcome the inconsistency (The Earthquake Research Committee, 2010) but also an interesting academic theme. Clear electrical conductivity variation is expected to be identifiable in the vicinity of an active fault as a result of enriched and interconnected fluid (meteoric waters and/or groundwater) in fractures and/or uneven fluid distribution across the fault because of impeded cross-fault fluid flow (e.g., Ritter *et al.*, 2005). The electrical conductivity distribution can provide a new image of the subsurface structure of an active fault.
A clear surface earthquake fault appeared associated with the 1927 Kita-Tango Earthquake in the Tango Peninsula of the northwestern part of Kinki district, Japan. This fault is named the Gomura fault and is one of the fault segments of the Yamada fault system.
We made an audio-frequency magnetotelluric (AMT) survey at twelve stations along a transection across the Gomura fault and obtained two-dimensional resistivity model (GMR model) along the line. The model is characterized by four conductive regions.
(1) Shallow sub-horizontal conductive layer (C1) between 160m and 300m in depth.
(2) Deep sub-horizontal conductive layer (C2) between 750m and 1200m in depth.
These layers are located to the east of a surface trace of the Gomura fault.
(3) Sub-vertical conductive zone (C3) beneath a surface trace of the Gomura fault.
(4) Weak and local conductive zone (C4) beneath a surface trace of the Go-seihou fault.
In this presentation, first we show MT responses for some typical resistivity structures which are expected to exist beneath an active fault, second explain some features of the GMR model, and finally interpret the GMR model with referring to the 1,300m-long borehole data.

Keywords: active fault, Magnetotellurics, Gomura fault

Geological and geomorphological surveys, geophysical surveys, and borehole surveys along the Gomura and Yamada fault zone, and these applicabilities and efficiencies for development of the active fault evaluation

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In the case of lacking the overlying sediments and cross-cutting relationships between the sediments and active faults, the fault activities were not identified clearly. In such case, the methodology of fault activity evaluation is needed to be improved. In our project commissioned by Secretariat of Nuclear Regulation Authority (S/NRA/R), we execute geological and geomorphological survey, geophysical survey, and borehole surveys along the Gomura fault zone ruptured during the 1927 Kita-Tango Earthquake and the Yamada fault zone located in the south of Gomura fault zone. Base on these surveys and its analysis, we organized these surveying technique and its applied condition for the evaluation of active fault, then we aimed for an establishment of the methodology for synthetic evaluation approach of active faults.

Keywords: fault activity evaluation, geological and geomorphological survey, geophysical explorations, borehole surveys, Gomura fault zone, Yamada fault zone

Estimations of fault locations based on Ground Penetrating Radar survey around the western river mouth of the Fuji river

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The 1854 Ansei Tokai earthquake presumably generated wide uplift around the western river mouth of the Fuji river, Shizuoka prefecture, Japan. The uplift indicates that the rapture area of the 1854 earthquake can extend from the Nankai and Suruga troughs to the Iriyamase fault. To forecast earthquake processes in the future, it is important to identify locations and activities of the Iriyamase fault.
We surveyed locations of the Iriyamase fault by using Ground Penetrating Radar (GPR) instrument on 4^{th}-8^{th} January, 2016. Because a strike angle of the Iriyamase fault is nearly north-south direction (Headquarters For Earthquake Research Promotion, HERP, 2010), most survey lines were set to be west-east direction, which is basically perpendicular to the fault. Length of the total survey lines are 13 km. The frequency of the used radio wave is 100 MHz. This spec can detect reflections of the layers about 5 m deep from the ground.
As a result, we found discontinuity of the layers at least at four locations on the survey lines within 2 km inland from the shoreline. There seem to be offsets at the discontinuity between the west and the east layers. The discontinuity extends just below filling, and the offsets are considered to be generated relatively late years. The locations of discontinuity are close to the Iriyamase fault estimated by HERP, and two of them are also close to locations of the faults estimated from seismic reflection survey for several tens to hundreds meters deep (Ito et al., 2014).
On the other hand, we also found the discontinuity at the north of Kambara junior high school and the east of old Ihara high school, which are apart from the locations of the Iriyamase fault. This indicates that the Iriyamase fault consists of splay faults as Ito et al. (2014) reported.

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Keywords: Ground Penetrating Radar, Iriyamase fault, 1854 Ansei Tokai earthquake

Continuation of Submarine Active Fault in the Suruga Trough towards Inland Area

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We discuss on continuation of submarine faults in Suruga trough to inland active faults based on the detailed submarine topographic map as well as field observation in the area along Fujikawa River. Many workers have considered that the Fujikawa-kako Fault Zone is the inland boundary of the Philippine Sea Plate. The fault zone is believed to be composed of active reverse fault traces with very high slip-rate as fast as 7m/1000 years. However, in spite of repeated paleoseismological field studies, concrete evidence for past activities of proposed active fault traces has not been so far found. The fault zone consists of two fault lines, namely east and west lines, and the east one following the eastern margin of the Habuna and Hoshiyama hills was first recognized by Tsuya (1940) as an arcuate fault scarp facing Mt. Fuji. We found similar faulted feature of the Habuna and Hoshiyama hills to the southwestern part of the outer rim of Taal caldera lake, Central Luzon, Philippines.
Therefore, we consider that the active faults composing the east line of the fault zone may be gravitational fault related to volcanic activity of Mt. Fuji. The submarine active fault in Suruga trough extends northward to the mouth of Yui river where Iriyama fault, the southern part of the west line of the Fujikawa-kakou Fault Zone is located. Active fault trace along the Iriyama fault is hardly recognizable due to its low slip-rate. We also newly found consistent left-lateral stream offsets along Minobu, Neguma and Tashirotoge faults previously known as thrust in the southern Fossa Magna zone between Itoigawa-Sizuoka Tectonic Line and Fujikawa river. In conclusion, it is necessary to collect more dependable evidence for discussion about location of the plate boundary in the northern margin of the Philippine Sea Plate.

Keywords: active fault, submarine active fault, Suruga trough, Fujikawa-kakou Fault Zone, plate boundary

Tectonic landform in the area around the southern segment of the Itoigawa-Shizuoka Tectonic Line, central Japan

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Tectonic landform around inland active fault is formed by fault accumulation displacement due to big earthquakes occurred repeatedly. Detail distribution of active fault and information on tectonic landform are necessarily to reveal structure progression developed by repeated active faulting. In this study, we focus on the area around Hakusyu fault, Shimotsuburai fault and Ichinose fault which compose the southern segment of the Itoigawa-Shizuoka Tectonic Line (ISTL) in central Japan where has highly activated recently.
In this study, to understand the relationship between tectonic landform and the active fault structure. we identify the active fault traces and tectonic landform using perspective maps made from the 5m-mesh digital elevation mode (DEM) data, stereo-examination of aerial photography, and conducted field investigations. Interpretations of perspective topographic maps, field investigations, and structural analysis of fault zones reveal that i) the active fault traces show more irregular, curved shape than previously studies; ii) trace of which dip-angle of thrust fault is low curves close to a contour line.
We classify the tectonic landform into 3 groups according to its shape. The first is the flexure scarp seen in the northern part of Hakusyu fault which have the highly relative elevation and which can't see the inclination of the inclination on the hanging wall side. The second is flexure scarp which has greatly monoclinal flexure near the fault, and seen geomorphic surface of reverse inclination on the hanging wall side (the west side) seen by the southern part of Hakusyu fault and an alluvial fan plateau leading edge department of eastern inclination in an area around the Ichinose gap. The third is flexure scarp with a fold scarp of low relative elevation and monoclinal flexure with the long wave length in the hanging wall side seen along Shimotsuburai fault.
To characterize these three types of tectonic landform, we establish fault scarp index (Fsi), which is defined by the length of the wing (L) of each flexure scarp divided by relative elevation (H). As a result, Fsi in Hakusyu fault plateau have relatively low values, Shimotsuburai fault has highest, and Ichinose fault has an intermediate. According to these results, fault dip is steep in Hakusyu fault which have low Fsi values. On the other hand, fault dip is almost horizontal in Shimotsuburai fault which have high Fsi values. This study indicates it is possible to presume the characteristics of the active fault from the feature of the tectonic landform and the fault scarp index (Fsi) is valid for assessing the property of active fault scarps.

Keywords: Itoigawa-Shizuoka Tectonic Line active fault system, active fault, Tectonic landform

Paleoseismological study on subsidiary surface fault ruptures produced by the 2014 Mw 6.2 Northern Nagano earthquake, central Japan: Preliminary report

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The 2014 Mw 6.2 Northern Nagano earthquake (central Japan) produced a 10 km long surface rupture zone that consists of main rupture and subsidiary ruptures. We carried out trench excavation surveys on the subsidiary ruptures to reveal paleoseismic activities. Reverse faults cutting bedrock and terrace deposits were exposed on the trench walls. Judging from upward fault termination and other deformation structures, we identified three paleoearthquake events. The timing of these events is still under way.

Seismic reflection survey across the coseismic surface ruptures of the 2014 nagano-ken-hokubu earthquake of Mw 6.2, central Japan

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The Nagano-ken-hokubu earthquake (Mw 6.2) struck Hakuba village, Nagano Prefecture, on 22 November 2014. A 9.2-km-long surface rupture appeared along the Kamishiro fault of the Itoigawa-Shizuoka tectonic line active fault system in association with the earthquake from Shiojima to Higasisano in Hakuba village. In this stady, to reveal the subsurface structure of the focal area, we executed seismic reflection survey across the Kamishiro fault on 19-28 October 2015. The seismic line has a length of 4.2 km and started from the center of Kamishiro basin to Route 406 via Mikka-ichiba and Horinouchi. The roads along the seismic line were under repair due to the earthquake. We needed a lot of adjustments to the progress of road repairing.
The source used in this survey was Enviro Vib (IVI Inc.). Sweep length was 16 sec and sweep frequency range beginning at 10 Hz up to 100 Hz. The receiver was GS-20DX (natural frequency, 10 Hz; Geospace Inc.). The source interval was 20 m and the receiver spacing was 10 m, with 192 ch geophones used for each recording. We selected the Geode recording system (Geometrics) and its sampling rate is 1 msec.
We thank Hakuba village office, Himekawa construction company, and Hakuba-mitsuno construction company for their assistance with our seismic survey.

Keywords: seismic reflection survey, 2014 Nagano-ken-hokubu earthquake, Kamishiro fault, Itoigawa-Shizuoka tectonic line active fault system

Outcrop data of geological structure associated with active thrust zone along western margin of Yamagata basin around Murayama city, NE Japan

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We describe deformation of Plio-Pleistocene strata and late Pleistocene terrace deposits associated with the active thrust zone along western margin of the Yamagata basin, which is composed of a complex faults and folds, based on observation of new outcrops. Outcrops along the foot of the mountain show monocline fold of steeply dipping Plio-Pleistocene strata, and growth strata on an angular unconformity. This structure is continuous along the foot of the mountain, and most large scale in the active thrust zone. Outcrop around Takamoriyama hill shows the steeply dipping middle Pleistocene Hayama mudflow and late Pleistocene fluvial terrace deposits over the back limb of the asymmetric fold, and decreasing dips upward in the terrace deposit (growth strata). Outcrops around Kawashimayama hill, where frontal deformation of the active thrust zone, show flexure, faults and folds of Hayama mudflow and terrace deposits. These deformations of the terraces around Kawashimayama hill suggest cumulative thrust fault slip. These results propose an active structure key to understanding profile across the complex active thrust zone.

Keywords: active thrust zone, active structure, growth strata

The origin of the anticline founded on fluvial terraces at the eastern part of the Tokamachi Basin, Niigata Prefecture

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Many fluvial terraces formed by Shinano River can be seen in the Tokamachi Basin, which is located between the Uonuma and Higashikubiki Hills. Previous researchers reported that some thrusts along the eastern and western margin of the basin cut and deformed those fluvial terraces, and have surveyed their distribution, activities and structures. The Headquarters for Earthquake Research Promotion (HERP) named these faults western and eastern segment of Tokamachi Fault Zone (TFZ) and revealed each last event based on the results of previous and contract researches. However, relationships with other faults around of the TFZ and their recurrence interval have still been highly debatable.
We found a plunging anticline on the terrace surface by detail geomorphological analyses around the eastern TFZ. The anticline, which is likely to be symmetric fold, has about 1.5 km-wavelength and uplifted the top terrace classified as Mibara group (formed in 140-300 ka) about 20 m high. Near Nakazaike village, one and two steps lower of the top terrace classified as Hoonokizaka (140-170 ka) and Kaisaka (50 ka) groups, respectively, have been uplifted progressively. In addition, geological survey about the Uonuma Formation, basement rock of the terraces revealed that the upper layer has deformed in keeping with the deformation pattern of the surface anticline. These results suggest that the anticline had deformed in the period at least from the time when the upper Uonuma Formation deposited until about 50 ka. The surface deformation which we judged as the anticline is looked as the deformation related to Hosoo-Nyoraiji Fault, striking NNE-SSW, reported by Active Fault Map in Urban Area (Tokamachi) and Active Faults in Japan (Active fault research group, 1991). Our geological and geomorphological study, however, revealed that there is no surface rupture along the fault and the anticline have NE-SW strike. Wavelength of the anticline yields thickness of deformed layer is about 1-1.5 km, suggesting that the anticline formed by the slip on the detachment fault inside of the Uonuma Formation. The depth of the detachment fault is consisted with that reported by Yokokura et al. (Chishitsu News, 2008). It implies that the detachment fault is connected to the eastern TFZ.
The contents of this presentation is a part of the result of the Complementary Survey Project of Active Fault by HERP in 2015 FY.

Keywords: Tokamachi Fault Zone , tectonic landforms, fluvial terraces, Uonuma Formation

Trench Excavation Study and Drilling Survey on the Eastern Segment of Tokamachi Fault Zone, Central Japan

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The eastern segment of Tokamachi fault zone is an active fault with 19 km length, located in the southern part of Niigata prefecture, in central Japan. It extends in NNE-SSW direction along the eastern margin of Tokamachi basin with east-side-up vertical displacement.
The Earthquake Research Committee evaluated that the probability of the earthquake occurrence in the future of this segment was uncertain because of luck of paleoseismological data, although Ota et al. (2010) had reported the timing of the last fault events of this segment as 3,800-3,200 yrs.BP based on results of several trench surveys.
We carried out trench excavation study and drilling surveys at Otajima, Tokamachi city, for estimating activity of the eastern segment of Tokamachi fault zone. The trench was excavated at the foot of a fault scarp with 4 m high on the Holocene fluvial terrace along the Shinano river.
Details of our results will be reported in the presentation.
This project is supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan.

Keywords: active fault, trench excavation study, drilling survey, Tokamachi Basin, Tokamachi fault zone

Tectonic map for the late Quaternary in and around the Kanto Plain; Based on Interpretation of Topographic Anaglyphs Derived Using a Detailed Digital Elevation Model

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Topographic anaglyph images were viewed with red-cyan glasses, making it possible to recognize topographic relief features easily. Anaglyphs produced from digital elevation model (DEM) data are a very effective way of identifying tectonic geomorphology. The aim of this paper was to introduce an extensive area of topographic anaglyph images produced from the 5-m-mesh and 10-m-mesh inland DEM of Geospatial Information Authority of Japan, as well as the 1-second-mesh DEM on the seafloor. This paper also aims to re-examine tectonic geomorphology and to present a new tectonic map for the late Quaternary in and around the Kanto Plain, which is sedimentary basin and the largest plain in Japan, by means of interpretation of the extensive topographical anaglyph image.

Keywords: digital elevation model (DEM), anaglyph, tectonic geomorphology, Kanto Plain

Fault Zone Off the coast of Shimoda and Irozaki Fault Inferred from Geomorphic Analysis for Digital Water Depth Model of 50 m mesh and 150 m mesh

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Izu Peninsula is located between Suruga Trough and Sagami Trough, and lies near and at the northern tip of the Izu-Bonin Arc. This Arc is currently colliding with the Central Japan Arc. And the great interplate earthquakes were frequently repeated at those subduction zones along Troughs, respectively. Instead, the inland large earthquakes were frequently occurred in Izu area due to the plate collision. To understand the collision tectonics, we made an anaglyph image and a figure of contour line from seafloor topography data of 150m mesh and the 50m mesh, and this study investigated a trace of the surface dislocation associated with faulting.
Irozaki Fault: An earthquake (Mw6.9) was occurred in 1974 from an inland active fault called Irozaki Fault, which was ruptured striking WNW-ESE at the southern tip of Izu Peninsula. However, the dislocation of the sea bottom is not clarified until now. Reefs, sea ridges and submarine valleys formed in the continental shelf are systematically offset right laterally in the sea part of east from the Irozaki fault when based on a contours map made of the 150m mesh. It is a dextral fault, coincident with the condition of fault offset in the inland. The sea gorge is blocked up associated with a drag of direction, and the gorge low land is expanded laterally along the fault trace. Irozaki fault, thus, extends to offing approximately 7-8km of Irozaki.
Fault Zone Off coast of the Shimoda (ITTL F2): We recognized three active faults lifting west, Faults a, b and c in order from west to east, cut the sea bottom of the Shimoda offing.
Fault a: Based on the DEM50 m mesh around Shimoda Port, we made a figure of contour line of the 2 m interval. There are Susaki Peninsula and the other submarine peninsula, jutting out into southeast in the north side and the south side of a submarine valley extending from the inlet of the Shimoda Port, respectively. In the neighborhood of tip of these peninsulas, the depth of the water is suddenly deepened. At Susaki Peninsula, the abrasion platform juts into the southeastern side from the shoreline. The submarine cliff of a drop of up to approximately 18m is observed on this abrasion platform. And it is divided into two steps of submarine terrace with depth of the water approximately 2-4m and 20-26m by the cliff. Also in the neighborhood of tip of the submarine peninsula of the south side, a submarine cliff of a fall up to approximately 16m is recognized at about 2 km point off a shoreline, and a submarine reef ridge is divided two steps. A small valley is formed in this cliff in our interpretation of the anaglyph image. And a low scarp of a 2m drop crosses the small submarine alluvial fan formed around and at the valley mouth. The resolution of topography data is not good, but may be caused by an active fault so as to be able to judge displacement, transformation because this low cliff develops in the direction at right angles to the valley. Fault to estimate in this study is more likely to be concordant with this dislocation model by Kitamura et al. (2015).
Faults B and C: We made a figure of contour line of the 10m interval from DEM150m mesh. A sea plateau is formed in and around the bent of the continental shelf slope of Shimoda offing approximately 10km. A water depth of the sea plateau is approximately 200-540m. On this sea plateau, the two flexure scarps, uplifting west, strike NNE-SSW in a parallel row. Fault length is approximately 26km each. Kim et al. (2012) assumed these two fault b and c in Shimoda offing (F2 of the ITTL), but we do make a redefinition for Fault Zone Off Coast of Shimoda involving Fault a. In addition, we judge that Irozaki Fault (WNW-ESE strike, High-angle dextral slip fault) has been formed in a conjugate relation with Fault Zone Off Coast of Shimoda (NNE-SSW strike, West dipping

reverse fault).
An address of gratitude: Tsunami mesh data of the Coast Guard Hydrographic & Oceanographic Department is used.

Keywords: Submarine Geomorophology, Izu Collision Zone, Irozaki Fault, Submarine Fault Zone Off Shimoda, Submarine Fault, ITTL

1:500,000 Compiled geological map of the Fujigawa-kako Fault Zone and its surroundings

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This geological map was created for seamless integration of land and sea geoinformation, based on the existing geology and active fault research results, in addition to the research results of Iriyamase fault that was carried out in “Geology and Active Fault Study of the Coastal Area” as the project of Geological Survey of Japan, AIST. The map is intended to be basic information diagram to be utilized for future research and disaster prevention. Therefore, it will be revised based on the research achievements of the future.

The older Fuji mudflows and lava flows of the Fuji Volcano (e.g., Tsuya, 1978) have been good reference surfaces to study the activities of the fault zone. However, based on the latest research results of new stratigraphy of the products of Fuji Volcano at the southwestern foot (e.g., Yamamoto, 2014), the older Fuji mudflows is divided into the volcanic fan Ⅳ deposits and Ⅲ volcanic fan deposits, whose abandonments occurred at MIS 4 and MIS 2, respectively. Furthermore, stratigraphy and ages of some lava flows deformed by active faults, has been corrected. Below, it shows the outline. As a result of review of existing studies based on these, some of the setting of the reference plane and the average displacement velocity were found to be necessary to be reconsidered.

(1) It became clear that continuity and configuration of the Iriyamase Fault in coastal area, based on results of onshore shallow seismic reflection survey (Ito and Yamaguchi, 2016), boring surveys (Ishihara and Mizuno, 2016) and offshore seismic reflection survey (Sato and Arai, 2016) of the GSJ project. In addition, there is a large possibility that two parallel or en echelon faults has been developed on both sides of the Kanbara Jishinyama (earthquake mound) (Omori, 1920).

(2) The average activity rate of the Iriyamase Fault estimated to be 7 m/1000 years is based on the altitude difference between the Suijin Lava Flow on the hanging wall side and the Obuchi Lava Flow distributed under the Fujikawa-kako Alluvial Fan on the footwall side (Yamazaki, 1979). However, the former has an age of 17 ka and was flowed from along the Fuji River to the southeast, the latter have an age of 10 ka and was flowed from the south-southwestern foot of the Fuji Volcano to the southwest (Yamamoto, 2014). In addition, Yamazaki (1979) was estimated the displacement of the Iriyamase Fault from elevation distribution map of lava flows under the alluvial fan by Murashita (1977), which shows the shape of the foot of Mt. Fuji to be reduced to the southwest direction at about 10 ka. However, there is almost no data on footwall side zone of width 2 km (from Matsuoka to Gokanjima districts) along the Iriyamase Fault in order to lacking lava flows are in boring core data, it is not possible to accurately estimate about depth of the lava flows in footwall side from the map. The lava flow as a reference is considered to be hardly deposited in the zone due to the downward erosion at the last glacial period and valley-filling sedimentation at the post-glacial period by the Paleo-Fuji River stream in addition to the subsidence by the Iriyamase Fault. And furthermore, effect of sea level between 10 ka and 17 ka to reach 60 to 70 meters (e.g., Siddall et al., 2003) must be also taken into account. In the present situation, by combining the various conditions of the above, the amount of displacement of the Iriyamase fault, can be large, or small than the existing estimates. Therefore, in order to estimate the exact average displacement rate of the Iriyamase Fault, it is necessary to carry out a new investigation.

(3) The Shibakawa and Iriyama Faults are distributed continuously as a geological fault, but unlikely as an active fault. Several N-S trending faults in length from 0.5 to 1.5 km are well

developed in the areas where both of faults are connected while bending. Among these, the Gendai Fault (Otsuka,1938) is considered to be an active fault.

Keywords: Fujikawa-kako Fault Zone, Iriyamase Fault, geological map, 1:500000

Topography of late Quaternary in the Tonami plain and activity of the Tonami-heiya fault zone, Toyama Prefecture

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The purpose of this research is to restudy the late Quaternary topography and activity of the Tonami-heiya fault zone, and to discuss the geomorphological development of the Tonami plain in the western part of Toyama Prefecture, central Japan.
The Holocene alluvial fans and flood plains formed by the Sho and Oyabe Rivers spread out in the Tonami plain from the central through the northern parts. Along the foot of the surrounding mountains and hills, higher, middle and lower terraces of late Pleistocene-Holocene in age are distributed. These terraces have been displaced, even during the Holocene time, by the reverse dip-slip activities of Tonami-heiya fault zone in a sense of upheaval in the mountains side.
We examined stratigraphic cross section utilizing borehole data and morphologically analyzed 5m-DEM in order to elucidate the fault trace of the Isurugi fault which belongs to the Western Tonami-heiya fault zone. As the results, the northern segment of Isurugi fault seems to run along the northeastern foot of Hodatsu hill and extends underground through the lower-most Oyabe River into the Toyama Bay. Consequently its total length reaches about 30 km. In the southern segment, a continuous fault scarplet was recognized to cut across the lower dissected fans. The slip-rate of Isurugi fault is estimated to be 0.31-0.64m/kyr. As for the Eastern Tonami-heiya fault zone, the mid-Holocene and later activities along Horinji and Takashozu faults were also identified from previous studies by trench excavation surveys (AIST, 2012, Toyama Pref., 2000).
In the Hokuriku region, reverse faulting and related folding with strike in a NE-SW direction have occurred during the late Quaternary. In this process, the upheaval of mountains and hills as well as the subsidence of plain were reactivated and have continued. Then, the hinge line of block movement due to the activities of the Tonami-heiya fault zone is revealed to have shifted from the mountain side into the plain side within the Holocene time. In conclusion, the Quaternary folding and faulting associated with the crustal warping at a wavelength of about 20 km is currently in progress, causing both the subsidence of Tonami plain and the upheaval of surrounding mountains and hills.

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Characteristics of the fault zones terminated by the Late Quaternary - an example of the Median Tectonic Line in Nara Prefecture -

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The activity assessment of the active faults basically needs younger sediments. To understand the fault activity in the area with no youner sediments, it is desired that the new method is developed to study the fault activity from the fault rocks in the basement rocks. A comparison of the fault zone characteristics between active faults and inactive faults. To understand the characteristics of inactive fault zone, we have studied the Median Tctonic Line (MTL) in Ohyodo, Nara Prefecture. The MTL is the active fault in the western part of the Kii peninsula to Shikoku Island. , which it is not active fault in the central to eastern part of the Kii peninsula. Okada and Togo (2000) showed that the fault activity of the MTL has terminated by the Late Quaternary in Ohyodo Nara Prefecture. Matsumoto (2001) studied the fault exposure in this area and reported that the MTL cut the upper Shobudani Formation. The MTL had been active in the Middle Quaternary, but it is not active in the Late Quaternary. In this exposure, the fault gouge with a thickness of 10cm extends to east-west and distributes between the Izumi Group in the northern side and the Shobudani Formation in the southern side. The Shobudani Formation is divided into the lower Shobudani Formation and the upper Shobudani Formation.
We collected the samples from this exposure , and performed the powder X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses. The samples collected 0.5 m, 1.5 m, 6 m below the uppermost of the exposure. The results of XRD show the formation of smectite in the fault gouge in 6 m below the uppermsot of the exposure. Albite is detected from the and the upper Shobudani Formation near the fault gouge and the intact rock of the Izumi Group in 0.5m below the uppermost. The results of XRF exhibit that the increases of Al_2O_3, Fe_2O_3, LOI, MgO, CaO and the decrease of SiO_2 in the fault gouge in 6m below the uppermost. In 1.5m below, the increases of LOI, MgO is recognized. In 0.5m below, no clear change of the chemical composition is detected in the fault gouge.
Compared among the same lithofacies in the intact rocks, the Izumi Group in 0.5m below shows the decreases of Na_2O and CaO, which no significant change is detected in 1.5m and 6m below. The Shobudani Formation and the fault gouge do not show clear change of the chemical composition.
This exposure had been in the underground before this site has been developed as a quarry. Near the uppermost of the exposure, the leaching of the elements in the fault gouge would be occurred due to the weathering.
Compared the fault zone characteristics studied in this study with that of active faults, the active fault zones are characterized by the formation of smectite and increase of manganese. To understand the differences of the fault zones between active and inactive faults, the characteristics of active fault zones would be detected.

Keywords: fault zone

Topographical and geological explorations along the Gomura and the Yamada fault zone: Part 2 observation and ESR analysis

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As a part of a research project commissioned by Secretariat of Nuclear Regulation Authority (S/NRA/R), to organize information about evaluation techniques of active faults, we executed topographical and geological explorations along the Gomura and the Yamada fault zone. Here, we show the fault rocks observed in outcrops and core samples, and results of Electron Spin Resonance (ESR) analyses in them.

Keywords: ESR analysis, Gomura fault zone, Yamada fault zone

Geophysical explorations along the Gomura and the Yamada fault zone, and its applicability: Part 2 P-wave seismic reflection survey, seismic refraction survey, CSAMT survey, and gravity survey

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As a part of a research project commissioned by Secretariat of Nuclear Regulation Authority (S/NRA/R), to reveal the subsurface geometry of active fault and geological structure around the Gomura fault zone and the Yamada fault zone, we execute a seismic reflection and refraction survey, S-wave shallow seismic reflection survey, CSAMT survey, high-density electrical resistivity survey, and gravity survey. In this presentation, we demonstrate detail results of P-wave seismic reflection survey, seismic refraction survey, CSAMT survey, and gravity survey. Finally, we summarize applicability and efficiency of these geophysical explorations for the strike-slip active fault.

Keywords: P-wave seismic reflection survey, seismic refraction survey, CSAMT survey, gravity survey, Gomura fault zone, Yamada fault zone

Geophysical explorations along the Gomura and the Yamada fault zone, and its applicability: Part 1 S-wave shallow seismic reflection survey and high-density electrical resistivity survey

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As a part of a research project commissioned by Secretariat of Nuclear Regulation Authority (S/NRA/R), to reveal the subsurface geometry of active fault and geological structure around the Gomura fault zone and the Yamada fault zone, we execute a seismic reflection and refraction survey, S-wave shallow seismic reflection survey, CSAMT survey, high-density electrical resistivity survey, and gravity survey. In this presentation, we demonstrate detail results of S-wave shallow seismic reflection survey and high-density electrical resistivity survey. Finally, we summarize applicability and efficiency of these geophysical explorations for the strike-slip active fault.

Keywords: S-wave shallow seismic reflection survey, high-density electrical resistivity survey, strike-slip fault, Gomura fault zone, Yamada fault zone

Topographical and geological explorations along the Gomura and the Yamada fault zone: Part 1 aerial photointerpretation and geological survey

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As a part of a research project commissioned by Secretariat of Nuclear Regulation Authority (S/NRA/R), to organize information about evaluation techniques of active faults, we executed topographical and geological explorations along the Gomura and the Yamada fault zone. Here, we show the results of aerial photointerpretation and geological survey.

Keywords: aerial photointerpretation, geological survey, Gomura fault zone, Yamada fault zone

Active faults around the Shimane Peninsula and their tectonic implications, northern Chugoku region, Japan

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The Shimane Peninsula is located along northern coast of the Chugoku district, and consists of the three mountains, the Seiretsu Mountains, the Churetsu Mountains, and the Toretsu Mountains. The Kashima Fault (Shinji Fault) develops along the southern margin of the western part of the Toretsu Mountains, but existence of certain active faults has not been known in the other area. Based on detailed investigation of aerial photograph and stereoscopic images delivered from 5 m –10 m DEM, we found active faults in the east and west extension of the previous reported active faults. In this presentation, we reported the distribution and characteristics of these active faults, and discuss tectonic implications of these active faults.
Based on the characteristics of the morphology of the Toretsu Mountains, we estimated the existence of northern-side-up concealed active faults with right-lateral slip along the southern margin of the Toretsu Mountains. We mapped three en echelon active faults in the Churetsu Mountains. We estimated that these active faults have right-lateral strike-slip components, based on right-lateral flection of stream valleys. We estimated that these active faults are secondary faults delivered from submarine active fault along the northern margin of the Churetsu Mountains.
Along the southern margin of the Seiretsu Mountains, we estimated existence of northern-side-up concealed active faults, based on the characteristics of the morphology of the Seiretsu Mountain, as in the Toretsu Mountains.
East and west of the Shimane Peninsula, long submarine active faults with east-west strike are known. These active faults develops along the coastal area of the Shimane and Tottori Prefecture, and form large tectonic deformation belt over several 100 km. we estimated that active faults in the Shimane Peninsula are extension of these submarine active faults, and are constitute a part of the large tectonic deformation belt.

Keywords: Kashima fault, active fault, Chugoku, inland earthquake, submarine fault, aerial photograph

Holocene activity of the Northern Marginal Faults of the Saga Plain

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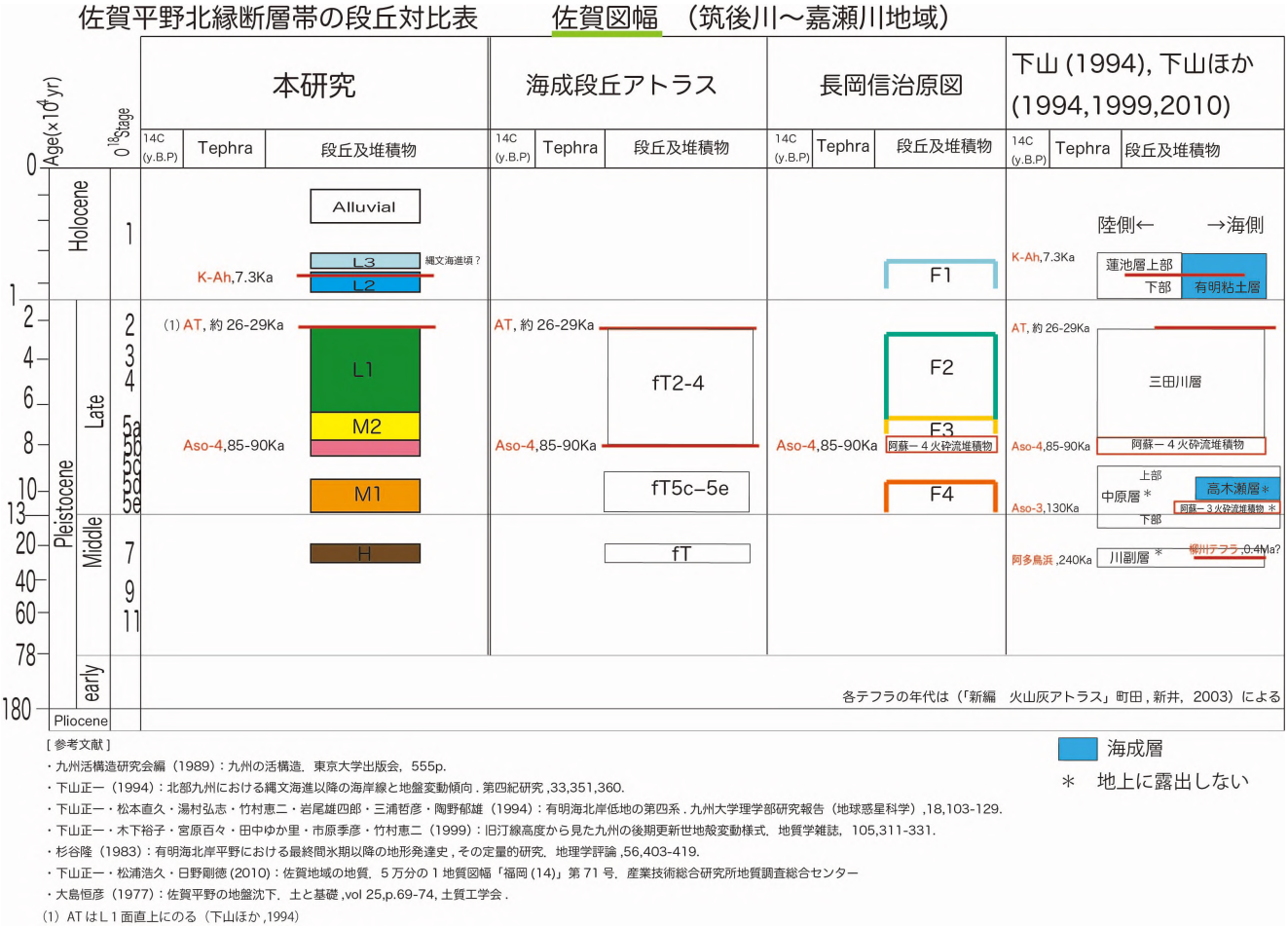
Kyushu of active faults is divided into three zones. Active faults of the central Kyushu, mainly extends to east-west direction. A study area the Northern Marginal Faults of the Saga Plain is located in the central Kyushu. Most of these active faults are normal faults by the force extended to north-south direction (Headquarters for Earthquake Research Promotion, 2012). The faults are normal faults, it is estimated that the south side is down (Headquarters for Earthquake Research Promotion, 2013). The distribution forms of these active faults are linear trace that extends east to west. Regarding the Northern Marginal Faults of the Saga Plain, Research Group for Active Tectonic Structures in Kyushu ed. (1989) and Nakata-Imaizumi ed. (2002) has certified the active faults along the boundary of the plains and mountains on the North side of the Ariake Sea. AIST (2014) reported that fault scarp of about 0.7~2.5m were observed intermittently along the south portion of the Saga plain. However, such as average vertical slip rate and the age of the latest activity of the Northern Marginal Faults of the Saga Plain are unknown because information of the trench survey poor. We have already done reports by the present study, Kagohara et al. (2014, 2015) and Imaizumi et al. (2014), Yoshida et al. (2015). In this report, F3~F7 fault be discussed on the basis of the average vertical slip rate of the faults for the activity in the Quaternary the Northern marginal faults of the Saga plain. H surfaces were MIS7 equivalent, M1 surface were located in the lower Aso-4 pyroclastic flow deposition surfaces, it were MIS5e equivalent of last interglacial period, Aso-4 pyroclastic flow deposits surfaces were 8.9ka and M2 surfaces were MIS 5a equivalent the formation age from such were covered discordance Aso-4.And we estimated to that L1 surfaces were MIS2-4 because AT (26-29ka) were included in the upper part of L1 sediments. L2 surfaces were estimated to MIS1 because K-Ah (7.3ka) was included in the upper part of L2 sediments.

F3 faults correspond to the active fault that has been pointed out in Research Group for Active Tectonic Structures in Kyushu ed. (1989) and Nakata-Imaizumi ed. (2002). The F3 faults were recognized as distinct scarps of about 1.8m on alluvial fan surface (L1 planes). These faults were intermittently until Jobaru-river from Saga City Yamato-cho, but could be clearly tracked. The average vertical slip rate of F3 faults in L1 planes were estimated to 0.07mm/yr. F6 faults could be tracked continuously lineament from the Kase-river to the Jobaru-river on L2 surfaces. F6 faults has tectonic bulge that may be low fault scarps or about 50cm low fault scarps on the L2 planes. These were observed the slopes of the terrace surfaces by field observations and topographic profile. The average vertical slip rate of F6 fault in L2 planes were estimated to 0.07mm/yr. F7 faults were located on the south side of the F6 faults. F7 faults could be tracked continuously from the Kase-river to the Jobaru-river on L2 planes. In Saga-city Kuboizumi-cho Shimoizumi, we made simple boring survey in the hanging wall and footwall side of the border the F7 faults. As a result, AT was confirmed in the deposits of L1 planes that were buried terraces. F7 faults of average vertical slip rate were estimated to be at least 185cm or more. Thus, average vertical slip rate of F7 faults were estimated to 0.07mm/yr.

Tectonic geomorphology that were estimated to scarps that were observed continuously on the L2 planes of the North portion of the Saga plain. Because of texture on the L2 surfaces were observed, Holocene activity of this fault zone was active at least once after L2 planes formation (7.3ka). L3 planes were observed scarps about 50cm, but it's issues there were also the possibility of

artificial modification.

Keywords: Northern Marginal Faults of the Saga Plain, normal fault, large-scale geographical map, tectonic bulge, average vertical slip rate



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Integrated Research for Beppu -Haneyama Fault Zone (East part of Oita Plain -Yufuin Fault) -Research in 2015 -

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Integrated Research for Beppu -Haneyama Fault Zone (East part of Oita Plain -Yufuin Fault) in central Kyushu started on 2014 as one of Integrated Research Project for Active Fault Systems of MEXT. We need more precise study on fault distribution, latest event in and around Beppu Bay region and relationship with western end of Median Tectonic Line for understanding of Beppu -Haneyama Fault Zone. We carry out geomorphological, geological and geophysical researches on the basis of existing research findings. Obtained new data on geomorphology and geology will let us know new findings on precise location and activity of fault in and around Beppu Bay area. Moreover, new geophysical data on subsurface structure indicate size and motion of earthquake fault reached to the earthquake occurrence layer, and we also calculate precisely ground motion on the basis of precise subsurface structure and earthquake fault model.Research group consists of about 40 researchers of Kyoto University, Kyushu University, Advanced Industrial Science and Technology and related Institutions, and also three sub-groups on the basis of methodology and science target. Sub-theme group 1: Research on precise location and shape of active fault, and average slip rate and event age. Sub-theme group 2: Research on three dimensional structure and subsurface structure of fault zone and the area. Sub-theme group 3: Research on establishment of subsurface structure model and evaluation of ground motion.The result during 2015 fiscal year will be presented in the session.

Keywords: Beppu -Haneyama Fault Zone, Integrated Research Project, Active fault and subsurface structure

Take advantage of high-resolution seismic survey in the submarine active fault

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[Background]
Trenching, bowling and geo-slicer has used to clarify the latest activity timing and interval of the active fault. In the sea area, there is a limit of survey methods unlike the land. So, we usually use seismic survey. On the other hand, sea area is sediment accumulated place, possibility that the history of the fault movement is preserved successively. Therefore, we can higher accuracy estimate of active faults with high-resolution seismic survey densely.
[Target area and study methods]
Hinagu Fault Zone extends from the Aso volcano to the Yatsuhiro-sea. In the Yatsushiro-sea, some seismic surveys were carried out so far, and clarified distribution of a number of submarine fault group.
In this study, we aim to reveal the subsurface deformation of fault using high-resolution seismic survey with 20-50 meters interval survey lines. Furthermore, we carried out core sampling to obtain the geological information.
[Analysis]
Results of high-resolution seismic survey, we obtained a good reflection profile of up to about depth 60m. We recognized some reflectors (R1~8 from the bottom) and some deposition sequences (A1,A2,A3,B1,B2,C,D layers from the top) based on their reflection patterns. We pick up the three-dimensional coordinate point data from each reflector and make surface models.
[Results]
1) Surface of R2
a) Vertical fault scarp was developed with NE-SW direction along master fault (A-FA1). b) In west side of A-FA1, we observed some faults which is extends to NE-SW direction and curves clockwise. This feature is similar to Negative flower structure. c) Bulge is developed along A-FA1. Three faults cut the bulge and oblique to A-FA1 with high angle. These features which are similar to R2 has recognized in surface of R3 and R4.
2) Surface of R5
Depressed formation like a funnel-shaped has developed along A-FA1 at central part of survey area. This feature is observed on seafloor also.
A number of studies for the model test of strike-slip faulting are conducted so far. And it is argued about growing process of fault. Therefore, it is a possibility to clarify the growing fault process and activity history of active faults in the sea area.

Keywords: Hinagu Fault Zone, High-resolution seismic survey, Seismic stratigraphy

Recognition of the sea-floor event deposits by continuous radiocarbon measurements of total organic carbon

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The depositional age of hemipelagic mud are generally determined by radiocarbon dating of planktonic foraminifera. Radiocarbon dating using total organic carbon of sediments is not common for age determination, because total organic carbon include organic carbon of various origins, such as marine, terrestrial, and reworked old fragments. In the forearc basins along the Nankai Trough, the amount of planktonic foraminifera in the sea-floor sediments is not enough for radiocarbon age determinations. Therefore, we try to determine the depositional age of hemipelagic mud by using radiocarbon dating of total organic carbon. Radiocarbon ages of total organic carbon were measured in 0.5 to one centi-meter intervals of sediment core, and compensated with small-scale radiocarbon sample measurement of planktonic foraminifera.
Radiocarbon ages were measured with accelerator mass spectrometer of Atmosphere and Ocean Research Institute, the University of Tokyo. Total organic carbon contents and stable isotope ratio of organic carbon were measured using an elemental analyzer and a mass spectrometer of the National Museum of Nature and Science, Tokyo.
Sediment core was acquired from the western part of Kumano Trough at 2000 m water depth by using multiple corer. The sediment is composed of olive black clayey silt in 40 cm long core. Two light colored layers, which include coarse silt, were observed in X-ray CT images of the hole core. Several ^{14}C ages determined from total organic carbon were older than those of lower horizons. These may be because the organic carbon samples include some older carbon fragments remobilized from submarine slope. We excluded these ages from our estimation of depositional ages. ^{14}C ages of total organic carbon were found to be about 900 to 1200 years older than those from planktonic foraminifera from the same horizons. We converted the ^{14}C ages of total organic carbon to calibrated ^{14}C ages by using the age difference between total organic carbon and foraminifera. Our results show that the 40cm long sediments were deposited during about past 600 years.
The organic carbon of the event layers, which excluded from estimation of depositional ages, is mostly marine origin. Therefore, we considered that these event layers were deposited as a consequence of submarine slope failure. The event layer in upper part of the core was considered to be deposited by shallow submarine slope failure or flood, because this layer includes terrestrial organic carbon. On the basis of our radiocarbon dating of total organic carbon and planktonic foraminifera, these event layers might be deposited as consequences of submarine slope failure associated with historical earthquakes and flood after fifteen century.
Radiocarbon dating with total organic carbon is possible tool for not only determination of depositional age but also recognition of event deposits in homogenous hemipelagic mud.

Keywords: hemipelagic mud, organic carbon, radiocarbon dating, earthquake

The Analysis of the Active Reverse Fault Zones in Japan through Gravity Anomalies

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The Japanese islands are located in a subduction zone and they have undergone complex deformations as a consequence of regional stress changes. Therefore the active structures are diverse. The object of our study is to reveal distinctive features of active faults and to examine their spatial continuity through gravity anomalies. Seismic reflection survey is a major method to detect subsurface structure of faults, but seismic velocity structure is obtained only on linear profiles. Over 20,000 points of gravity data has been measured in Japan. Recently released high resolution data set enable us to detect detailed density differences in a wide area around faults. We analyzed 43 reverse fault zones in northeast Japan and northern part of southwest Japan among major active fault zones selected by Headquarters for Earthquake Research Promotion.
The gravity data published by GSI [2006], Yamamoto *et al.* [2011], and Geological Survey of Japan (AIST) [2013] and Kanazawa University data were compiled in this study. We applied terrain corrections using 10 m DEM and filtered data with a band pass filter in addition to normal correction procedures, then obtained the Bouguer anomalies.
Steep Bouguer gravity gradients are clearly observed along the faults at 21 faults zones, a weak correlation is recognized at 13 faults, and no correlation at 9 faults. We evaluate the continuity of the faults based on the continuity of maximum points of the horizontal first derivation and inflection points of vertical first derivation together with geological and topographical observations. We infer a faulting type and a direction of dipping from fault traces and the maximum isoline or the inflection isoline of the derivations.
For example, we recognize following features for the Itoigawa Shizuoka tectonic line. The fault end seems to extend at the northern end. A left stepping of the faults in the subsurface is revealed around Hakuba. The maximum isoline and the inflection isoline are distributed on the east of the fault rupture in the north and on the west in the south, indicating that the dip direction changes the east dipping to the west dipping from north to south.

Keywords: gravity anomaly, active fault zone, spatial continuity of the fault

Co-seismic conjugate Riedel faulting associated with the 2014 M_w 6.9 Yutian earthquake on the Altyn Tagh Fault, Tibetan Plateau

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The Altyn Tagh Fault is located at the northwestern edge of the Tibetan Plateau, and is the largest active strike-slip fault in Asia with a total length of ~2000 km. The fault accommodates sinistral motion between the Tibetan Plateau and the Tarim Basin within the India–Eurasia collision zone. Although the Altyn Tagh Fault plays a key role in accommodating India–Eurasia convergence, little is known about its nature as a seismogenic strike-slip fault due to a lack of instrumentally recorded large earthquakes on the fault. The 12 February 2014 M_w 6.9 Yutian earthquake, which occurred in the Yutian region of the Tibetan Plateau, provides an opportunity to study the seismotectonic nature of the Altyn Tagh strike-slip fault system.

Field investigations reveal that the 2014 M_w 6.9 Yutian earthquake on the left-lateral strike-slip Altyn Tagh fault system, Tibetan Plateau, produced a ~25-km-long surface rupture zone that contains conjugate Riedel shear faults (Li et al., 2016). The co-seismic surface ruptures occurred mainly along two parallel ENE-trending active left-lateral strike-slip faults. Rupture also occurred in a conjugate, WNW-trending zone along an active right-lateral strike-slip fault. The ENE-trending ruptures are concentrated in a zone of <500 m wide and ~25 km long, and are characterized by Riedel shear structures including distinct shear faults (Y) with a maximum sinistral displacement of ~1 m, right-stepping en echelon cracks, and mole tracks. In contrast, the WNW-trending ruptures occur within a zone of up to 1.5 km wide and ~4 km long in the jog area between the two parallel ENE-trending faults, and this zone is characterized by discontinuous shear faults with dextral displacements of <0.5 m, left-stepping en echelon cracks, and mole tracks, all oriented oblique to the ENE-trending rupture zones at an angle of 30°–40°. The lengths and displacements of the co-seismic surface ruptures measured in the field are comparable with those obtained from the empirical relationships between magnitude and co-seismic surface rupture length and displacement. Our findings demonstrate that the co-seismic conjugate Riedel faulting was controlled mainly by pre-existing active faults of the Altyn Tagh fault system, reflecting the present-day tectonic stress field associated with the ongoing penetration of the Indian Plate into the Eurasian Plate.

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Keywords: Altyn Tagh fault, 2014 Mw 6.9 Yutian earthquake, Co-seismic conjugate faulting, Tibet Plateau

Role of the Longquan fault in the active deformation of the Longmen Shan fold-and-thrust belt, eastern Tibetan Plateau

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Present-day convergence within the Longmen Shan fold-and-thrust belt (LSFTB) was manifested by the 2008 Mw 7.9 Wenchuan and 2013 Mw 6.6 Lushan earthquakes, which ruptured multiple thrust ramps beneath the range front structures. However, it is still unclear whether fault slip has been propagated eastward into the foreland, closer to the Chengdu population center. In this study, we provide constraints on the 3D subsurface structure, fault activity and seismic hazards of the Longquan fault that is located in the central Sichuan basin, ~100 km east of the range front structures of the LSFTB. Our detailed 3D model of the Longquan fault reveals a segmented fault array involving an east-dipping back-thrust at the edge of the Quaternary basin between west-dipping fore-thrusts to the north and south. We evaluate the activity of the Longquan fault by interpretations of high-resolution satellite images, field mapping, paleoseismic logging of trench exposure walls and radiocarbon geochronology. Our results reveal that at least two surface rupturing events occurred on the Longquan fault in the Holocene, with the minimum of 3.2 m and 2.5-3.7 m slip for the most recent and penultimate events, respectively. The most recent event is inferred to be occurred in the period between 2060±30 yr BP and 580±30 yr BP, while the penultimate event occurred in the period before but around 3050±30 yr BP. These findings indicate a Holocene slip rate ranging from 0.95 to 1.65 mm/yr for the Longquan fault. The 3D structural model and the late Holocene faulting events occurred along the Longquan fault reveals that upper crustal shortening in the Sichuan basin is accommodated on a frontal thrust system that is linked to the recently active range front blind structures by a shallow detachment. We suggest that a dynamic weakening mechanism following fault activity closer to the Longmen Shan range front could help unlock the up-dip portion of this shallow detachment, sending slip eastward to the foreland and to the surface along the Longquan thrust ramps. These findings have important implications for seismic hazards of active frontal thrusts linked by upper crustal detachments in the Sichuan basin, as well as other active fold-and-thrust belts around the world.

Keywords: Active thrusting, paleoseismology, 3D structural modeling

