Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SSS32-01 Room:A04 Time:May 26 14:15-14:30

Long-term seismic quiescence before the recent great earthquakes along the Kurile Trench

KATSUMATA, Kei[1*]

[1]Inst Seismo Volcano, Hokkaido Univ

The 1994 Hokkaido-toho-oki earthquake (Mw8.3) was preceded by a long-term seismic quiescence started 13 years before the main shock. The 2003 Tokachi-oki earthquake (Mw8.3) was preceded by a long-term seismic quiescence started 10 years before the main shock. The 2006 naka-Chishima earthquake (Mw8.3) was preceded by a long-term seismic quiescence started 10 years before the main shock. An earthquake catalog created by International Seismological Center (ISC) is analyzed in the study area, 140E to 160E, 39N to 55N, between January 1964 and June 2012, including 1641 earthquakes shallower than 60 km with the body wave magnitude of $5.0 \leq$ mb ≤ 7.2. Clustered events such as earthquake swarms and aftershocks are removed from the ISC catalog by using a stochastic declustering method developed by Zhuang et al. (2002). A detailed analysis of the earthquake catalog using a gridding technique (ZMAP) shows that the quiescence areas are located in and around the focal areas of the three great earthquakes. The quiescence area for the 1994 Hokkaido-toho-oki earthquake is a circle centered at (43.5N, 146.9E) with a radius of 32 km. The quiescence area for the 2003 Tokachi-oki earthquake is a circle centered at (42.5N, 143.5E) with a radius of 88 km. The quiescence area for the 2006 naka-Chishima earthquake is a circle centered at (47.2N, 153.1E) with a radius of 68 km. Moreover I find a long-term seismic quiescence in two areas, which has not been followed by a great earthquake yet. One of them is a circular area centered at (39.8N, 144.2E) with a radius of 68 km, which is a southern part of the focal area of the 1968 Tokachi-oki earthquake. The other one is located in and around the focal area of the 1963 Etorofu earthquake.

Keywords: seismicity, seismic quiescence, Kurile trench, great earthquake, body wave magnitude, ISC

SSS32-02 Room:A04 Time:May 26 14:30-14:45

Triggering process of the M6.4 Eastern Shizuoka earthquake on March 15, 2011

TAMURA, Rina[1*] ; MIYAZAWA, Masatoshi[2]

[1]Graduate School of Science, Kyoto University, [2]Disaster Prevention Research Institute, Kyoto University

We investigated the triggering process of the M_{JMA}6.4 Eastern Shizuoka earthquake which occurred near Mt. Fuji at a depth of about 14 km, four days after the Mw9.0 2011 Tohoku-oki earthquake. The Eastern Shizuoka earthquake may have been triggered by the static stress changes from the 2011 Tohoku-oki earthquake and/or the dynamic stress and strain changes due to the passage of surface waves from the M_{JMA}6.2 Fukushima-oki earthquake which occurred about 230 sec earlier and at a site located about 400km away.

Keywords: 2011 Eastern Shizuoka earthquake, 2011 Tohoku-oki earthquake, static stress changes, dynamic stress changes, triggering

SSS32-03 Room:A04 Time:May 26 14:45-15:00

2011 Yamagata-Fukuhsima Border Earthquake Swarm and Tanakura Tectonic Line

NIITSUMA, Nobuaki[1*] ; HASEGAWA, Akira[2] ; OKADA, Tomomi[2] ; YOSHIDA, Keisuke[3]

[1]Institute of Geosciences, Shizuoka University, Sendai, [2]Research Center for Prediction of Earthquakes and Volcanic Eruptions, Tohoku University, [3]National Research Institute for Earth Sciences and Disaster Prevention

An active earthquake swarm occured in the Yamagata-Fukushima border induced by the 2011 Thohoku-Oki earthquake. Hypocenters were relocated precisely by temporary stations, which clearly showed hypocenter migration (Okada et al., 2014). The migration has been estimated to be related with the flow of fluid which reduced the mechanical strength. This study examined the relation between seismicity and geologic structures.

The focal area locates on the mountainous region with 1000-2000m of altitude in the Yamagata and Fukushima border to the west of Azuma Volcano and to the north of Bandai Volcano. In the geologic view, the focal area is passed through with north-south trend by Tanakura Tectonic Line, which is estimated to be formed by sinistral strike slip fault movement in late Createaceous (100-80 Ma) [?] along the eastern margin of Asian Continent. The Tanakura Tectonic Line is major tectonic line in the Japanese Island Arcs and bounds northeast and southwest Japan. The west of Tanakura Tectonic Line is composed by Ashio Belt of Jurassic accreationary complex with the intrution of Asahi Paleogene granits and the east with Abukuma Creatacous granits. Ashio Belt is eastern extend from Mino and Tamba Belts in southwest Japan.

The epicenters do not fit to the active volanos and subsiding area in Yonezawa Basin of north and Kitakata Basin of southwest.

The geology of the focal area is summarized as follow;

1) pre-rifting stage: Jurassic accretionary complex, Abukua Createaceous granits (100-85Ma), Asahi Paleogene granits (65-54Ma) along eastern margin of Asian Continent,

2) rifting stage [concentric bent slab started to fall into lower mantle] : overlaid terrestrial sediments on rifting continental margin (20-16 Ma),

3) Japan Sea opening stage [slab falled into lower mantle]: marine sediments with so called green tuff (15-14 Ma),

4) peak of transgressive and sinking stage [collapse of slab]: pelagic sediments (13-12 Ma),

5) regressive stage [break and falling down of slab and subduction of next slab]: terrestrial volcanic efusives of caldera (8-5 Ma),

6) dacitic volcanism.

Jurassic accretionary complex intruded by Asahi Plaeogene granits exposes in the west and Abukuma Createaceous granits in the east of the focal area, which indicates for Tanakura Tectionic Line to pass between them.

The focal area is located at a caldera (5) and dacitic (6) volcanisms. It suggests the magma reservoir of the volcanisms relating to the earthquake swarm. The earthquake swarm initiated from the central part of the dacitic volcanism (6) where thick dyke for the main vent exposes after the uplift and erosion of the volcanic body. It is estimated that decrease of the east-west compressional stress by the Tohoku-Oki earthquake induced uplift of fluid into the upper crust which reduced mechanical strength of the upper crust and induced those earthquakes.

In the early stage, hypocenters migrated up westward along eastward dipping plane in the central part of the focal area. Then, changing the direction, hypocenters migrated eastward along the main westward dipping plane. It is not easy to correlate the westward dipping plane with the surface geology, because the hypocenter depths range 8-10 km. However the westward dipping nodal planes of focal mechanisms trend along this westward dipping plane. Thus we can use the intersection of the nodal planes with the surface for the correlation. Because the intersections are paralleled to the unconformity of overlaid terrestrial sediments (2) on Abukuma Createaceous granits (1) along Tanakura Tectionic Line, the westward dipping plane can be correlated with Takankura Tectonic Line. The migration of hypocenter can be estimated with flow of the fluid along Tanakura Tectonic Line.

In the later stage, hypocenters migrated westward without significant differences of depth, which may relates to fractures on the hanging wall of magma reservoir

Keywords: Yamagata-Fukushima border, Tanakura Tectonic Line, distribution of hypocenters, migration of hypocenter, nodal plane, geologic structure

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SSS32-04 Room:A04 Time:May 26 15:00-15:15

Seismic activity and stress field in and around Tarumae Volcano

CHIBA, Keita[1*] ; TANADA, Toshikazu[1]

[1]National Research Institute for Earth Science and Disaster Prevention

Tarumae Volcano, which is located in the southern part of Shikotsu caldera, is an active volcano that has repeated various volcanic activities since historical records. Although the volcanic activity has recently been inactive in and around the volcano, crustal deformation accompanied with volcanic activity was found in the deeper region in the northwest part near the summit from the end of June, 2013 through the beginning of July and following then the seismic activity has also increased in the western part around the summit at a depth of 3-5km from the beginning of July, 2013 through August. It is considered that these activities have been the most active since the installation of the seismic observation of 1967 in and around the volcano (Report of Coordinating Committee for Prediction of Volcanic Eruption, 2013). Furthermore, the event of M=5.3 occurred in the western part around the summit at 18:05 (JST) on 8 July, 2014 and then many aftershocks were also observed. It is expected that examining the seismic activity and the stress field in and around the magma chamber to understand the magma feeding system in the volcano leads to the improving the prediction of the volcanic eruption in addition to understanding the volcanic activity.

In this study, we especially focused on the seismic activities before and after the 2014 mainshock (Mw=5.3) and determined the hypocenter by using the method of the hypomh (Hirata and Matsu'ura 1987), taking account of the station correction of the observation stations in and around the volcano. The seismic activity after the mainshock is likely distributed to the west side of the volcano, compared to the distribution before the mainshock. On the other hand, the distribution of the seismic activity beneath the volcano did not change before and after the mainshock. We also determined focal mechanisms using S-wave/P-wave amplitude ratios in addition to P-wave first motion polarities, using the method of Hardebeck and Shearer (2003) and then performed the stress tensor inversion using of the code by Martinez et al. (2014). As a result, the stress fields before and after the mainshock did not significantly changed, showing the stress fields of reverse to strike-slip fault type with the maximum horizontal stress in WNW-ESE direction in both term. Furthermore, to clarify whether the seismic activity after the mainshock was affected by the static stress change by the mainshock, we calculated $\triangle$CFS, referring to some focal mechanisms obtained in this study as a receiver fault. It was found that quite a few aftershocks occurred on the area with $\triangle$CFS <0 and all the aftershock did not necessarily occurred only in the area with $\triangle$CFS >0.

It is thus implied that although the seismic activity in and around the volcano has basically occurred under the regional stress field accompanied by the plate subduction, some factors except for the regional stress also contribute to the occurrence of the seismic activity in and around the volcano. In addition, it is thought that there is little influence in the volcanic activity in Tarumae volcano due to the 2014 mainshock since the remarkable change in seismic activity is not seen beneath the volcano.

Keywords: volcanic activity, hypocenter distribution, stress field, static stress change

Japan Geoscience Union Meeting 2015
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SSS32-05 Room:A04 Time:May 26 15:15-15:30

An improvement of JMA's earthquake catalogs

SHOJI, Tetsuya[1*] ; KATAYAMA, Hiroaki[1] ; TAMARIBUCHI, Koji[1] ; MORIWAKI, Ken[1] ; HASHIMOTO, Tetsuo[1]

[1]Japan Meteorological Agency

Based on measures of The Headquarters for Earthquake Research Promotion, Japan Meteorological Agency(JMA) is collecting the data of the high-sensitivity seismographs nationwide, performs the processing of hypocenter determination centrally, etc, and publishes the result as the earthquake catalogs.

In current earthquake catalogs, we post things that meet certain criteria as a result of scrutiny. However, after The 2011 off the Pacific coast of Tohoku Earthquake, in the aftershock area, although aftershock activity has been reduced, seismic activity is located in the lively situation in comparison with the previous, so we are processing by raising the lower limit of the magnitude of the earthquake to be processed. Therefore, some earthquake, like an earthquake that has not enough accuracy or smaller than processing limit, are not listed in the earthquake catalog. In addition, by the deployment of seismic network of sea waters that are planning in future, improvement of earthquake detection level is expected to in the waters, and number of earthquakes to be processed is expected to increase than ever. So it is necessary to conduct more effective and more efficient treatment than ever from now on.

Against the backdrop of these things, under the Earthquake Research Committee, an examine for improvement for the way of earthquake catalogs was performed in 2013 fiscal year, and summarized reports that shows three directions, 1) to maintain the earthquake detection capability, 2) to post all of the earthquakes detected to the earthquake catalogs, 3) to perform the quality management with a stage to accuracy.

Based on this report, Japan Meteorological Agency is planning to improve and change the hypocenter determination process, taking advantage of automatic picking processing, for example.

Here, I will introduce the changes of the earthquake catalogs from present to next.

Keywords: Earthquake Catalog

SSS32-06 Room:A04 Time:May 26 15:30-15:45

Relationship between half-graben and high-velocities area at depths of 10km 8

OISHI, Yukio[1*]

[1] Atelier Science

Figure indicates four special geological areas at the depths of 10km in Japan after tomography of Nakamura 2008.
1 high velocities and high Poisson's ratio area (HVHP area) indicated in purple or red

Purple indicates HVHP areas. Red also indicates HVHP areas, but where major destructive earthquake occurred since around 1800.It is a noteworthy fact that five of the eight major destructive earthquakes since 1995(Han-Shin Awaji 1995, Western Tottori 2000, Northern Miyagi 2003, Chuetsu 2004, West Off Hukuoka2005) occurred in these areas.
MORB(Mid Ocean Ridge Basalt) in Muroto and Kii peninsula,mantle peridotite in The Central Hokkaido, and Izu Peninsula are in HVHP area. We might say that HVHP area is alike MORB, mantle peridotite, oceanic island. By the way breaking start point of March 11, 2011 Disaster exists on the plate boundary of the surface of subducting Pacific plate that is HVHP area.
2 high velocities and low Poisson's ratio area (VHLP area) indicated in blue

Many of normal fault earthquakes around Idosawa Fault occurred in one of these areas after Mach 11 Disaster.
3 low velocities and high Poisson's ratio area (LVHP areas) indicated in brown
For example oil fields in Niigata and Shizuoka prefecture.

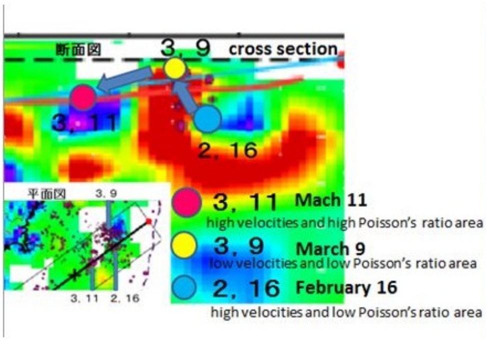
4 low velocities and low Poisson's ratio area (LVLP areas) indicated in yellow

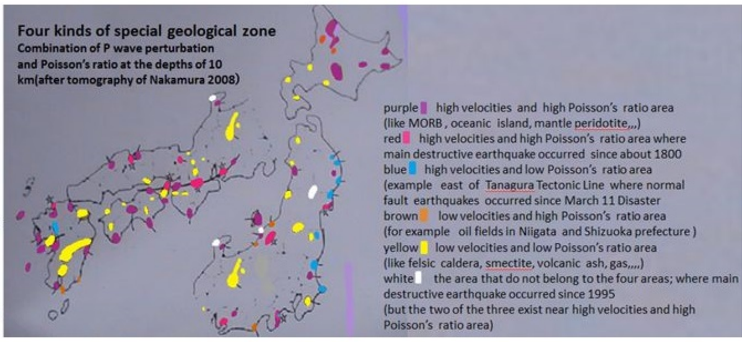
These areas have Unzen, Beppu, (Japanese famous hot spring) Kakutou caldera, Aira caldera and so on.
Given the situation, we can say that these areas may concern with felsic caldera and smectite, volcanic activity, volcanic ash, volcanic gas and so on.
Northern Nagano earthquake 2014 (Hakuba, northern part of Itoigawa-Shizuoka Tectonic Line) also occurred in LVLP area. By the way Azumino and Matsukawa are LVLP areas on the same Tectonic Line. I want to watch this area closely.

M7 class earthquake on March 9 and Slow quakes since January 27 in 2011 around on the plate boundary of subducting Pacific plate that is LVLP area lying east from the epicenter of March 11 Disaster. The existence of smectite on the plate boundary of the shallow part of the fault on March 11 Disaster, C0019 (Ujiie 2014) is congruent with this finding.
It may be a clue to the mystery of interlocking movement of Mach 11, 2011 Disaster to study smectite (especially whose fluidity and conduction property) and to study electric outbreak by particle of smectite bombardment and electrolysis of the water by the electrogeness. And more, casifications such as oxygen and hydrogen gas by the electrolysis of the water, outbreak of the water by the explosion of the gas, and movement of the smectite between the plates. It is thought that a complex study is necessary.

Keywords: high velocities and high Poisson's area(HVHParea), MORB, low velocities and low Poisson's ratio area (LVLP area), smectite, caldera

SSS32-06 Room:A04 Time:May 26 15:30-15:45





SSS32-07 Room:A04 Time:May 26 16:15-16:30

Focal mechanism determinations along the North Anatolian fault, below the Sea of Marmara and the Aegean Sea

NAKANO, Masaru[1*] ; CITAK, Seckin ozgur[1] ; KALAFAT, Dogan[2]

[1]JAMSTEC, [2]KOERI, Bogazici Univ.

Rapid determinations of centroid moment tensor (CMT) of earthquakes, namely the source centroid location, focal mechanism, and magnitude is important for early disaster responses and issuing Tsunami warnings. Using the SWIFT system (Source parameter determinations based on Waveform Inversion of Fourier Transformed seismograms) developed by Nakano et al. (2008), we are developing earthquake monitoring system in Turkey. Also determinations of CMT solutions for background seismicity would reveal the tectonics in the target region, which contribute to develop scenarios for future disastrous earthquakes.

The North Anatolian fault (NAF) is one of most active fault in Turkey, which is a right-lateral fault system running in the East-West direction. NAF can be separated into a number of segments of which ruptures have propagated from east to west in the 20th century. The 1999 Izmit (Kocaeli) earthquake (Mw 7.4) is the westernmost activity along NAF in recent years, and next activity below the Sea of Marmara is anticipated. On 24 May 2014, an Mw 6.9 (USGS) earthquake occurred beneath the northern Aegean Sea, western extension of NAF. A seismic gap between these events still exists beneath the Sea of Marmara.

Using data from broad-band seismometers (Guralp CMG-3T, CMG-3ESP, or CMG-3ESPC) of the regional network in Turkey, we determined CMT solutions of earthquakes along the NAF beneath the Sea of Marmara and Aegean Sea. Seismic events are selected from the USGS ANSS Comprehensive Catalog (ComCat) with magnitude larger than 4 in the target area. We analyzed earthquakes that occurred between 2008 and 2014. We selected seismograms with good data quality. The seismograms are corrected for the seismometer response, band-pass filtered between 20-50 s, and integrated in time to obtain displacement seismograms. The Green functions are synthesized assuming the standard Earth model ak135. Assuming a double-couple source, waveforms are inverted in the frequency domain to obtain best-fit source location and mechanism.

Most events are outside the observation network and the azimuthal gap is larger than 180 and 270 degree for events beneath the Sea of Marmara and the Aegean Sea, respectively. However, for most events the obtained source location in our analysis were almost identical to, or different at most 0.1 degree from, the initial source location from the ANSS catalogue. Because of the large azimuthal gap, we also carefully checked the stability of the obtained focal mechanism.

For the 2014 event beneath the northern Aegean Sea, we obtained a right-lateral strike-slip focal mechanism (Mw=7.2), of which one of nodal planes was directing in ENE-WSW consistent with the slip on NAF. Most of other events represented similar focal mechanisms. Some normal faulting events were also observed several tens of kilometers east of the 2014 earthquake and beneath of the Sea of Marmara.

The Sea of Marmara is a pull-apart basin developed at a segment boundary of NAF, where the crust opens and extensional stress develops. The normal-fault earthquakes may represent such tectonic settings. Detailed descriptions of fault segments would help to estimate future earthquake magnitudes. Normal faulting earthquakes beneath the sea would cause tsunamis if large enough. Historical studies of earthquakes beneath the Sea of Marmara revealed that damaging tsunamis had been triggered due to large earthquakes. Therefore, mapping normal faults and evaluation of their seismic potential are important for disaster mitigation from tsunami in this region.

In the research project of SATREPS-Earthquake and tsunami disaster mitigation in the Marmara region and disaster education in Turkey, we will develop a CMT determination system and a CMT catalogue in Turkey.

Keywords: North Anatolian fault, pull-apart basin, centroid moment tensor

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SSS32-08 Room:A04 Time:May 26 16:30-16:45

Offshore seismicity in the western Marmara Sea, Turkey, revealed by ocean bottom observation

YAMAMOTO, Yojiro[1*] ; TAKAHASHI, Narumi[1] ; CITAK, Seckin ozgur[1] ; KALAFAT, Dogan[2] ; PINAR, Ali[2] ; GURBUZ, Cemil[2] ; KANEDA, Yoshiyuki[3]

[1]JAMSTEC, [2]Bogazici University, [3]Nagoya University

The North Anatolian Fault (NAF) extends 1600 km westward from a junction with the East Anatolian Fault at the Karliova Triple Junction in eastern Turkey, across northern Turkey and into the Aegean Sea, accommodating about 25 mm/yr of right-lateral motion between Anatolia and the Eurasian plate. Since 1939, devastating earthquakes with magnitude greater than seven ruptured NAF westward, starting from 1939 Erzincan (Ms=7.9) at the eastern Turkey and including the latest 1999 Izmit-Golcuk (Ms=7.7) and the Duzce (Ms=7.4) earthquakes in the Marmara region. Considering the fault segments ruptured by the May 24th, 2014 Northern Aegean earthquake (Mw=6.9), the only un-ruptured segments left behind the 1600 km long NAF locate beneath the Marmara Sea and those segments keep their mystery due to their underwater location.

To obtain the detailed information about fault geometry and its stick-slip behavior beneath the western Marmara Sea, we started to operate a series of ocean bottom seismographic (OBS) observations. As a first step, we deployed 3 pop-up type OBSs on 20th of Mar. 2014 as a trial observation, and recovered them on 18th of Jun. 2014. Although one of the OBSs worked only 6 days from the start of the observation, other two OBSs functioned properly during the whole 3-month observation period.

We first searched for the microearthquakes missing by the land seismic network and estimated their precious location by using the initial 6 days data, i.e., using all the temporary OBS stations. Although there are only 3 earthquakes listed on the Kandilli Observatory and Earthquake Research Institute (KOERI) catalogue, we could identify 41 earthquakes with more than 5 picking data of P and S first arrivals, and two-third of them located within the OBS network. We found the earthquake cluster (cluster-A) along the main NAF and whose depth interval is 12-20 km, and some event pair within cluster-A has similar waveform. The location of cluster-A indicates that the dip angle of the main NAF is almost vertical.

Then, we relocated the KOERI-catalogued earthquakes in 3 months periods by combining the land and OBS data. The results indicated that some earthquakes occurred 5-10 km away from the main NAF, and the upper limit of seismicity along NAF seems to dip eastward. Besides, we calculated the correlation coefficient between the waveform data of cluster-A earthquakes and continuous 3-month OBS records to estimate the temporal change of cluster-A activity. The result indicates that the cluster-A became inactive on the end of March. Since the KOERI catalogue reported the active seismicity from 13th to 18th of Mar. near the cluster-A, there is a possibility that the duration of the cluster-A activity was about 2-3 weeks.

To obtain more information of the fault geometry beneath the Marmara Sea, we started a second step observation by using 10 OBSs from Sep. 2014 to Jun. 2015. In addition, we are planning to add 5 OBSs to this observation in Mar. 2015. All OBS observations are conducted as a part of the “Earthquake and Tsunami Disaster Mitigation in the Marmara Region and Disaster Education in Turkey” project, financially supported by Japan International Cooperation Agency (JICA), Japan Science and Technology Agency (JST), and the Ministry of Development in Turkey.

Keywords: The Marmara Sea, The North Anatolian Fault, Seismicity, Ocean bottom seismograph

SSS32-09 Room:A04 Time:May 26 16:45-17:00

Relocation and fault planes of the 1945 Mikawa earthquake

HURUKAWA, Nobuo[1*]

[1]Building Research Institute

We relocated the mainshock, and its foreshocks and aftershocks of the 1945 Mikawa earthquake (M 6.8) using the modified joint hypocenter determination (MJHD) method in order to obtain their accurate hypocenters and to identify fault planes of the mainshock. We used both P- and S-wave initial arrival times at stations reported by the Japan Meteorological Agency (JMA). We confirmed by relocated hypocenters that the mainshock and aftershocks had occurred along the two fault planes proposed by Takano and Kimata (2009) based on triangulation surveys and surface trace of the earthquake faults.

SSS32-10 Room:A04 Time:May 26 17:00-17:15

Landslides triggered by the 1596 Keicho Bungo earthquake in Kitsuki, Beppu, and Yufuin, Oita Prefecture, Kyushu, Japan

NAKANISHI, Ichiro[1*]

[1]Department of Geophysics, Graduate School of Science, Kyoto University

Most studies on the 1596 Keicho Bungo earthquake concern only tsunamis in surrounding coastal areas of Beppu Bay. Both data collection and calculation of tsunami height based on fault models are limited to the inside and mouth of the bay. It is well known that this earthquake generated not only tsunamis but also strong ground motion in the land areas of Bungo, old name of Oita Prefecture. Collection of historical documents on this earthquake conducted by the Earthquake Research Institute, The University of Tokyo shows landslide of slope of Mt. Takasaki and collapse of Yuzuhara-Hachiman Hai-den, which means worshipers' hall.

The aim of this study is to collect data on the earthquake in the documents of the lord family "daimyo-ke" that ruled Bungo in the period right after the occurrence of the earthquake and to estimate earthquake size and source location, and associated natural phenomena. These families are Hosokawa, Matsui, Nakagawa, Kinoshita, Saeki-Mouri, Kurushima, and Inaba. Nakagawa entered Bungo in 1594, Hosokawa, Matsui, and Inaba in 1600, Kinoshita, Saeki-Mouri, and Kurushima in 1601. Matsui was a vassal of Hosokawa and not "daimyo-ke". However, both sho-gun and Hosokawa gave Matsui "daimyo-ke" status and Matsui was the lord of the castle Yatsushiro, Kumamoto.

We have found two records in the documents of Matsui (Yatsushiro Municipal Museum). Here we report on one of the records, a letter sent from Hosokawa Tadaoki to Matsui Yasuyuki on April 22, Keicho 6 (Japanese Calendar) (1601) (Toritsu, personal communication, 2014), about five years later the earthquake. According to Tadaoki, the fief of Hayami-gun, present Kitsuki, Beppu, and Yufuin, yield 60,000 koku. He ordered Yasuyuki to consider damage of about 5,500 koku due to earthquake and reduce land tax in the fief. In the letter no mention was made about earthquake date. We assume the earthquake in the letter is the 1596 Keicho Bungo earthquake.

Using a list of annual rice production of every village in Hayami-gun including Yufuin (1601) (documents of Matsui), we have tried to identify the villages which suffered from destructive landslides. These are Takasu (Kitsuki-City Katano), Yashiro (Hiji-Town Manai Yashiro), Tsujima (Hiji-Town Toyooka), Hamawaki, Tateishi, Tsurumi, Butsusanji, Baba, Yatsukawa, Wakamiya-Hachimansha, and Kozennin, where abbreviation of "old name (present name)" is adopted. The landslides near coasts may enter Beppu Bay, and generate tsunamis.

Acknowledgements: We are supported by Kyoto University Library of Graduate School of Law, Yatsushiro Municipal Museum, Kumamoto University Library, Kumamoto Prefecture Library, Kitsuki City Library, Hiji Town Banri Library, and Oita Prefecture Library.

Keywords: 1596 Keicho-Bungo earthquake, strong ground motion, landslide, tsunami, documents of Matsui, letter written by Hosokawa Tadaoki

SSS32-P01 Room:Convention Hall Time:May 26 18:15-19:30

Inference of a slip distribution from aftershock data and friction law: a Bayesian model with a prior of magnitude

IWATA, Takaki[1]*

[1]Tokiwa University

An statistical method to estimate a fault slip distribution of a mainshock with the spatial distribution of its aftershocks and rate- and state-dependent friction law [Dieterich, 1994] has been suggested [Iwata, 2008]. In this method, the fault plane of a mainshock is divided into subfaults, and then the amplitudes of slip in each of the subfaults are optimized to fit the real spatial distribution of the aftershock activity with the distribution expected from the rate- and state-friction law. Because we optimize a large number of parameters simultaneously in this approach, a roughness penalty is imposed to stabilize the optimization; for this purpose, a Bayesian model with a smoothness prior for the spatial slip distribution is constructed and the estimation is carried out.

One of the problems in this method is how to determine the strength of the roughness penalty objectively. In many cases of seismological/geophysical studies, the strength is determined by the principle of the minimization of Akaike's Bayesian Information Criterion [ABIC; Akaike, 1980] and ABIC is computed through the Laplace approximation [Tierny and Kadane, 1986]. However, because of some technical reasons originated from the formula of the friction law, the Laplace approximation is not applicable to this method and the computation of the value of ABIC is impractical.

This study proposes that the information on the magnitude of a mainshock is incorporated in the Bayesian model. This is because it has been empirically found that the amplitudes of the estimated slip in the subfaults or the corresponding magnitude to the estimated slip distribution much depends on the strength of the roughness penalty; if we impose a constraint on the magnitude, then the appropriate strength could be chosen objectively. To implement this idea, a prior distribution of the magnitude of a mainshock is constructed. It is supposed to be a normal distribution of which mean is retrieved from the Global CMT catalogue and standard deviation is given from Kagan [2010]. Then, the posterior distributions of the strength and the spatial slip distribution are computed simultaneously through the Markov chain Mote Carlo method. This framework provides the practical computational method to estimate the spatial slip distribution of a mainshock inferred from its aftershock data.

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Keywords: slip distribution, aftershocks, Bayesian estimation, prior distribution, Markov chain Monte Carlo method

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SSS32-P02 Room:Convention Hall Time:May 26 18:15-19:30

Tidal triggering of earthquakes after the 2011 Tohoku earthquake

TANAKA, Sachiko[1*]

[1]NIED

I examined correlations between the Earth tides and earthquakes off the Pacific coast of eastern Japan for about four years after the 2011 Tohoku earthquake (Mw 9.1). A previous study has reported a high correlation in the northern part of the Tohoku source area, where the mainshock rupture initiated, in about ten years prior to the Tohoku earthquake (Tanaka, 2012). The data I used are the Global Centroid Moment Tensor (CMT) solutions of shallow earthquakes (depths less than 70 km) with Mw 5.0 or larger for the period from 1976 to 2014. For each event, I theoretically calculated tidal shear stresses on the fault plane considering both the solid Earth tides and ocean loading tides (Tanaka et al., 2002). Assigning the tidal phase angle at the origin time of each event, I tested whether they concentrate near some particular angle or not by using the Schuster's test. In this test, the result is evaluated by p-value, which represents the significance level to reject the null hypothesis that the earthquakes occur randomly irrespective of the tidal phase angle. For about four years after the Tohoku earthquake, no significant correlation was found in the area of high correlation before the Tohoku earthquake; p-values there are larger than 30% in the post-Tohoku earthquake period. On the other hand, small p-values were observed off the Iwate prefecture, north of the Tohoku source area. The smallest (2.8%) is near the coast, where large postseismic afterslip has been identified by geodetic measurements (Ozawa et al., 2012). In this region, no significant correlation was found for about 35 years prior to the Tohoku earthquake. Furthermore, the temporal variation of p-value in the post-Tohoku earthquake period revealed that the p-value was smallest (1.4%) just after the Tohoku earthquake, and gradually increased with time. This seems to be correlated with the time evolution of afterslip showing rapid decay over time (Ozawa et al., 2012). These observations suggest that in addition to the precursory stage of a giant earthquake, tidal triggering could occur in the early acceleration stage of large postseismic slip.

Keywords: the 2011 Tohoku earthquake, Earth tides, earthquake triggering, postseismic afterslip

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SSS32-P03 Room:Convention Hall Time:May 26 18:15-19:30

Seismic activity and attenuation structure aroud the Fukushima and Yamagata Prefectures' border after Tohoku earthquake

MIYAGKI, Keiichiro[1] ; TSUMURA, Noriko[1*]

[1]Graduate School of Science Chiba University

Around the border between Fukushima and Yamagata prefectures, seismicity was suddenly activated after off the Pacific coast of Tohoku earthquake. We estimated distribution and focal mechanisms of the earthquakes to clarify features of the seismic activity. A three?dimensional seismic structure in the northeastern Japan derived in a previous study showed that fluid might affect the seismic activity in this swarm. A Qp/Qs and Qs value greatly change by existence of fluid. Then, we estimated the Q values to clarify physical properties in this region by taking velocity amplitude spectral ratio between P and S waves.

First, we found that hypocenters were concentrated into four clusters. We also observed hypocenter migration to lateral and vertical direction in some clusters. Most earthquakes have the thrust-type focal mechanisms. Average Qp/Qs and Qs values on the ray paths from hypocenters to stations show high Qp/Qs and low Qs at relatively near stations from source region. While paths from the hypocenters to far stations show low Qp/Qs and high Qs. This feature might indicate that high attenuation region exists in nearby source region. Further, we estimated a detail Q structure of the swarm area by using combination of spectra ratio data which have very similar ray paths. As a result, the blocks in which many earthquakes occurred have high Qp/Qs and low Qs, whereas those for the region between the clusters show vice versa. When we compared with other geophysical data, this high Qp/Qs and low Qs values seem to reflect the influence of fluid. Hypocenter migration would be explained by upward migration of fluids due to difference of density.

Keywords: attenuation structure, Seismic activity, swarm, hypocenter migration, fluid

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Changes in frequency ratio of inter-plate vs intra-plate earthquakes in the source area of the 2011 Tohoku earthquake

IMOTO, Masajiro[1*] ; MORIKAWA, Nobuyuki[1] ; FUJIWARA, Hiroyuki[1]

[1]NIED

In the current seismic hazard maps for Japan, contributions from earthquakes of non-specified fault parameters in the subduction area are considered either as interplate or intraplate earthquakes. Here, a ratio of the number of interplate earthquakes to the total number of quakes is used as a given parameter obtained from the frequency distribution of earthquakes in depth. In the present study, we attempt to employ focal mechanism solutions for estimating the ratio. As a case study, ratios are examined from 3663 mechanism solutions of earthquakes of magnitude 4.0 or greater occurring in the area of 36N-41N and 139E-144E, which covers the source area of the 2011 Tohoku earthquake (M9.0). First, we calculate the minimum 3-D rotation angle (Kagan angle) between the observed mechanism of an earthquake and expected one, which can be estimated on assumptions of configurations of plate interfaces and relative motions between the plates. Inter plate events are assigned, of which Kagan angles are less than a certain threshold level. We estimate a ratio at every 0.1 by 0.1 spacing grids. After operating smoothing method with ABIC, we obtain those ratios at every grids. The estimate is separated into that for the pre 2011 Tohoku earthquake period or for the post-earthquake period. As a result, we have found that, in general, ratios of the inter-plate earthquakes for the post-earthquake period are smaller than those for the pre-earthquake period. The ratios obtained in the present study are significantly smaller than the current ones.

Keywords: seismic hazard maps for Japan, Tohoku, interplate earthquake, Kagan angel, 2011 Tohoku earthquake

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Focal mechanism of earthquake swarms in Gassan and Ooisawa, Yamagata Prefecture

OSHIMA, Atsushi[1] ; IWATA, Naoyoshi[1] ; HASEMI, Akiko[1*]

[1]Faculty of Science, Yamagata University

Seismic activity near Gassan Mountain was activated 6 days after the 2011 off the Pacific coast of Tohoku Earthquake. In this area, the activity had been low before the Tohoku earthquake. About 15km south of this area, earthquake swarm activity has repeated in Ooisawa area. Recent activities occurred in 2003 and 2006. Triggered activity was not occurred there. We determined source mechanisms of earthquakes magnitude larger than 2.0 of Gassan and Ooisawa activities using P-wave first motion to investigate a difference between two regions. The numbers of source mechanisms determined were 33, 14 and 12 for Gassan, 2003 Ooisawa and 2006 ooisawa activities, respectively. In Gassan, 7 of 33 were strike slip faults, 20 reverse faults with strike slip component, 2 reverse faults and 4 normal faults with strike slip component. Okada et al.(2011) calculated Coulomb stress change on the fault plane of the strike slip event on Apr 4, and obtained a positive change of 0.29MPa. Since the mechanism solutions determined in this study contained strike slip component similar to that used by Okada et al.(2011) , Coulomb stress change may be the cause of the Gassan activity. Considering 6days delay and the low velocity lower crust beneath Gassan into account, an increase of pore fluid pressure is supposed to be another cause of triggering. For Ooisawa swarm, we determined 26 mechanism solutions. All of them were reverse slip faults with E-W or NWN-SES P-axis. As reasons why activities were not triggered in Ooisawa, we suppose that reverse faults, on which a slip was inhibited by the Tohoku earthquake, are predominant, and/or that fluid was not moved into the upper crust there.

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Keywords: 2011 Tohoku-Oki earthquake, induced seismicity, focal mechanism, Gassan, Oisawa

SSS32-P06 Room:Convention Hall Time:May 26 18:15-19:30

Active foreshocks of M>7.5 earthquakes in the northern Japan to Kuril Trenches

HARADA, Tomoya[1*] ; YOKOI, Sayoko[1] ; SATAKE, Kenji[1]

[1]Earthquake Research Institute, Univ. of Tokyo

Along the northern Japan to Kuril Trenches, active foreshock sequences preceded some M>7.5 earthquakes, providing a good opportunity to understand the characteristics of foreshocks for large interplate events. Active foreshocks are identified in the M-T diagrams and cumulative frequency curve of earthquakes before and after the mainshocks. The earthquakes preceded by active foreshocks are: the 2006 (Mw8.3) and 2007 (Mw8.1) offshore Simushir earthquakes, the 1963 (Mw8.6), 1991 (Mw7.6), 1995 (Mw7.9) offshore Urup events, the 1978 (Mw7.8) offshore Iturup event, the 1969 (Mw8.2) offshore Shikotan event, the 1989 (Mw7.4) offshore northern Sanriku event. In contrast, M>7.5 interplate earthquakes offshore Hokkaido to northern Sanriku in 1952 (Mw8.1), 1968 (Mw8.3), 1973 (Mw7.8), 1994 (Mw7.8), 2003 (Mw8.1), and intraslab earthquakes in 1958 (Mw8.4), 1978 (Mw7.8), 1993 (Mw7.7), 1994 (Mw8.3) had few or no foreshocks.

Some results from our examination of the foreshock sequences are as follows. Fitting the ETAS model (Ogata, 1988, 1992) to foreshock sequences show that the active foreshocks were composed of large foreshocks and their aftershocks. Foreshocks of the 2007 Kuril outer-rise earthquake were interpreted as aftershocks of the 2006 interplate earthquake. Relocated foreshocks show that they migrate in various, not unique, directions. Distributions of foreshock do not overlap with the large coseismic slips (asperities) of the mainshocks of interplate earthquakes.

Relocation of foreshocks and maishocks were made by the modified JHD method and time-difference grid-search method (Hurukawa & Harada, 2014). The coseismic slip distributions were estimated by the teleseismic body-wave inversion (Kikuchi & Kanamori, 2003).

Keywords: northern Japan Trench to Kuril Trench, Remarkable foreshock activity, ETAS model, Modified Joint Hypocenter Determination method, time-difference grid search method, teleseimic body-wave inversion

SSS32-P07 Room:Convention Hall Time:May 26 18:15-19:30

Precursory seismic activity surrounding the source region of the 1968 Tokachi-oki earthquake

HIRATSUKA, Shinya[1*]

[1]ISV, Faculty of Science, Hokkaido Univ.

The 1968 Tokachi-oki earthquake (Mw8.2) occurred off the Pacific coast of Aomori prefecture and ruptured northern and southern asperities. 26 years later, the 1994 Sanriku-haruka-oki earthquake (Mw7.7) occurred near the epicenter of 1968 event and ruptured only its southern asperity [Nagai et al. (2001)]. According to Sato et al. (1996), the rupture process of the 1994 event was very similar to the earlier stage rupture process of the 1968 event. The question arises, "Why did the 1994 event not rupture the northern asperity of 1968 event"? In order to address this question, we investigated the long-term seismicity pattern with reference to the slip distribution of the 1968 Tokachi-oki (Mw8.2) and 1994 Sanriku-haruka-oki (Mw7.7) earthquakes. We used the earthquake catalogue compiled by the Japan Meteorological Agency (JMA) for the past 90 years since 1923.

There are two major clusters that are considered to be important for characterizing the spatio-temporal seismicity pattern in and around the source region of the 1968 event. The one is a cluster of events located off the Pacific coast of Iwate prefecture between the Japan Trench and the southern asperity of the 1968 event. We call this cluster the "east-west trending seismic activity", because it is distributed along the east-west direction. The other is a cluster of events located off the Pacific coast of Iwate prefecture between the 10 and 20km depth contours of the upper interface of the subducted Pacific plate. We call this cluster the "southern seismic activity", because it is located southern side of the southern asperity of the 1968 event. The epicentral area of the southern seismic activity include the rupture zone of the 1989 and 1992 Sanriku-oki earthquakes, which are regarded as the ultra-slow earthquake by Kawasaki et al. (1995, 1998, 2001).

The 1931 Iwate-oki earthquake (M7.2) occurred off the Pacific coast of Sanriku and ruptured the southern asperity of the 1968 event [Yamanaka and Kikuchi (2004)]. The 1931 event was preceded three years earlier by a M7.0 event that occurred about 30km to the west. 4 years later, a M6.9 earthquake occurred very close to the epicenter of the M7.0 event in 1935. The 1933 activity in the zone of east-west trending seismic activity consists of nine large earthquakes (M>6.0) with the largest of M7.1. Three of the events initially occurred in the eastern part of the zone, then expanded into the west. The 1933 Sanriku-oki earthquake (M8.1) occurred in the outer-rise region off the Pacific coast of Iwate prefecture. The 1941 activity in the zone of southern seismic activity consists of four large earthquakes (M>6.0). Two of the events occurred in the eastern part of the zone, then the other two events occurred in the western part of the zone. A strong swarm activity (including eight M>6.0 earthquakes) occurred in the zone in 1952. The 1960 Iwate-oki earthquake (M7.2) occurred off the Pacific coast of Sanriku and ruptured the southern periphery of the southern asperity of the 1968 event. The rupture propagated to the deep direction from the hypocenter [Yamanaka and Kikuchi (2004)]. A 1945 event (M7.1) occurred off the Pacific coast of Aomori prefecture and ruptured the northern asperity of the 1968 event. The 1945 event was preceded two years earlier by a M7.1 event that occurred about 40km to the east. On March 22, 1944, M6.1 event occurred in the region sandwiched by the northern and southern asperities of the 1968 event. This event may contribute to weaken the strength of this region and allowed to propagate the rupture from the southern to northern asperities when main shock of the 1968 event occurred.

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Keywords: 1968 Tokachi-oki earthquake, 1994 Sanriku-haruka-oki earthquake, 1933 Sanriku-oki earthquake, precursory seismic activity, asperity

SSS32-P08 Room:Convention Hall Time:May 26 18:15-19:30

Seismic activity around the upper surface of the Pacific slab beneath Kanto

HIKITA, Masahiro[1*] ; NAKAJIMA, Junichi[1]

[1]Tohoku University

Kanto is known as a unique region characterized by the subduction of two oceanic plates, the Philippine Sea plate and the Pacific plate, and intensive seismicity occurs along the upper surfaces of the two subducting plates (e.g., Uchida et al., 2007). In particular, many interplate earthquakes occur along the upper surface of the Pacific slab from the north of the Tokyo bay to southern Ibaraki prefecture, forming an N-S-trending marked seismic cluster at depths of 60-90 km, and the seismic cluster is composed of many isolated sub-clusters. In this study, we apply double-difference location method (Waldhauser and Ellsworth, 2000) to a large number of catalog-derived differential arrival-time data, and relocate sub-earthquakes in the N-S-trending cluster. Delineation of detailed distribution hypocenters around the upper surface of the Pacific slab provides a clue to understand the cause of the marked seismic activity in this area.

The main results obtained in this study are as follows: (1) most of the sub-clusters have the thickness of 5-10 km. (2) small repeating earthquakes and thrust-type earthquakes mainly occur at the middle and deeper part of the sub-clusters. (3) earthquakes that occur at the shallow part of the sub-clusters have focal mechanisms different from low-angle thrust type. In the next step, we will relocate hypocenters more precisely using waveform-derived differential arrival-time data, and investigate the seismogenesis along the upper surface of the Pacific slab beneath Kanto.

Keywords: repeating earthquakes, Kanto, activity of earthquakes

SSS32-P09 Room:Convention Hall Time:May 26 18:15-19:30

Matched Filter Method implemented as an automatic hypocenter location system

OHMI, Shiro[1*]

[1]Disaster Prevention Research Institute, Kyoto University

Seismic activity near Mt. Hotaka in the Hida Mountains, central Japan was analyzed by using the Matched Filter Method (MFM). In this analysis, MFM was implemented as an automatic hypocenter relocation system. We selected about thirty (30) template earthquakes in the target region that enables us to detect more than 3,000 events and locate about 800 earthquakes in the time period from April 2013 to October 2013. Comparison with manually inspected results indicates that location errors by MFM system is within a couple of kilometers. The seismic activity in the target region started in April 2013 and most intense activity occurred in October 2013. The largest event took place on October 8, 2013 at 19:28 (JST) whose magnitude was 3.9 (JMA). Epicentral area extends about 4 km in EW direction with 1 km in NS direction at the eastern frank of Mt. Hotaka. Although manually inspected catalogue data is essential to evaluate seismic activity, we suppose MFM is one of the powerful tools to automatically obtain preliminary results for the swarm activity that concentrated in a small area such like this study or volcanic regions.

Keywords: Swarm activity, Hida Mountain range, Matched Filter Method

SSS32-P10 Room:Convention Hall Time:May 26 18:15-19:30

Relocation of the 1944 Tonankai earthquake and its aftershocks: The fault plane and characteristics of the seismicity

HURUKAWA, Nobuo[1*] ; HARADA, Tomoya[2]

[1]Building Research Institute, [2]Earthquake Research Institute, University of Tokyo

We relocated the mainshock and its aftershocks of the 1944 Tonankai earthquake (M 7.9) using the modified joint hypocenter determination (MJHD) method in order to obtain their accurate hypocenters and to identify the fault plane of the mainshock. We used both P- and S-wave initial arrival times at stations worldwide reported by the Japan Meteorological Agency (JMA) and International Seismological Summary (ISS). We confirmed by relocated hypocenters that the mainshock and many direct aftershocks had occurred along the plate boundary between the Eurasian and Philippine Sea plates. We also confirmed that the eastern end of the aftershock area reached the Tenryu River, where induced shallow crustal earthquakes also occurred. The aftershocks south of Shionomisaki and along the SE coast of the Kii Peninsula are crustal earthquakes induced by the mainshock.

SSS32-P11 Room:Convention Hall Time:May 26 18:15-19:30

Southern Extent of Seismicity in the Philippine Sea plate south of the Nankai Trough

NAKATA, Kenji[1*] ; KOBAYASHI, Akio[1] ; HIRATA, Kenji[2] ; YAMAZAKI, Akira[3] ; TSUSHIMA, Hiroaki[1] ; BABA, Hisatoshi[4] ; USHIDA, Takashi[4] ; ICHINOSE, Satomi[4] ; ISHIHARA, Takanori[4] ; INAMURA, Kazuya[4] ; HASUZAWA, Tsuyoshi[4] ; KATSUMATA, Akio[1] ; MAEDA, Kenji[1]

[1]Meteorological Research Institute, JMA, [2]National Research Institute for Earth Science and Disaster Prevention, [3]Kakioka Magnetic Observatory, JMA, [4]Tokai University

Meteorological Research Institute (MRI) has deployed the pop-up type Ocean Bottom Seismometers (OBSs) in the area south off Kii peninsula for several times to investigate seismicity in the area. Yamazaki et al. (2011, Tech. Rep. MRI) confirmed the microearthquake activities at a depth of 10-25 km around the Nankai Trough by the four time operations since 2005. Hirata et al. (2013 and 2012, JpGU meeting; 2012, SSJ meeting) carried out observations on the south of the Nankai Trough in 2010. They found microearthquakes at a depth of around 10 km by using the 22 OBSs. It was considered that these microearthquakes were classified as seismic activities in the oceanic crust of the Philippine Sea Plate (PSP) (Obana et al., 2005, JGR).

Where is the southern limit of this seismic activity? To investigate the extent of the seismic activity, we conducted the OBS observations in 2013 and 2014, in the area farther south of the 2010 network. The observation network was deployed in the range of 31.6-32.3N. We retrieved 10 OBSs in each 2013 and 2014 observations. First, clock time was corrected based on the time differences at the deployment and the retrieval. Next, event waveform data were selected from the continuous data by an event trigger. Finally, we picked the arrival times and amplitudes and determined the hypocenters with the method of Hirata and Matsu'ura, 1986. Here, we used the same velocity-structure model of P-wave velocity as Hirata et al. (2013) which was base on Kodaira et al. 2000. Sediment layer correction was done using the arrival times of PS converted wave.

Magnitude and hypocenter of an earthquake were determined for the events inside the observation network of 2013 and 2014. Magnitudes of events ranged in about M 0.0-0.5 and depths were estimated at about 10 km. This result shows that the same type of microearthquakes occur as in the area of the 2010 observation. Numbers of events determined inside the observation network of 2013 and 2014 are 36 and 23. Total number of the two operations is approximately half of the number of 112 in 2010. The seismic activity of the microearthquakes in the southern area of the observation network is relatively lower than that in the northern area. Furthermore we investigated the hypocenters determined outside the observation network. As a result, there are some hypocenters (M>=1) on the north of the network, however, there are not any hypocenters determined on the south of the network. Therefore, it indicates that the southern extent of the seismicity of the inside PSP (M>=1) is around 31.6-31.9N in the area of 135.3-136.3E.

We used short-period OBSs (4.5 Hz, 3-comp.). Deployment and retrieval of OBSs were done by the Keifu-maru and the Ryofu-maru of JMA. Observation periods, area and numbers of retrieved OBSs were as follows,
2010: Period, from 12/June to 14/Sep./2010 (about 3 months); Number of OBSs, 22;
Area, south off Kii Peninsula (off Cape Shiono-misaki) (31.9-32.8N, 135.6-136.2E)
2013: Period, from 12/July to 30/Sep./2013 (about 3 months); Number of OBSs, 10;
Area, south off Kii Peninsula (far south of obs. in 2010) (31.8-32.3N, 135.8-136.3E)
2014: Period, from 7/Aug. to 30/Oct./2010 (about 3 months); Number of OBSs, 10;
Area, south off Kii Peninsula (west side of obs. in 2013) (31.6-32.3N, 135.3-135.8E)

Keywords: seismicity, microearthquake, OBS, Nankai trough, outer rise

SSS32-P12 Room:Convention Hall Time:May 26 18:15-19:30

Imaging an active fault in the eastern Guadalquivir basin (Southern Spain) with high-resolution seismic tomography

SERRANO, Inmaculada[1*] ; TORCAL, Federico[2] ; MARTIN, Jose benito[1]

[1]Andalusian Institute of Geophysics, Granada University, Spain, [2]Pablo Olavide University, Seville, Spain

The Torreperogil seismic series took place in the Guadalquivir Basin (Southern Spain), a large flexural foreland basin with a linear ENE-WSW trending bounded to the north by the Iberian Massif and to the south by the Betic Cordillera and filled from a middle Miocene to Plio-Quaternary sedimentary sequence characterized by a large number of low magnitude (below Mw 3.7 or Md 3.9) and very shallow microearthquakes. We calculated the high resolution seismic velocity, Poisson's ratio, crack density and saturation ratio structures in and around the source areas of the Torreperogil seismic series (October 2012-April 2013).

In the upper layers of the crust, strong low-velocity anomalies are extensively distributed under the central zone, which together with high Poisson's ratio and crack density values may correspond to rocks which are less likely to fracture, perhaps due to the accumulation of tectonic and seismic stress. 93% of the earthquakes occurred at depths of up to 8 km, which could indicate that the base of the seismogenic zone lies at this depth. The seismic series was concentrated in layers of strong structural heterogeneities (in the boundary area between low and high anomalies), which were likely to generate earthquakes due to differential strain accumulation beneath the region. The high velocity areas are also considered to be strong yet brittle parts of the fault zone, which are likely to generate earthquakes (at depths of between 5 km and 9 km). In contrast, low velocity areas are probably less likely to fracture, allowing seismic slippage to take place (from 2 to 4 km depth).

The best estimate of the depth of the main shock (mbLg: 3.9) is 7.6 km, which could tend to nucleate at the base of the seismogenic zone, at the "fault end" on the boundary between a low velocity zone to the east and a high velocity zone to the west, indicating the fault plane which separates both areas laterally. Assuming that this seismic contrast is one of the main Torreperogil faults it could imply that stress has accumulated in an existing fault zone with lateral heterogeneity in velocity.

Keywords: Seismic tomography, Seismicity, Tectonic, Spain, Betic Cordilleras

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Precursory seismicity change of the 2013 Nantou, Taiwan earthquake sequence revealed by ETAS, PI, and Z-value methods

KAWAMURA, Masashi[1*] ; CHEN, Chien-chih[2] ; WU, Yih-min[3]

[1]Dep. of Earth Sciences, National Taiwan Normal Univ., [2]Dep. of Earth Sciences, National Central Univ., Taiwan, [3]Dep. of Geosciences, National Taiwan Univ.

M_L6.2 and M_L6.3 earthquakes occurred in the Nantou area of central Taiwan on Mar. 27, 2013 and June 2, 2013, respectively. Because their epicenters are close to one another, we regard the March M_L6.2 and June M_L6.3 earthquakes as an event sequence. To investigate precursory seismicity change of the Nantou earthquake sequence (or the March M_L6.2 earthquake), we applied the Epidemic-Type Aftershock-Sequences model (ETAS model) to the earthquake catalog data of the Central Weather Bureau (CWB) covering broader Taiwan region. Application of more than one model to an earthquake catalog would be informative in elucidating the relationships between seismicity precursors and the preparatory processes of large earthquakes. Based on this motivation, we further applied two different approaches: the pattern informatics (PI) method and the ZMAP method, which is a gridding technique based on the standard deviate (Z-value) test to the same earthquake catalog data of CWB. As a result, we found that the epicenter of the 2013 M_L6.2 Nantou earthquake was surrounded by three main seismic quiescence regions prior to its occurrence. The assumption that this is due to precursory slip (stress drop) on fault plane or its deeper extent of the M_L6.2 Nantou earthquake is supported by previous researches based on seismicity data, geodedic data, and numerical simulations using rate- and state-dependent friction laws (Kawamura and Chen, 2013).

Keywords: Seismic quiescence, The Nantou earthquake, Stress accumulation, ETAS model, Pattern informatics, ZMAP