Proceedings of the 15th Japan-Taiwan International Workshop on Hydrological and Geochemical Research for Earthquake Prediction

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GSJ, AIST, Tsukuba, Japan

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IEVG
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1-1 Higashi 1-Chome, Tsukuba, Ibaraki, 305-8567 Japan
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The 15th Japan-Taiwan International Workshop on Hydrological and Geochemical Research for Earthquake Prediction

7 September, 2016

Meeting room No.2, GSJ, AIST, Tsukuba, Japan

No	From	To	Name	Presentation
				Morning sesson
	10:00	10:10	Eikichi Tsukuda (AIST)	Greeting
1	10:10	10:35	Yuzo Ishikawa (AIST)	The 2016 Kumamoto M6.5 & M7.3 earthquakes
2	10:35	11:00	Naoji Koizumi (USP)	Groundwater changes related to the 2016 Kumamoto earthquakes
3	11:00	11:25	Yasuyuki Kano (DPRI, KU)	Hot Spring Anomalies Observed in Kumamoto Prefecture Associated with the 1946 Nankai Earthquake
4	11:25	11:50	Ryoya Ikuta (SU)	Probability Assessment of Huge Inter-plate Earthquakes in Global Subduction Zones -from the View of Slip Deficit-
5	11:50	12:15	Masataka Ando (SU)	Need for more seafloor geodetic observations in the southernmost Ryukyu arc
	12:15	12:30	Group Photo at the 1st floor of the building	
	12:30	13:40	Lunch (Lunch Meeting for presenters at Meeting Room No.1 at 8th floor)	
				Afternoon session #1
6	13:40	14:05	Min-Chien Tsai (CWB)	Preliminary study of GPS observation and seismic activity: 2016 Meinong earthquake, Taiwan
7	14:05	14:30	Jyr-Ching Hu (NTU)	Seismic Hazards on High Strain Accumulation in SW Taiwan: Insight from Multiple Fault Slip Triggered by 2016 Mw 6.4 Meinong Earthquake
8	14:30	14:55	Ching-Chou Fu (IES, AS)	Temporal changes in gas geochemistry and gamma rays as a precursor of the 2016 M6.6 Meinong earthquake, southern Taiwan
9	14:55	15:20	Wen-Chi Lai (DPRC, NCU)	The study of the coseismic groundwater level changes in Taiwan: An updated in ML 6.4 Tainan earthquake, Feb. 6th 2016
	15:20	15:50	Coffee break and Poster session	
				Afternoon session #2
10	15:50	16:15	Fumiaki Tsunomori (UT)	Temporary Change of Gas Composition in Groundwater of Atotsugawa Observation Well, Japan
11	16:15	16:40	Hidemi Tanaka (UT)	Hydrological characteristics of the Kamishiro fault deduced from fluid discharge by 2014 North-Nagano earthquake
12	16:40	17:05	Kuo-Fong Ma (NCU)	Hydrological Parameters Estimation Through Seismological Investigation on Fluid Migration Activity After Earthquakes: Case Study for 1999 M7.6 Chi-Chi, and 2016 M6.4 Meinong, Taiwan, earthquakes
13	17:05	17:30	Norio Matsumoto (AIST)	In-Situ Permeability of Fault Zones Estimated by Hydraulic Tests and Continuous Groundwater-Level Observation
	17:30	18:00		Discussion
	18:00			Banquet (Café Piquenique)

Title of posters

P1. T. Shibata (Institute for Geothermal Sciences, Kyoto University), P. Méjean, N. Takahata and Y. Sano (Atmosphere and Ocean Research Institute, University of Tokyo) Helium measurements in a hot spring well in Beppu, Japan

P2. T. Sato (AIST) Anomalous continuous discharge of hot spring water over five years due to the 2011 Iwaki earthquake in Japan

P3. Y. S. Togo (AIST) Contribution of slab-derived water in deep groundwater in Tohoku

P4. K. Kazahaya, Takahashi M (AIST), Matsuzawa T, Hasegawa A (Tohoku Univ.), Yasuhara M., Oyama Y, Kirita T(AIST), Iwamori H (JAMSTEC) Cogenetic distributions of deep-seated fluids and earthquakes in Japan arc: Implications for slab fluid processes

P5. N. Matsumoto (AIST) Response of groundwater level to large strain change associated with high embankment near the well

IES, AS: Institute of Earth Sciences, Academia Sinica, Taiwan
NCU: National Central University, Taiwan
CWB: Central Weather Bureau, Taiwan,
NTU: National Taiwan University, Taiwan
DPRC，NCKU: Disaster Prevention Research Center, National Cheng Kung University, Taiwan
USP: The University of Shiga Prefecture
DPRI, KU: Disaster Prevention Research Institute, Kyoto University
SU: Shizuoka University
UT: University of Tokyo
AIST: National Institute of Advanced Industrial Science and Technology

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The 2016 Kumamoto M6.5 & M7.3 earthquakes

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The large earthquake M7.3 occurred on April 16 in Kumamoto prefecture. It was the biggest one in inland Kyushu in Japanese history. Before the mainshock, M6.5 and M6.3 earthquakes occurred along the Hinagu(日奈久) active fault. The right-lateral strike-slip with normal fault component faults were founded in source area. The b value of foreshock's aftershocks is 0.74 (min Mj3.2). This b value is some smaller than general large earthquakes, but there was one example along Hinagu fault. The M5.0 event occurred on June 8, 2000 along Hinagu fault. The b value of M5.0 aftershocks was 0.61 (min Mj1.4). This b value is smaller than 0.74 and M5.0 terminated without the bigger event. So, nobody thought that M6.5 and its aftershocks were the foreshock of M7.3 at that time.

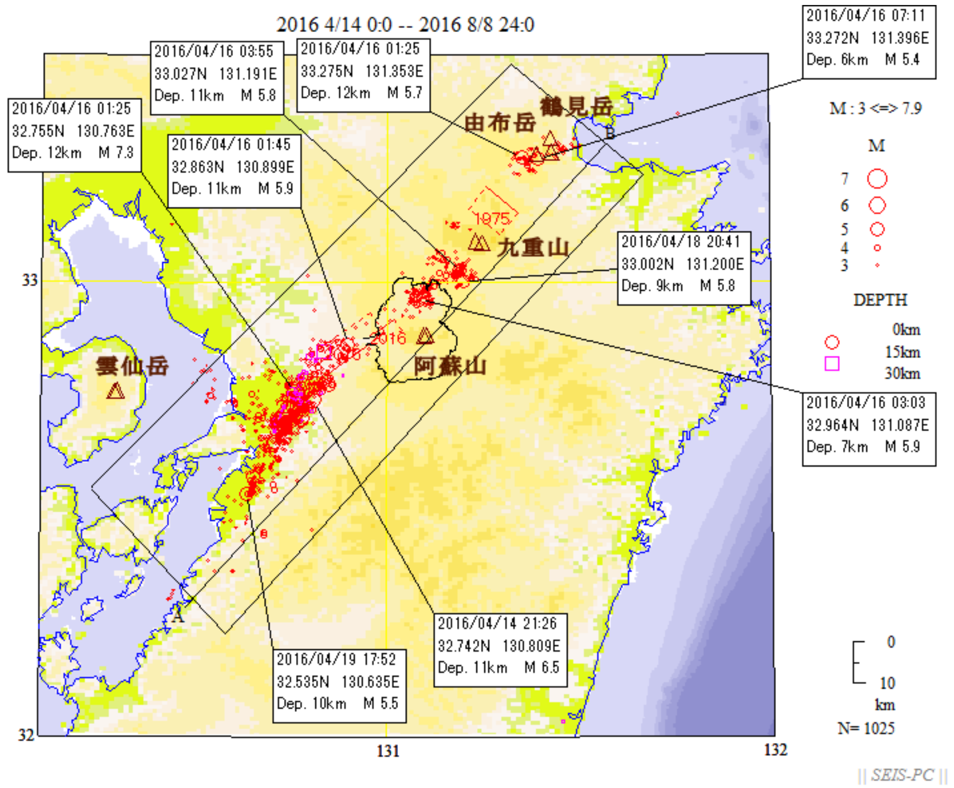


Figure 1. Epicenter distribution of the Kumamoto earthquake from April 14 to Aug. 8. Mjma=>3 and dep=<30km. The source faults were drawn in red with year. 1975 event was the Central Oita M6.4. The black line shows the Aso caldera and brown triangles show volcanoes.

The Mashiki(益城) intensity station recorded twice intensity 7 in JMA scale. It was the first time of the Japanese history of reporting intensity. The Volcanic observatory of Kyoto university at Aso mountain was severely damaged by these earthquakes.

The M7.3 occurred along the Hutagawa(布田川) active fault. This event also showed the right lateral strike slip with normal fault component fault. The maximum surface dislocation reported was about 2.2m horizontally.

The northern end of the Hinagu fault contacted with the Hutagawa faut. Three source faults were estimated as 20.0x12.5, 5.1x6.6, and 10.2x13.0km, respectively by GSI. These located at from Kumamoto city to Aso caldera area. Maximum dislocation estimated was about 4.1m. The Kumamoto M7.3 induced new seismicity in Aso area and Oita prefecture. M5.9 and M5.8 earthquakes in Aso area generated the large landslide and severe damage. 10 people were killed by the landslide and 37 people by house collapses (after The Asahi newspaper). Total 50 people were killed.

The Kumamoto earthquake was caused by two active fault systems and induced other seismicity in some far region, so number of event is much more than the past events. The Kumamoto earthquake was 1009 events in 2 months (M>=3, Dep=<30km). the 2004 Chuetsu (中越地震) M6.8 had 506 events in 3 months and 1995 Kobe M7.3 (兵庫県南部地震) had only 251 events in 3 months.

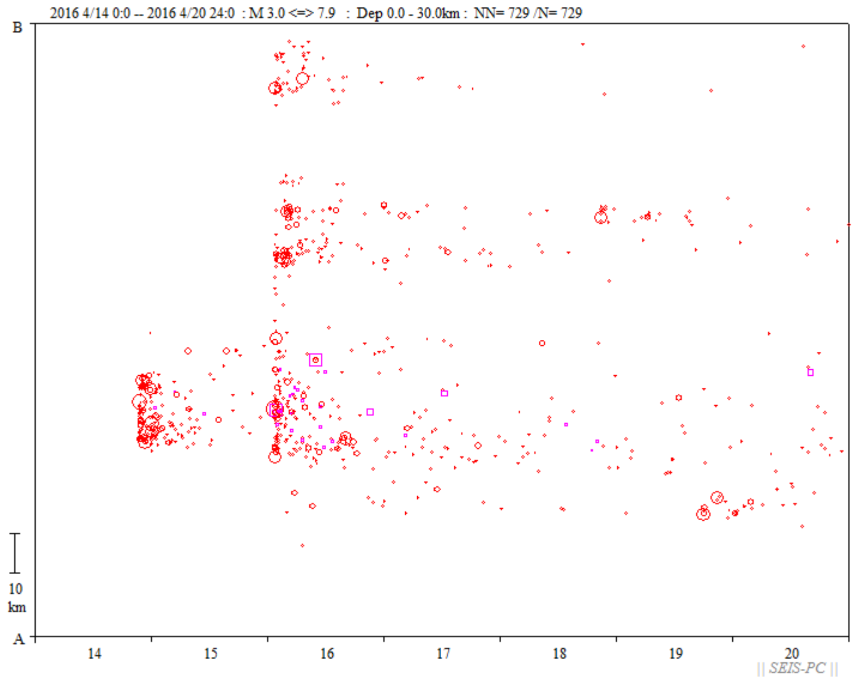


Figure 2: Time-space distribution of foreshocks, main shock and aftershocks from April 14 to 20 in the rectangle of figure 1 (MJ>=3, Dep=<30km). The upper side is north-east side. Foreshocks occurred only near Kumamoto city. After the mainshock, induced earthquakes occurred in Aso area and Oita prefecture.

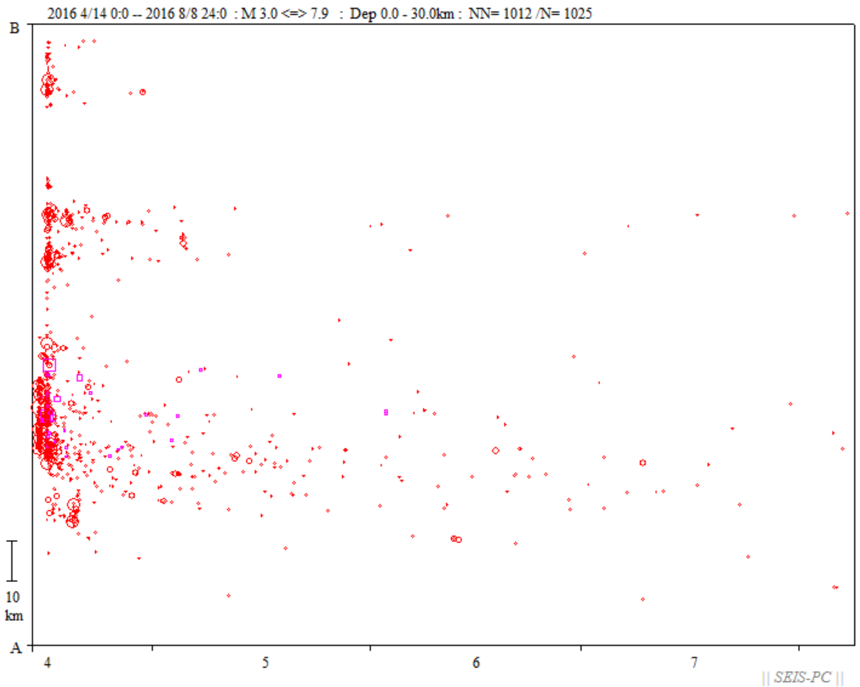


Figure 3: Time space distribution of the Kumamoto earthquake from April 14 to Aug. 8. Most of aftershocks were convergenced except Kumamoto area.

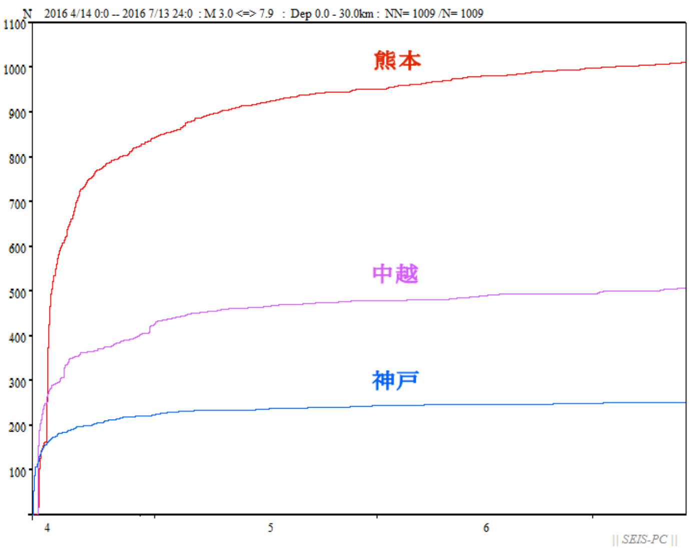


Figure 4: Cumulative event number of Kumamoto, Chuetsu, and Kobe earthquakes (Mj>=3) for about 3 months.

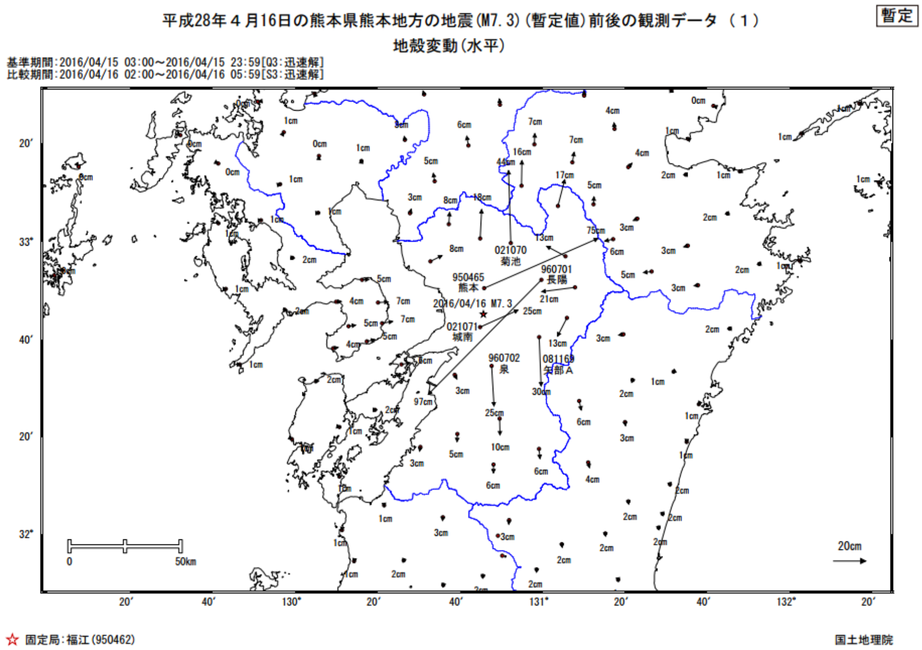


Figure 5: Horizontal displacement of M7.3 by GEONET (after GSI,2016)

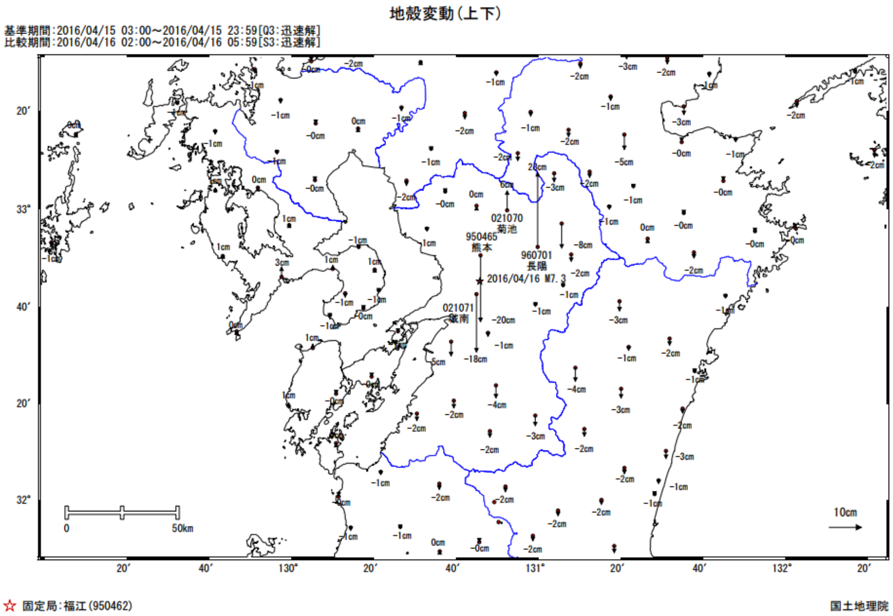
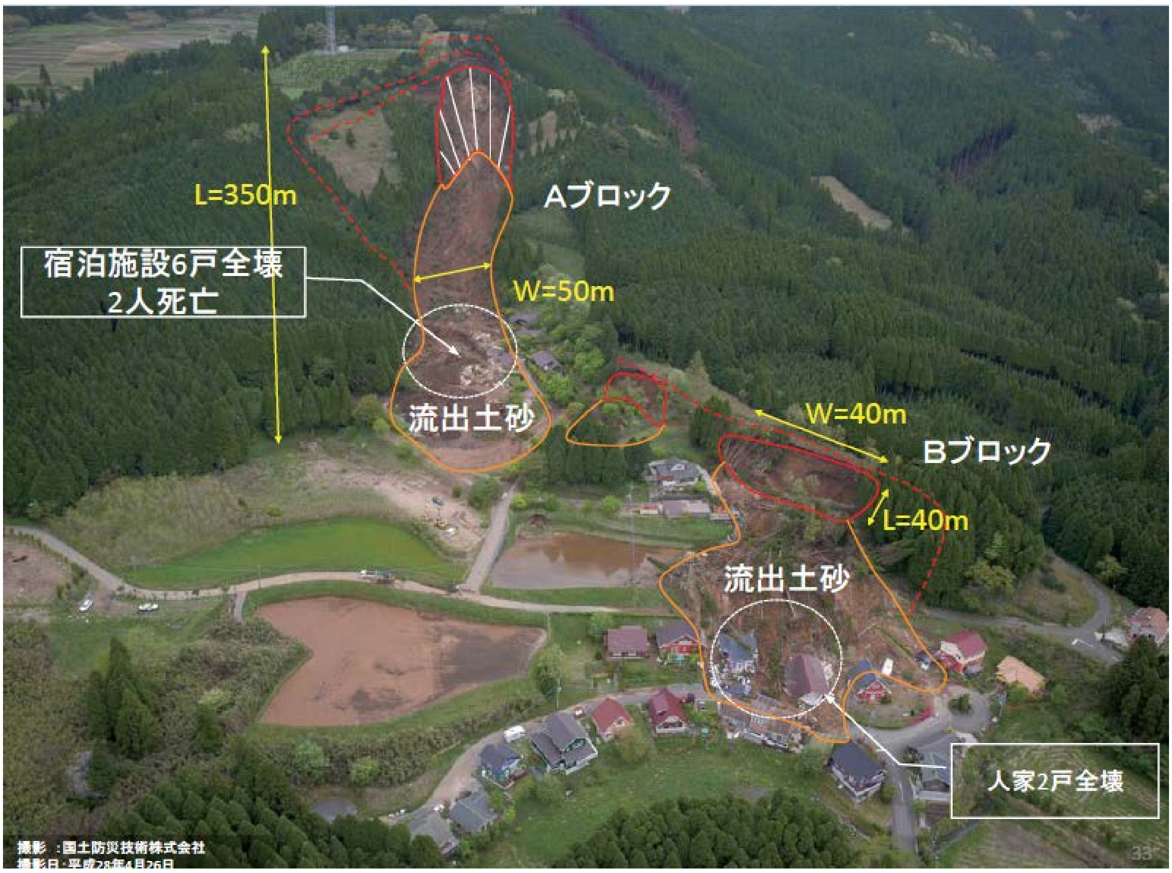


Figure 6: Vertical displacement of M7.3 by GEONET (after GSI,2016).

Surface fracture by the Kumamoto earthquake taken by M. Yoshimi (2016).



Landslides by the Kumamoto earthquake at Hinotori area after Shinya Nakamura(2016).

Groundwater changes related to the 2016 Kumamoto earthquakes

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The 2016 Kumamoto earthquakes started with an M6.5 event, called foreshock, on April 14. 28 hours after the first event or the foreshock, the largest event with M7.3, called main shock, occurred on April 16. There have been also many aftershocks. These earthquake series caused severe damage mainly in Kumamoto and Oita Prefectures in Japan. The main shock caused groundwater changes not only in the source region but also in the Shikoku, Kinki and Tokai regions, which are far from the source region. We will report those groundwater changes.

There are about 50 groundwater observation stations of Geological Survey of Japan, AIST (GSJ) in the Shikoku, Kinki and Tokai regions. We investigated groundwater head (pressure) changes at those stations just after the main shock and comparted them with coseismic volumetric strain changes calculated from the fault model of the main shock suggested by Geospatial Information Authority of Japan (2016). We also three times surveyed groundwater changes in the source region of Kumamoto Prefecture.

All of the groundwater observation stations of GSJ, which mainly observed confined groundwater, are situated in the coseismic extension region of the main shock and the coseismic groundwater head drops were recorded at many of the stations when the main shock occurred. However distribution of coseismic or postseismic groundwater changes in the source region is complicated and has no clear relation to the distribution of the coseismic volumetric strain changes of the main shock.

Generally water head in confined groundwater drops when volumetric strain is increased. It means that head of confined groundwater drops in extension region. On the other hand, groundwater head is also changed by ground shaking. Therefore we have to consider the effects of coseismic volumetric strain changes and ground shaking on groundwater head (Koizumi, 2013). It seems that the coseismic groundwater head drops at many of the stations of GSJ as mentioned above can be qualitatively explained by the coseismic volumetric changes caused by the main shock. However, the effect of the ground shaking should be also considered for further analysis.

In the presentation we will report the groundwater changes after the main shock in more detail and try to explain the mechanism of them.

Hot Spring Anomalies Observed in Kumamoto Prefecture Associated with the 1946 Nankai Earthquake

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Groundwater anomalies are frequently observed associated with large earthquakes in the focal area and also at greater distances. The anomalies appear in various forms: change in water level or pressure, flow rate, temperature, color and chemical compositions. The Hydrographic Bureau (1946) reported anomalies of well water levels observed around Ise Bay, the south coast of Shikoku island, the east coast of Kyusyu island, and the Seto Inland Sea at the time of the 1946 Nankai earthquake. Here anomalous changes at hot springs in Kumamoto Prefecture after the 1946 Nankai earthquake are reported.

Kumamoto-Ken Saii-shi (Record of natural disasters in Kumamoto Prefecture) published by the Kumamoto meteorological station in 1952 describes the 1946 Nankai earthquake in the chapter for earthquakes, "No. 242, December 21, Showa-21: Great earthquake in the Nankai area. The hypocenter is south of Kii (Wakayama Prefecture). There are anomalies in groundwater at many hot springs." (Only related descriptions are extracted and translated here). The anomalies are summarized in a table. The hot springs where anomalies are observed are located in the areas corresponding to Hitoyoshi, Kumamoto, Amakusa, Yatsushiro, Tamana, Minamata and Oguni, using the present location names. The conditions or changes in flow rate, color, and temperature are listed for 15 hot springs. The times of the changes at the hot springs varies from December 23, 1946 to January 6, 1947. The observation periods are from several days to about a half month. The changes in flow rate, both increases and decreases, began on the day of the earthquake and continued over 10 days for most hot springs. The color changes were observed for 10 hot springs. The color changed to light brown, milky white, rust color, clay red, or black at the time of or after the earthquake.

Groundwater anomalies are generally explained by static strain steps or dynamic strain oscillations i.e. seismic waves. Static volumetric strain steps calculated assuming the model of Sagiya and Thatcher (1999) are extension with order of 10^{-7}, which will produce at most 50 cm of ground water level decrease for usual poroelastic materials. Although the ground water level decrease should produce decrease in flow rate, both increases and decreases in flow rate are reported in the *Kumamoto-Ken Saii-shi*. It is difficult to explain the anomalies solely by static strain steps and poroelastic effects. Local permeability changes caused by dynamic strain or shaking may cause some of the reported anomalies.

Probability Assessment of Huge Inter-plate Earthquakes in Global Subduction Zones -from the View of Slip Deficit-

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2. Department of Science, Shizuoka University, Japan

We compared the cumulative seismic slip of interplate earthquakes (≥M5.5) with relative plate motion at subduction zones. By assuming that each interplate earthquake occurred on a stick–slip patch, we used the slip history of each patch to calculate the interplate slip in the surrounding area. We considered that areas in which interplate earthquakes occurred but that had small cumulative slips compared with relative plate motion were accumulating slip deficit (this concept is shown as schematic illustration of Fig.1), and we calculated the size of these areas. We first used this method to test the rupture areas of six M9-class interplate earthquakes that have occurred during the past 100 years. The cumulative seismic slip preceding and following the six earthquakes was smaller than the relative plate motion in the rupture areas of the earthquakes (Fig.2). We interpret the areas of slip-deficient stick–slip patches to be the rupture areas of future huge earthquakes. We applied the same procedure to global subduction zones and found that slip-deficient stick–slip patches with large spatial extents (equivalent to the rupture area of M9-class earthquakes) occur in an additional 25 locations. Considering that six M9-class earthquakes have occurred in the past 110 years and that the recurrence interval in each case is probably between a few hundred and a thousand years, it is not surprising that 25 regions globally are capable of producing M9-class earthquakes. These regions may be the most likely candidates for the rupture areas of future M9-class interplate earthquakes.

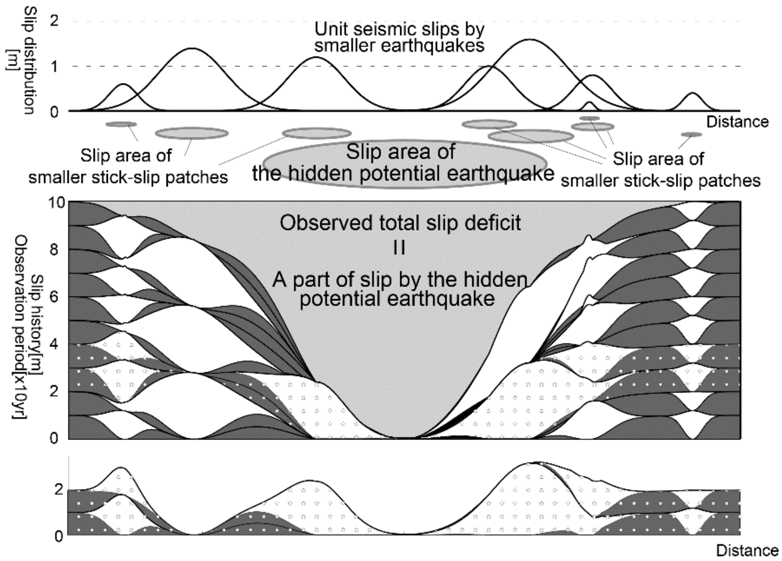

Fig. 1. Schematic illustration of the interplate slip model. Top: Locations of stick–slip patches on the plate boundary (ellipses) and their amount of seismic slip (Gaussian curves) by individual earthquakes. Eight stick–slip patches have their own earthquake sizes. A stick–slip patch on the plate boundary has the potential to produce an earthquake with an area and slip much larger than those of the other eight patches. Middle: Slip history along the plate boundary at a constant time interval. Seismic and aseismic slip are shown by white and dark gray colors, respectively. Each stick–slip patch releases its slip deficit mainly by seismic slip. The accumulated slip increases with increasing distance from the center of the hidden potential stick–slip patch. In this case, each time interval corresponds to a relative plate motion of 1 m. The area covered by small stars corresponds to the slip during periods from time steps #2 to #4. Bottom: Slip history for the period from time steps #2 to #4 extracted from the middle figure. The slip deficit due to the hidden potential earthquake is not apparent.

Acknowledgements

This presentation is mainly based on a manuscript titled “Evaluation of strain accumulation in global subduction zones from seismicity data” published in EPS in 2015 (DOI 10.1186/s40623-015-0361-5).

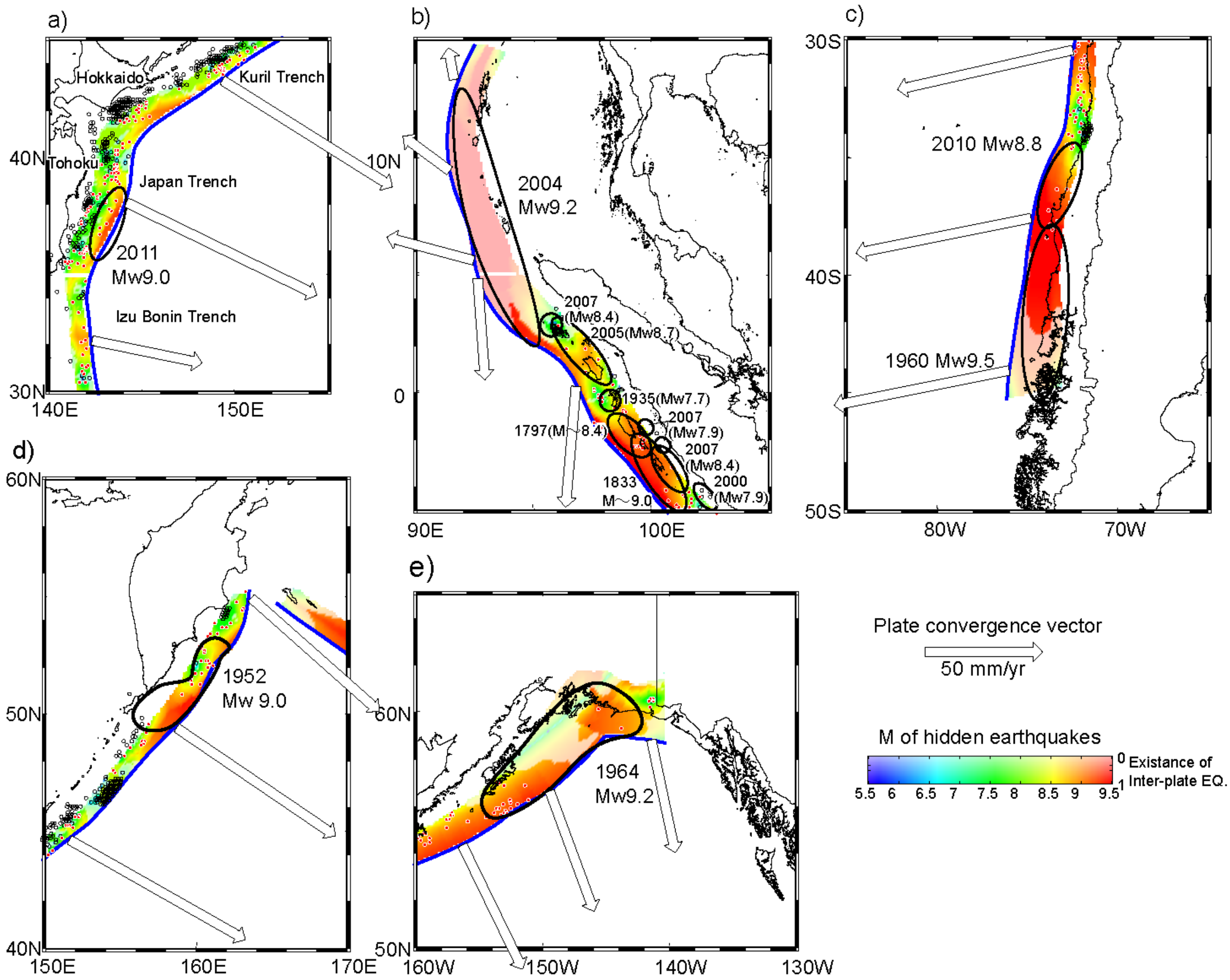

Fig. 2. The expected earthquake size around the source areas of actual M9-class events, as estimated using the seismic catalog before (a–c) and after (c–e) the seismic events. Color shows the magnitudes of the potential earthquakes that are estimated from the size of the slip-deficient ellipse for each grid point. Unreliable grid points that have no slip-deficient grid points within their ellipses are shown by translucent colors. (a) The Kuril, Japan, and Izu–Bonin trenches. The source area of the 2011 Tohoku earthquake (Mw9.0) is enclosed by a solid line and the trench is shown by a solid blue line. Arrows show the relative motion of the overriding plate with respect to the subducting slab. (b) The Java trench. The source areas of past earthquakes including the 2004 Sumatra earthquake (Mw9.2) are enclosed by solid lines. The rupture areas of the 2005 (Mw8.7), 2007 (Mw7.9), 2007 (Mw8.4), 2007 (Mw8.4), 1935 (Mw7.7), 1833 (M~9.0), and 1797 (M~8.4) events are modified from Briggs *et al.* (2006). (c) The Chile trench. The source areas of the two M9-class events are shown by solid lines (e.g., Barrientos and Ward, 1990; Pollitz *et al.*, 2011). (d) Kamchatka. The source area of the 1952 Kamchatka earthquake (Mw9.0) is enclosed by a solid line. (e) Alaska. The source area of the 1964 Alaska earthquake (Mw9.2) is enclosed by a solid line. The rupture area is modified from Christensen and Beck (1994). The color scales, legend, and arrow length are the same for a–e.

Need for more seafloor geodetic observations in the southernmost Ryukyu arc

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Seafloor geodesy has been proved to be a useful method to estimate crustal deformation offshore. The seafloor geodetic survey can give a key dataset to obtain a high spatial resolution of the source mechanism of interseismic and coseismic offshore deformation as well as volcanic activities. Accordingly, the idea has been widely accepted that the seafloor geodetic survey is one of the major tools in crustal deformation studies and hazard assessment.

At the southern Ryukyu trench where the convergence rate 12.5 cm/y is highest among the subduction boundaries in the earth, the seafloor geodetic survey (KGPS/Acoustic Ranging) has been conducted at three sites in the past several years (Fig. 1). They are located at 1) 80 km off the coast of Ishigaki Island and 60 km north of the Ryukyu trench axis (Shizuoka Univ / Ryukyu Univ), 2) 60 km off the coast of Ilan and 10-20 km from a possible spreading axis of the Okinawa trough (Inst. Earth Sci., IES) and 3) 50 km off the coast of Hualien and 50 km north of the Ryukyu trench axis (IES). The survey at each site has an individual purpose for monitoring: 1) deformation of the upper plate where an extensional stress regime is dominant related to the retreat of the Ryukyu trench and the spreading of the Okinawa trough, 2) deformation of the upper plate related to the subduction of PHS and the spreading of the Okinawa trough, and 3) deformation of the upper plate associated with the subduction of the PHS. The two research groups have been cooperating for the analyses of observed data and data exchange.

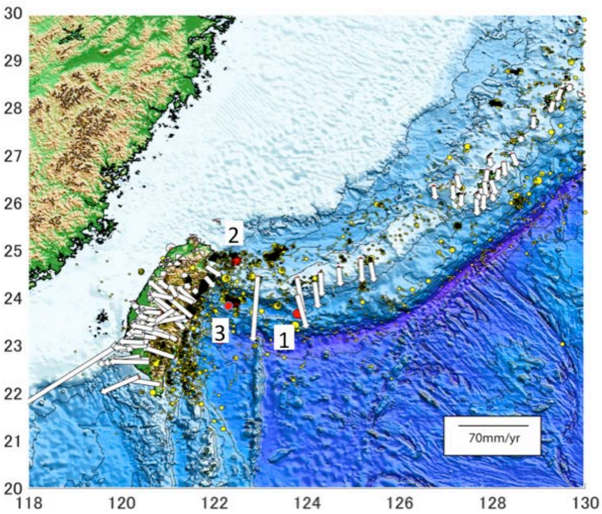

Fig.1 Three seafloor geodetic sites, Nos. 1 to 3 (red dots). More sites are necessary across and along the trench axis and Okinawa trough to monitor the offshore crustal deformation.

The results obtained so far are summarized as follows: site 1 moved 20 mm southward in the period from 2014 to 2016, which is consistent with the model of stretching of the upper plate of the retreat of the PHS; site 2 moved 10 mm southward in the period 2012 and 2015. The observations are consistent with a southward movement due to the stretching of the upper plate and the spreading of the Okinawa trough. These observations prove that the seafloor crustal measurement system is a suitable method to detect deformation near the trench and spreading axes.

Despite the currently available seafloor observations, we still have a very unclear picture of the coupling along the Ryukyu subduction zone and the spreading at the Okinawa trough. Thus, the present questions of the tectonics of this region cannot be resolved based on currently available data. It is necessary to obtain crustal deformation data at more sites, normal to and parallel to the Ryukyu trench and Okinawa trough. We need to adopt seafloor geodetic techniques, water pressure gauges as well as the KGPS/acoustic system. It should be emphasized that these observations need to be carried out for a long time, say five years or more, to obtain meaningful results.

Preliminary study of GPS observation and seismic activity: 2016 Meinong earthquake, Taiwan

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Taiwan is situated in an active tectonic region with numerous thrust faults and folds due to on-going collision between the Luzon arc and Chinese continental margin. The rapid crustal deformation and frequent earthquakes suggest us the large seismogenic potential in Taiwan area. The Meinong earthquake which occurred at Feb. 6, 2016 in southwestern Taiwan caused lots of damages, injuries and deaths. The Global Positioning System (GPS) has become an efficient tool for studying active tectonics and geodynamics. After 1999 Chi-chi earthquake (Mw = 7.6), there were more than 150 new continuous GPS (cGPS) stations established. These continuous GPS stations have been operated by various agencies, including the Central Weather Bureau (CWB), Institute of Earth Sciences, Academia Sinica (IESAS), Central Geological Survey (CGS) and Ministry of the Interior (MOI) since 1994. Until now, we have more than 500 cGPS stations in Taiwan area, which is a very dense cGPS network. This dense cGPS network provide a wealth of cGPS data, also the frequent earthquakes apply a rich database for studying about precursor.

In this study, we obtained some suspected precursor signals from cGPS observations and seismicity. All the cGPS data are processed by GAMIT/GLOBK v.10.6. We analysis the GPS baseline variation form 2007-2015. Furthermore, in order to understand the precision of baseline data, the formalism proposed by Savage and Prescott (1973) is utilized to describe the precision of the epoch GPS measurements as a function of baseline length:

$$\sigma_L = \sqrt{a^2 + b^2 \cdot L^2}$$

Where σ_L is the standard deviation, L is the baseline length, and b are constant and length dependent source of error, respectively. The result indicates the precision is much worse in vertical component. Therefore, the baseline estimation we only use north and east two components. The observation of baseline from daily solution helps us understand more and the fault activity, area tectonic structure, and possible precursor signal. Moreover, many long-term seismic observations show the results found the seismic quiescence before the large earthquake occurred in the region nearby the epicenter. By estimating the seismic activity indicators (ex: *a*- and *b*- value), we can assess the seismic potential or possible precursor signal in southwestern Taiwan.

Seismic Hazards on High Strain Accumulation in SW Taiwan: Insight from Multiple Fault Slip Triggered by 2016 Mw 6.4 Meinong Earthquake

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Abstract

Rapid strain accommodation across the fold-and-thrust belt in SW Taiwan are revealed by the Continuous GPS, precise leveling and SAR interferometry. The previous block model based on GPS measurement suggested a high seismic risk in SW Taiwan. However, a clear evidence of multiple fault slip along a fold-and-thrust belt at 5-10 km depth was triggered by the 2016 Mw Meinong earthquake at 15-20 km depth. The primary coseismic fault slip was deduced with kinematic model based on seismic and geodetic measurements and triggered fault slip along the shallow fold-and-thrust belt was constrained by SAR interferometry. We hypothesize that the surface coseismic deformation is mainly controlled by a structure related to the shallow detachment at around 5-10 km depth, which a proposed duplex in a region of high pressure and high interseismic uplift rate might be sensitive to stress perturbations induced by moderate lower crustal earthquake. It is surprising to notice that the footwall of Longchuan reverse fault demonstrates a high uplift rate of ~20-30 mm/yr in interseismic period. This anomalous deformation rate might part be related with a ramp duplex located in the footwall and the triggered slip of moderate earthquake in nearby area. In addition, the mechanical heterogeneity of mudstone in the Gutingkang formation might play a crucial role of anomalous deformation. Consequently, we use an Efficient Unstructured Finite Element method (DynearthSol2D) to simulate and discuss the contrast of viscosity in mudstone and sandstone contributed in deformation pattern and upward mobility. We also want to check the previous hypothesis of mud diapirism of recent study and incorporate a new mud-cored anticline model for mechanic explanation of anomalous interseismic deformation occurred in SW Taiwan.

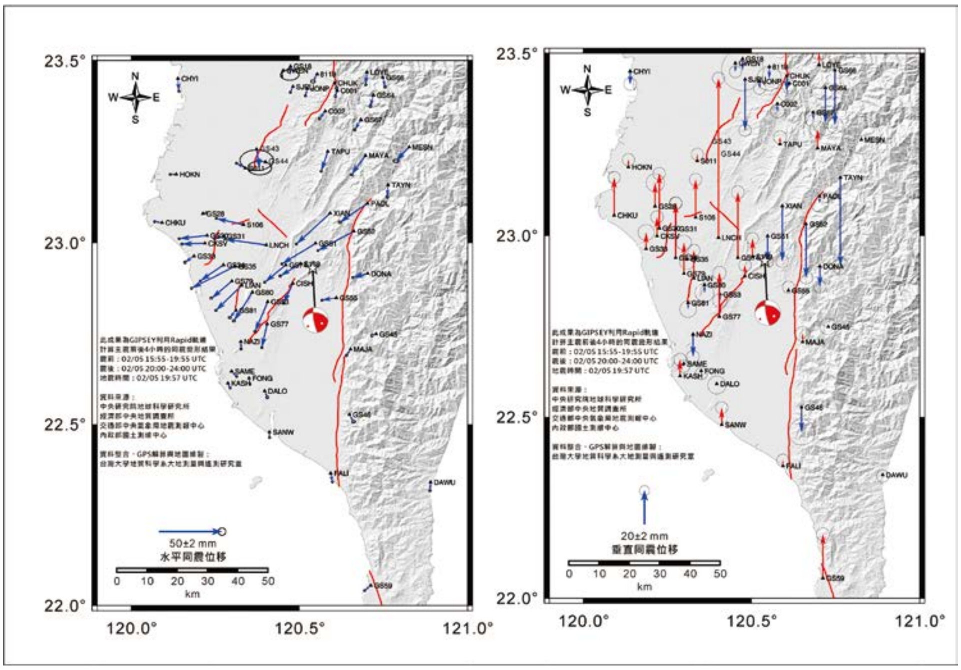

Fig. 1. Coseismic displacement of the Meinong Earthquake derived from the continuous GPS. White star indicates the epicenter of Meinong event. In vertical coseismic displacement, red arrows represent uplift, blue arrows represent subsidence.

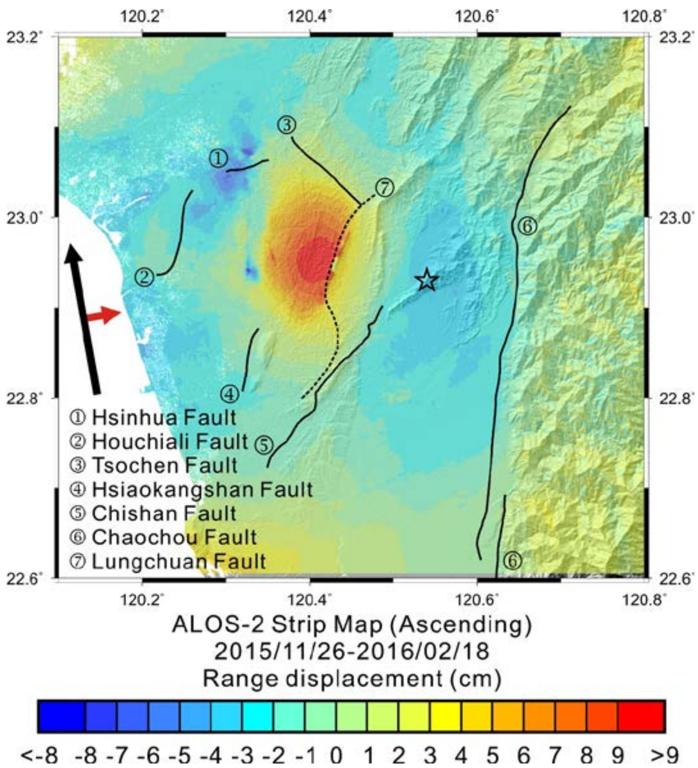

Fig. 2. Coseismic displacement along the line of sight toward the satellite derived from ALOS-2 ascending images by D-InSAR. White star represent the epicenter of Meinong Earthquake.

Temporal changes in gas geochemistry and gamma rays as a precursor of the 2016 M6.6 Meinong earthquake, southern Taiwan

Ching-Chou Fu[1, 2], Lou-Chuang Lee[1], Tsanyao Frank Yang[2], Peng-Kang Wang[1], Tsung-Kwei Liu[2], Vivek Walia[3], Cheng-Hong Chen[2], Cheng-Horng Lin[1], Tzu-Hua Lai[4], Gioacchino Giuliani[5] and Dimitar Ouzounov[6]

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Key words: radon, gamma rays, Meinong Earthquake

Taiwan is tectonically situated in a terrain resulting from the oblique collision between the Philippine Sea plate and the continental margin of the Asiatic plate, with a continuous stress causing the density of earthquakes and faults. The continuous observations of soil radon for earthquake studies have been recorded and are compared with the data from gamma rays observations. Some anomalous high radon concentrations and gamma-ray counts at certain times can be identified. A significant increase of soil radon concentrations was observed at Gukeng (GK), Chunglun (CL) and Pingtung (PT) station, and an increase in gamma-ray counts at the Chung Cheng University (CCUG) was also observed around two weeks before the Meinong Earthquake (M_L = 6.6, February 6, 2016) in southern Taiwan. The precursory changes in multi-parameters monitoring may reflect the preparation stage of a large earthquake. And, precursory signals are observed simultaneously that can conduce to expect the approximate location of the impending earthquake with high confidence. The continuous monitoring on the multiple parameters can improve our understanding of the relationship between the observed radon and gamma-ray variations and the regional crustal stress/strain in the area.

The study of the coseismic groundwater level changes in Taiwan: An updated in M_L 6.4 Tainan earthquake, Feb. 6th 2016

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The different response by various natural stimuli and processes (tidal force, barometric loading, ground shaking and crustal strain) were used as the elements of the hydraulic information in the earthquake induced groundwater level changes. Using the natural force to act as naturally recurring stimuli to provide a sufficiently varied distribution of excitations in time and space, and represented the hydro-geological changes responses to the earthquake processes. The purposes of this study are to analyze the recently observation results of the earthquake induced pre-seismic / co-seismic variation of groundwater level ML 6.4 Tainan earthquake, Feb. 6th 2016. The analysis of the high-sampling water level responses be used to estimate the mechanical properties of the aquifer. Comparison the observation high-sampling water level changes in the each event, offers the opportunity to discussion the possible mechanism of the hydrologic response to earthquake. Some of the coseismic groundwater level changes can be explained as the poroelastic responses to the earthquake-induced volumetric strain changes inferred from the fault dislocation models. But the other changes can not be explained by the volumetric strain changes either qualitatively or quantitatively. We regarded the coseismic static volumetric strain change and the ground acceleration as the main factors to cause the coseismic groundwater level changes. The study provides some information for the pre-seismic / co-seismic mechanism but more investigations are required.

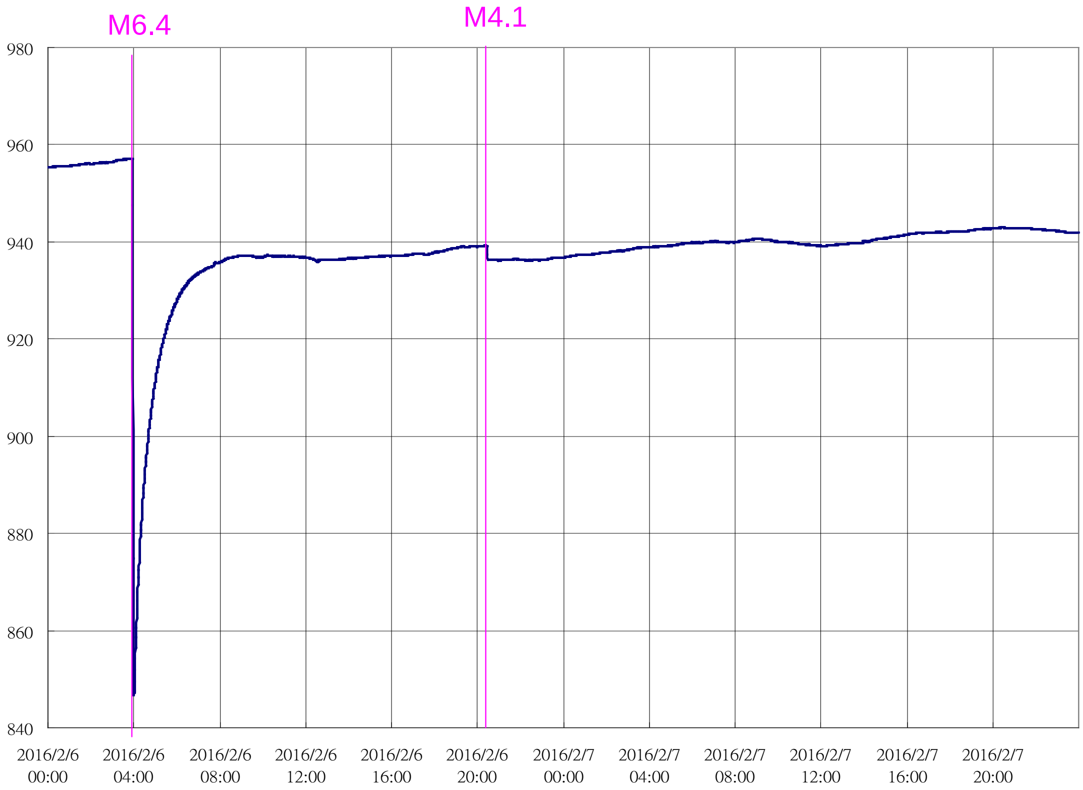

Figure 1. The coseismic groundwater level changes in M_L 6.4 Tainan earthquake, Feb. 6_{th} 2016

Temporary Change of Gas Composition in Groundwater of Atotsugawa Observation Well, Japan

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Abstract

Temporary change of gas composition in groundwater obtained at Atostugawa monitoring well will be discussed. We remodeled a commarcially available mass spectrometer for contiunous use. In addition, a gas-water separator and a dehumidifier were added to the spectrometer. Mass spectra of extracted gas and blank were recorded, and the composition of gas was calculated. The abundance of each gas varied with time, but all anomalous signals did not synchronize to the seismic events. On the other hand, a ternary composition of helium, nitrogene and argon made a trajectory on a ternary diagram between air component and crustal component. Therefore the temporary change of a ternary component of helium, argon and nitrogen in a gas sample will be a potential indicator to estimate the effect of the crust on the damage zone which acts as a pathway of geofluids.

Conclusions

1. A system for a continuous monitoring of dissolved gas in groundwater by use of a quadrupole mass spectrometer was successfully developed.
2. A ternary composition of He, N_2 and ^{40}Ar is a good candidate of an indicator to estimate a mixing of gas among the crustal gas, air and the magmatic gas.

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Hydrological characteristics of the Kamishiro fault deduced from fluid discharge by 2014 North-Nagano earthquake

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November 22, 2014 10:00 PM, M6.7 earthquake occurred at northern part of Nagano prefecture, central Japan. Focal depth is about 5 km on the Kamishiro fault. It is called North-Nagano earthquake. Aftershocks distribution is rather planer dipping 50 to 60 degree to the east, which coincide with the dip of the Kamishiro Fault. InSAR analysis shows surface deformation zone extends N10E along the Kamishiro fault and the deformation is larger in south of focal point than north of it. Surface rupture appeared at southern part of focal point along the Kamishiro fault with about 10 km in length. Maximum vertical displacement is about 1.0 m with 20 cm right lateral displacement. In contrast to the surface deformation, numbers of aftershocks larger Numbers of aftershocks larger than M1 is much larger in the north region (1200) than those of south region (200) in a week after the main shock.

Fluid discharge was observed at about 5 km north of the focal point along the sub-fault of Active trace of Kamishiro fault. We measured flow amount, temperature of the spring, EC and pH at the spring site. Maximum flow was 160 L / min which is the amount of right after the splash and gradually reduced to zero in middle March. Mode of flow reduction with time is approximated by exponential decay (Figure 2, $R^2 = 0.83$). Total volume of flow-out fluids was 7300 m^3. Results of chemical composition measurements indicate that the fluid is rather diluted, and categorized into Na – HCO_3 type being common in inland hot spring. Results of oxygen-hydrogen isotopic composition measurements show that the fluid is originated from meteoric water.

However, the gas composition shows high ^{3}He ratio (Ra ~ 5.0), and main gas component is methane, suggesting existence of deep source fluid. The activated fault is distributed in volcanic area. Thus magmatic fluid, especially the gas, would be mixed together with crust-circulated fluids.

Figure 1

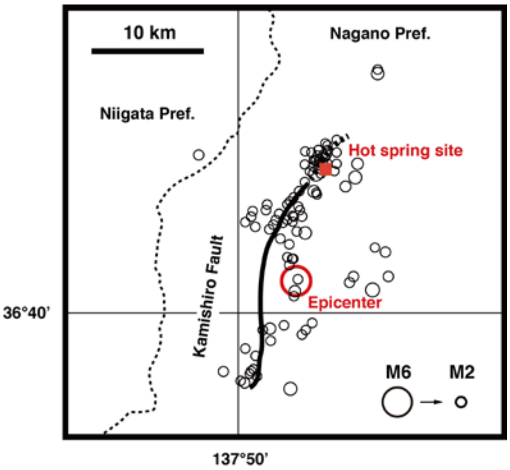
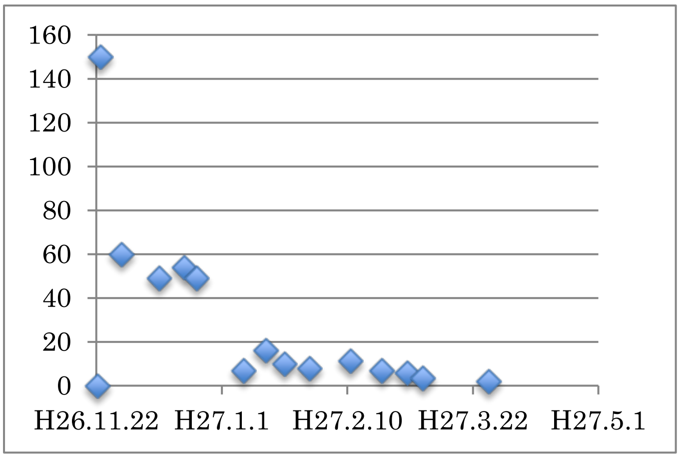


Figure 2



We modeled the fluid discharge assuming that fluid had passed through the fracture zone of the Kamishiro Fault, and the discharge was triggered by North Nagano earthquake. We would like to discuss about ability of the model and resultant hydrological structure of the fracture zone of the fault in this meeting.

Hydrological Parameters Estimation Through Seismological Investigation on Fluid Migration Activity After Earthquakes: Case Study for 1999 M7.6 Chi-Chi, and 2016 M6.4 Meinong, Taiwan, earthquakes

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Fluid had been considered as a possible factor in triggering earthquakes, but, the evidence in elucidating the behavior and mechanism is still unresolved. Our previous studies in attenuation, noted as 1/ Qs, for the 1999 Chi-Chi earthquake suggest that the fracture zone associated with fault zone could be considered as a fluid reservoir, which possibly yield to some observations/detections of phenomena associated with pre-, co- or post-seismic of a larger earthquake. The sudden changes in attenuation co-seismically with decay following a diffusion process indicated possible high pore-fluid saturation within fractured fault zone from fully to partial saturation. The evidence was also revealed through Qs/Qp tomography as using the ratio of Qs/Qp as the indicator of fluid partial/full saturation. We suspect this process might yield the migration of fluid flow, and thus, related to the occurrence of some aftershocks. To elucidate the fluid triggered events, we search the events at the depth less than 10km within 90 days of the mainshock, and examined the seismic spectra ratio of S/P of the corresponding stations. We identified the possible fluid triggered events as tensile crack mechanism with the spectra ratio of S/P~2, compared to shear faulting events of S/P~6. These identified events were within the depth of 5-8km, and more significantly observed for the time period of about 15-40days after the mainshock. According to the migration of the possible fluid triggered seismicity, the fluid flow has the speed of about 220m/day. The migration of fluid flow increases the pore-pressure, which reduce the normal stress, and, thus, yield the co-seismic negative Coulomb's stress regime to become positive to trigger these fluid flow associated aftershocks. The regime of the possible fluid flow zone was used to give the estimation of the hydrological parameters, and the fluid budget in the fault zone. Similar studies were employed to the shallow seismicity near the mud volcanoes activity regime associated with the 2016 M6.4 Meinong earthquake. Through these studies, we hope to understand the possible passage of fluid flow/gas after earthquake and understand its transient behavior.

In-Situ Permeability of Fault Zones Estimated by Hydraulic Tests and Continuous Groundwater-Level Observation

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The permeability structure of fault core and damage zone has an important role in fault hydrogeology and slip behavior. Although there are many studies about laboratory measurements of permeability of natural and synthetic fault products, in-situ observation of permeability within the fault zone is quite a few. We show results of in-situ measurement of permeability near the fault core and within damage zone of the Median Tectonic Line (MTL), and compare with laboratory permeability measurement of MTL fault rocks (Wibberley and Shimamoto, 2003).

GSJ, AIST constructed an integrated groundwater observatory at Matsusaka-Iitaka (ITA) as a part of the groundwater and crustal deformation observation network for the prediction research of the Nankai and Tonankai earthquakes (Shigematsu et al., 2012; Koizumi, 2013). Hole 1 (total depth 600m) was penetrated the Median Tectonic Line (MTL) at a depth of 473.9m. Total depth of Hole 2 is 208m. We obtained core samples and well logging data and conducted hydraulic tests in these wells. Screened depth of Hole 1 is 547.6-558.5 m and is located in the lower fracture zone of the MTL fault zone developed in the Sanbagawa metamorphic rocks. Screened depth of Hole 2 is 145.5-156.4 m and is located at a branch fault in the Ryoke granitolds (Shigematsu et al., 2012).

Slug tests in Hole 1 at ITA performed six times by filling the water up to the top of the well head. We started groundwater-level observation at the Hole 1 in June, 2008. After January 2010, well head of the Hole 1 was closed and then groundwater pressure have been observed. Groundwater-pressure recovery could observed in Aug. 2011 and Feb. 2012 because of opening and closing of the well head due to instrument maintainance. Hydraulic diffusivities of slug test Nos. 1-6 and two well water-pressure recoveries are analyzed, and range 1.8 - 8.5 x 10^{-16} m^2.

At Hole 2, ITA, we firstly analyzed data of well pressure recovery in Oct. 2008. After that we obtained hydraulic diffusivity $T = 1.8 \times 10^{-15}$ m^2 as a result of pump test by assuming $S = 1.0 \times 10^{-5}$ and screened length = 17 m.

We compared in-situ permeabilities of Hole 1 and Hole 2 at ITA with laboratory permeability measurement of MTL fault rocks (Wibberley and Shimamoto, 2003) sampled from Tsukide outcrop about 15 km away from ITA. Wibberley and Shimamoto (2003) represented detailed permeability structure in and around fault core. In-situ permeabilities are basically consistent with Wibberley and Shimamoto (2003)'s results.