Meeting venue
National Center for Research on Earthquake Engineering

The main gate of NCREE
The entrance of the room 101
Hosts

Taiwan Earthquake Model

Ministry of Science and Technology

National Cheng Kung University

National Center for Research on Earthquake Engineering

Taiwan Earthquake Research Center
Sponsors

Earth Science Research Promotion Center

National Science and Technology Center for Disaster Reduction

Institute of Earth Sciences, Academia Sinica

National Central University

Sinotech Engineering Consultants, Inc.
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# Program on 19 May, 2014

## Morning

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<tr>
<td>08:30 - 09:00</td>
<td>Registration</td>
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<td>09:00 - 09:10</td>
<td>Welcome from NARLabs president, Professor Ching-Hua Lo</td>
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### Session I: Current status of Seismic Hazard Assessment for each country

**Chair/Co-Chair:** Ruey-Juin Rau/ Ken Xiansheng Hao

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<thead>
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<th>Time</th>
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<tr>
<td>09:10 - 09:30</td>
<td>Current Status of Taiwan Earthquake Model</td>
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<tr>
<td></td>
<td>Kuo-Fong Ma</td>
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<tr>
<td>09:30 - 09:50</td>
<td>Seismic hazard assessment for Japan: Reconsiderations after the great east Japan earthquake disaster</td>
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<tr>
<td></td>
<td>Hiroyuki Fujiwara</td>
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<tr>
<td>09:50 - 10:10</td>
<td>Seismic hazard modeling in New Zealand</td>
</tr>
<tr>
<td></td>
<td>Matt Gerstenberger</td>
</tr>
<tr>
<td>10:10 - 10:30</td>
<td>Discussion</td>
</tr>
<tr>
<td>10:30 - 10:50</td>
<td>Break</td>
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</tbody>
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### Session II: Active Faults and Paleoseismology

**Chair/Co-Chair:** J. Bruce H. Shyu/ Mark Stirling

<table>
<thead>
<tr>
<th>Time</th>
<th>Agenda</th>
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<tbody>
<tr>
<td>10:50 - 11:10</td>
<td>Progress of constructing a new seismogenic structure source model for the Taiwan earthquake model (TEM)</td>
</tr>
<tr>
<td></td>
<td>J. Bruce H. Shyu</td>
</tr>
<tr>
<td>11:10 - 11:30</td>
<td>Recent progress in active fault research and paleoseismology in Japan</td>
</tr>
<tr>
<td></td>
<td>Tadashi Maruyama</td>
</tr>
<tr>
<td>11:30 - 11:50</td>
<td>Incorporating Active Fault Data into Probabilistic Seismic Hazard Models</td>
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<tr>
<td></td>
<td>Mark Stirling</td>
</tr>
<tr>
<td>11:50 - 12:20</td>
<td>Discussion</td>
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<tr>
<td>12:20 - 13:30</td>
<td>Lunch and poster viewing</td>
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### Afternoon

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<thead>
<tr>
<th>Time</th>
<th>Session III: Geodetic Strain</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>13:30 - 13:50</td>
<td>Implications of geodetic strain rate for future large earthquakes in Taiwan</td>
<td>Kuo-En Ching</td>
</tr>
<tr>
<td>13:50 - 14:10</td>
<td>Slip deficit distribution and seismic supercycles along the Japan islands</td>
<td>Kazuki Koketsu</td>
</tr>
<tr>
<td>14:10 - 14:30</td>
<td>Including geodesy and non-traditional seismic radiation in seismic hazard assessment in New Zealand</td>
<td>Bill Fry</td>
</tr>
<tr>
<td>14:30 - 15:00</td>
<td>Discussion</td>
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<tr>
<td>15:00 - 15:20</td>
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<table>
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<th>Time</th>
<th>Session IV: Sub-surface Structure Mapping</th>
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<tr>
<td>15:20 - 15:40</td>
<td>Overview of shallow s-wave velocity structure in Taiwan estimated from microtremor</td>
<td>Kuo-Liang Wen</td>
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<tr>
<td>15:40 - 16:00</td>
<td>Modeling of the subsurface structure from the seismic bedrock to the ground surface for a broadband strong motion evaluation</td>
<td>Shigeki Senna</td>
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<td>16:00 - 16:20</td>
<td>Multi-method noise-based imaging of an earthquake prone valley, lower North Island, New Zealand</td>
<td>Bill Fry</td>
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<td>16:20 - 16:40</td>
<td>Estimations of Vs30 in Taiwan</td>
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<td>16:40 - 17:10</td>
<td>Discussion</td>
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<td>17:10 - 18:00</td>
<td>Poster session</td>
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## Morning

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<td><strong>Session V: Ground Motion Prediction</strong></td>
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<tr>
<td>08:40 - 09:00</td>
<td>The development of ground-motion prediction equation incorporating ground-motion simulation</td>
</tr>
<tr>
<td>09:00 - 09:20</td>
<td>A new ground motion prediction equation for Japan</td>
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<tr>
<td>09:20 - 09:40</td>
<td>Recent efforts in empirical ground motion prediction in New Zealand</td>
</tr>
<tr>
<td>09:40 - 10:10</td>
<td>Discussion</td>
</tr>
<tr>
<td>10:10 - 10:30</td>
<td>Break</td>
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**Session VI: Earthquake Scenario Simulation**

Chair/Co-chair: Kuo-Fong Ma/ Shin Aoi

| 10:30 - 10:50 | Earthquake scenario simulations for active faults and seismogenic structures in Taiwan | Shiann-Jong Lee |
| 10:50 - 11:10 | Ground motion simulation for large earthquakes along Ryukyu Trench offshore Taiwan | Yin-Tung Yen |
| 11:10 - 11:30 | Finite-difference simulation of long-period ground motion for the Nankai Trough earthquakes | Takahiro Maeda |
| 11:30 - 11:50 | Employing multiple approaches to simulate ground motions for scenario events | Caroline Holden |
| 11:50 - 12:20 | Discussion |
| 12:20 - 13:30 | Lunch and poster viewing |
# Afternoon

## Session VII: PSHA

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<tr>
<th>Time</th>
<th>Title</th>
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<tbody>
<tr>
<td>13:30 - 13:50</td>
<td>Probabilistic seismic hazard assessment for Taiwan: Implementation of the TEM parameters</td>
<td>Chung-Han Chan</td>
</tr>
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<td>13:50 - 14:10</td>
<td>Some clues for approaching Japanese PSHA maps by OpenQuake</td>
<td>Ken Xiansheng Hao</td>
</tr>
<tr>
<td>14:10 - 14:30</td>
<td>Rethinking PSHA</td>
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<tr>
<td>14:30 - 15:00</td>
<td>Discussion</td>
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<td>15:00 - 15:20</td>
<td>Break</td>
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## Session VIII: PSHA applications

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<tr>
<th>Time</th>
<th>Title</th>
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<tbody>
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<td>15:20 - 15:40</td>
<td>Current status of Taiwan earthquake loss estimation system</td>
<td>Chin-Hsun Yeh</td>
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<tr>
<td>15:40 - 16:00</td>
<td>Seismic risk analysis based on national seismic hazard maps for Japan</td>
<td>Satoshi Shimizu</td>
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<td>16:00 - 16:20</td>
<td>Riskscape and risk products in New Zealand</td>
<td>Nick Horspool</td>
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<tr>
<td>16:20 - 16:40</td>
<td>PSHA applications and its social scientific approach</td>
<td>Hiroki Azuma</td>
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**Conclusion of workshop**
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<table>
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<tr>
<th>Name</th>
<th>Title of presentation</th>
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<tr>
<td>Yi-Wun Liao</td>
<td>Ground motion simulation of the 1909 Taipei historical earthquake</td>
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<td>Yu-Ju Wang</td>
<td>New attenuation relationship for peak ground acceleration and response spectra of normal faulting events in the northeast offshore Taiwan</td>
</tr>
<tr>
<td>Ya-Ting Lee</td>
<td>The empirical equation with a new definition of effective shaking duration for Taiwan earthquakes</td>
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<td>Hong-Chun Wu</td>
<td>Jet streams anomalies as possible short-term precursors of earthquakes with M&gt;6.0</td>
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<tr>
<td>Hongjun Si</td>
<td>Evaluation of strong ground motion for the Wenchuan and Lushan earthquakes based on empirical methods</td>
</tr>
<tr>
<td>Chun-Te Chen</td>
<td>Shallow s-wave velocity structure of the western coastal plain of Taiwan estimated from microtremor array</td>
</tr>
<tr>
<td>Yuan-Hsi Lee</td>
<td>Segmentation of the active faults around the Chiayi area</td>
</tr>
<tr>
<td>Shih-Nan Cheng</td>
<td>Digitization and processing of historical seismograms in Taiwan</td>
</tr>
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</table>
Current Status of Taiwan Earthquake Model

Kuo-Fong Ma

Department of Earth Sciences, National Central University

ABSTRACT

The Taiwan Earthquake Model (TEM) is a team project established in 2012 under the support of NSC, now MOST, Ministry of Science and Technology. TEM is also a public participant of Global Earthquake Model. Under the scope of TEM, we made a collaborative effort to engage earthquake science and technology communities to collaborate on building a platform for seismic hazard evaluation and risk management.

For year 2013-2014, we intent to construct the Taiwan Probability on Seismic Hazard Analysis (PSHA) for detailed earthquake risk assessment. Components of the Taiwan PSHA include: (1) A Fault source database and model for both inland and offshore events and compilation of fault source parameters. (2) Create a seismic source historical database (1600 to present), in partnership with the Central Weather Bureau’s Seismic Network, to archive historical earthquakes recorded in literature (prior to 1900) and seismic waveforms of major earthquakes (1900-1960). (3) A Geodetic strain model to provide information on long-term or short-term slip rates of fault sources. (4) A Ground Motion Prediction Equation (GMPE) for crustal and subduction zone earthquakes and prediction of strong motion durations. (5) Shallow structure and site response through compilation of logging, seismic reflection, micro tremor and seismic tomography studies to create 2D and 3D mapping of shallow Vp and Vs structures to the depths of seismic basement (Vs~3km/sec) and/or engineering basement (Vs~300m/sec). (6) Earthquake Scenarios and shakeout maps through the development of computational seismology and high-resolution velocity structures.

Our future target is to integrate PSHA-based risk, socio-economic impact, and scenario-based risk to minimize resulting damage and impact for the Socio-economic impact modeling and assessment and an Association with an innovative risk-reduction effort. As the effort of TEM with international collaboration as with NIED, Japan and GNS, New Zealand aims to contribute to increase risk awareness, decisions and plans for the risk mitigation.

KEYWORDS: Taiwan Earthquake Model, Hazard, Risk
Seismic Hazard Assessment for Japan: 
Reconsiderations after the Great East Japan Earthquake Disaster

Hiroyuki Fujiwara¹

¹ Director, National Research Institute for Earth Science and Disaster Prevention, Japan. E-mail: fujiwara@bosai.go.jp

ABSTRACT

We have been carrying out the seismic hazard assessment for Japan after the 1995 Hyogo-ken Nanbu Earthquake and have made the National Seismic Hazard Maps for Japan, under guidance of the Headquarters for Earthquake Research Promotion (HERP) of Japan. The National Seismic Hazard Maps for Japan are prepared to estimate strong motions caused by earthquakes that could occur in Japan in the future and show the estimated results on the maps. The hazard maps consist of two kinds of maps. One is a probabilistic seismic hazard map that shows the relation between seismic intensity value and its probability of exceedance within a certain time period. The other one is a scenario earthquake shaking map. In order to promote the use of the National Seismic Hazard Maps, we have developed an open web system to provide information interactively, and named this system as Japan Seismic Hazard Information Station, J-SHIS.

The 2011 Tohoku Earthquake (Mw 9.0) was the largest event in the history of Japan. This mega-thrust earthquake was not considered in the National Seismic Hazard Maps for Japan. Based on the lessons learned from this earthquake disaster and experiences that we have engaged in the seismic hazard mapping project of Japan, we consider problems and issues to be resolved for seismic hazard assessment and make some proposals to improve seismic hazard assessment for Japan.

1) Modeling of seismic activity with no oversight to low-probability earthquakes.
2) Preparation of strong-motion evaluation considering low-probability earthquakes.
3) Development of methodology for complementary use of PSHM and SESM.
4) Sophistication of techniques for prediction of strong-motion for mega earthquakes.
5) Sophistication of utilization and transmission of seismic hazard information.

We have made revisions of the seismic hazard assessment based on the revised versions of the "Long-term evaluation of seismic activity for the region from the off Sanriku to the off Boso" and the "Long-term evaluation of seismic activity for the Nankai Trough" by the HERP. Revisions of seismic activity models for other regions of Japan have been undergoing. After these revisions of long-term evaluation for whole of Japan, we will revise seismic hazard assessment for Japan.

KEYWORDS: Seismic Hazard Assessment, Strong ground motion, Seismic Hazard Map, J-SHIS
Seismic Hazard Modelling in New Zealand

M.C. Gerstenberger1 and M.W. Stirling2

1 Risk & Engineering Team Leader, GNS Science, New Zealand. E-mail: m.gerstenberger@gns.cri.nz
2 Senior Scientist, GNS Science, New Zealand. E-mail: m.stirling@gns.cri.nz

ABSTRACT

Applied seismic hazard modelling in New Zealand has been largely based on probabilistic seismic hazard modelling since the beginning of the 1980s when models were developed by a number of New Zealand based researchers. Initially the models were zone based and the were directly used for the development of the New Zealand seismic design standards. This zone based approach was significantly modified by Stirling et. al. (1998, 2002) with the use of a nation-wide model of active faults, a gridded seismicity model, and a single ground motion prediction equation (GMPE; McVerry, et. al., 2006). This model was again revised by Stirling, et. al. (2012) and now contains more than 500 active faults and a smoothed seismicity model based on the earthquake catalogue from 1840. Additionally, for applications of the model in more recent versions of the seismic loadings standard, a minimum design earthquake has been used and is applied to deterministically estimate design motions in areas of lower hazard (e.g., with probabilistic motions below a certain threshold).

In more recent work we have developed a time-dependent seismic hazard model for the Canterbury region, following the initiation of the Canterbury earthquake sequence. For this model we developed a hybrid source model that captured time-dependence on three different time scales, from short-term to long-term. Additionally, a logic tree was used to combine the McVerry et al (2006) GMPE with the more recently developed Bradley (2010) GMPE and to incorporate uncertainties in different parameterisations of the models.

Our current work in seismic hazard is focused on rethinking some of the fundamentals of how we develop our PSHA. This includes such things as how a source model is defined and what information should be included in it, how to best capture epistemic uncertainty in ground motion modelling, subduction zone modelling, and how we can quantify if a new model is indeed an improved model. Finally we are investigating how modelling of synthetic seismicity and ground motions based on physics can be used in future seismic hazard in New Zealand.

KEYWORDS: PSHA, GMPE, Time-dependence, New Zealand, Building Standards
Progress of constructing a new seismogenic structure source model for the Taiwan Earthquake Model (TEM)

J. Bruce H. Shyu¹, Yi-Rung Chuang¹,², Ya-Lin Chen¹, Yi-Rui Lee², Thomas Chin-Tung Cheng²

¹ Department of Geosciences, National Taiwan University, Taipei, Taiwan. E-mail: jbhs@ntu.edu.tw
² Disaster Prevention Technology Research Center, Sinotech Engineering Consultants, Inc., Taipei, Taiwan.

ABSTRACT

One of the most fundamental tasks for the Taiwan Earthquake Model (TEM) is to build a complete seismogenic structure database to understand the seismogenic structure source models. In the Global Earthquake Model (GEM) project, this is done in the form of the GEM Faulted Earth sub-project, and is led by scientists from the US, New Zealand, Argentina, and Singapore. The goal of this project is to build a complete active structure database in the world for engineers and hazard mitigation agencies.

Toward this end, we are also on the progress of constructing a new seismogenic structure source model for Taiwan. We have reviewed existed active structure databases, and attempted to obtain new information for structures that have not been thoroughly analyzed before. For existing databases, the Central Geological Survey of Taiwan has published a comprehensive database of active faults in Taiwan. In addition, many other potential seismogenic structures, such as blind faults or folds, have also been mapped and reported in several previous investigations. We have combined these existing databases, and proposed a digitized three-dimensional seismogenic structure map for Taiwan. On the other hand, long-term slip rates and potential recurrence intervals of most of these structures have not been systematically calculated or analyzed. Therefore, we have been conducting field surveys and investigations to collect slip-rate information for the structures. All of the information are combined together to construct new seismogenic structure source model. We hope this new database would become important input source model for TEM, and would assist the future earthquake hazard assessment in Taiwan.

KEYWORDS: Taiwan Earthquake Model, seismogenic structure, slip rate, earthquake hazard assessment.
Recent progress in active fault research and paleoseismology in Japan

T. Maruyama

1 Senior Researcher, Geological Survey of Japan/AIST, Japan. E-mail: tadashi-maruyama@aist.go.jp

ABSTRACT

The Headquarters for Earthquake Research Promotion (HERP), which was established in response to the devastating 1995 Kobe earthquake, has announced officially results of evaluation of individual major active fault zones that have potential to generate large ($M \geq 7.0$) earthquakes, such as location, expected magnitude and slip, and probability of earthquakes in the coming 30 years. However, recent inland damaging earthquakes have been caused by moderate-sized ($Mw$ 6.6-6.8), which did not be covered as the subject of the evaluation, and have occurred either where active faults were not mapped before the event or active faults were mapped but not evaluated, ironically. In response to these facts, HERP has selected newly active fault zones that can generate earthquakes with $M \geq 6.8$ to be evaluated, and assessed probability of earthquakes in a certain region based on integration of data of individual fault zones and seismicity data. These new evaluation has important significance in considering quantitatively the earthquake hazard in region. In order to properly assess the earthquake hazard in a given region, identifying and characterizing active faults having potential to generate large to moderate earthquakes without omissions are fundamental. Recent explosion of airborne LiDAR survey has revolutionized in identifying active faults with weak geomorphic expression and especially those in mountainous area with dense vegetation and in urban area with dense building. Application of state-of-the-art paleoseismological techniques such as integration of seismic profiling, borehole transect, paleoseismic trenching with high-resolution stratigraphic age determination by AMS dating allows to reveal geometry and long-term history active faults and folds in detail. Promotion of these researches might improve our understanding on rupture properties of active faulting, which leads to better assessment of the earthquake hazard. Recent inland earthquakes made us face new challenges. Sudden switch of upper crustal stress regime and resultant abundant shallow normal faulting earthquakes in NE Honshu triggered by the 2011 great Tohoku earthquake raised questions about long-term steady behavior of active faults. We report the present state and challenge in research on active faults and paleoseimology in Japan.

KEYWORDS: Inland earthquake, active fault, paleoseimology, LiDAR
Incorporating Active Fault Data into Probabilistic Seismic Hazard Models

M.W. Stirling

ABSTRACT

Active fault data are used to provide constraints on the location, size and recurrence behaviour of large, infrequent earthquakes, and as such they extend the relatively short duration of historical earthquake catalogues. The disciplines of earthquake geology and paleoseismology have developed over the last 40 years to provide what is now considered to be a fundamental input to standard probabilistic seismic hazard analysis (PSHA). Fault source models are developed from active fault data, in which the length, assumed width, and activity metric of each fault source (i.e. slip rate or paleoseismically-derived recurrence interval) are used to estimate the magnitude and recurrence interval of the source. The process of developing a fault source model therefore requires considerable care and interpretation in turning fault traces into coherent earthquake sources. Not surprisingly, the methods of fault source parameterisation are many and varied, and the resulting uncertainties are considerable.

The approach to developing fault source models for the New Zealand national seismic hazard model (NSHM) has varied over the three most recent versions of the model. The 1998 and 2002 NSHMs used a three-tier hierarchy of methods to develop fault source parameters (magnitude and recurrence interval) based on the quality and quantity of available data. In contrast the 2012 NSHM used a single approach that rationalised issues associated with anomalously short recurrence intervals that were attributed to underestimated source rupture lengths. The most notable issue was an excess of large events produced by the model. Specifically, the 2002 NSHM predicted a recurrence interval of just three years for M\geq 7, whereas the newer model predicts these events with a recurrence interval of about 10-15 years. The latter is less discrepant with the historical record of M\geq 7 events. Present efforts to improve fault source modelling for the next NSHM include investigating alternative methods (e.g. UCERF3 grand inversion), quantifying rate uncertainties, examining alternative magnitude frequency distributions, and a more statistically defensible linking of fault source and distributed source models. The New Zealand NSHM therefore provides a useful case history of the progressive development of fault sources models.

KEYWORDS: Active fault, source, seismic hazard
Implications of geodetic strain for future large earthquakes in Taiwan

Kuo-En Ching¹, Ruey-Juin Rau², Chia-Hsun Yang³

¹ Assistant Professor, Dept. of Geomatics, National Cheng Kung University, Taiwan. E-mail: jingkuen@mail.ncku.edu.tw
² Professor, Dept. of Earth Sciences, National Cheng Kung University, Taiwan. E-mail: raaurj@mail.ncku.edu.tw
³ Ph. D student, Dept. of Earth Sciences, National Cheng Kung University, Taiwan. E-mail: yangjx.timothy@gmail.com

ABSTRACT

Geodetic strain rate is usually adopted to estimate the interseismically scalar moment accumulation rate because it enables us to infer the locking state of the active fault. Therefore horizontal velocity field from more than 1300 GPS stations in whole Taiwan during 2002-2013 is used to understand the relationship between the strain rate and the probability of future large earthquakes. In this study we mainly focus on six areas with strain rates larger than 1 μstrain/yr. Two extremely high strain rate areas of larger than 3 μstrain/yr are shown in eastern Taiwan along the plate boundary between the Eurasian and the Philippine Sea plates and the Kaohsiung area in SW Taiwan, the second biggest city of Taiwan. The active creeping faults in mudstone formation are responsible for the ultra-high strain rates in these two regions. However, the occurrence of M 6-7 earthquakes in eastern Taiwan indicates the asperity still existing at the depth between 5 and 20 km. About 1-2 μstrain/yr at east of the Chelungpu fault in central Taiwan represents the postseismic relaxation following the 1999 Mw 7.6 Chi-Chi earthquake. The Chianan area between the Chelungpu fault and the Kaohsiung city with about 1-2 μstrain/yr has been proposed as the region with highest seismic hazard except for the eastern Taiwan. However, analyzing with the leveling vertical velocities, we propose that the high strain accumulation is on the eastward connected detachment. In the southern tip of Taiwan, we also detect a high strain rate of ~1 μstrain/yr. We propose that this high strain rates are resulted from the aseismic movement of the active fault triggered by the 2006 Mw 7.0 Pingtung earthquake. Finally, we discovered a high strain rate area, ~1 μstrain/yr, at south of the Kaohsiung city, which evidences the presence of a buried fault, the Fengshan transfer fault. About 10 mm/yr velocity difference across the fault within 2 km in distance proposes that this fault is a creeping fault and produce high strain rates. According to our analyses, the high strain rate areas in Taiwan are mainly caused by the aseismic deformation. Comparing with the hypocenters of recent major earthquakes in Taiwan, most of them are located at the low strain rate regions. We therefore need to re-think about the role of strain rate in Taiwan for seismic hazard assessment.

KEYWORDS: second invariant of the strain rate, seismic hazard, creeping fault
Slip deficit distribution and seismic supercycles along the Japan islands

S. Higuchi¹, K. Koketsu²*, Y. Yokota³

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2 Professor, Earthquake Research Institute, University of Tokyo, Japan. E-mail: koketsu@eri.u-tokyo.ac.jp
3 Scientist, Hydrographic and Oceanographic Department, Japan Coast Guard, Japan.

ABSTRACT

The Japan islands are located along several plate boundaries, where the oceanic plates are subducting beneath the continental plates. Due to this subduction, slip deficits are being generated and strain is being accumulated in coupled zones of the plate boundaries so that many large earthquakes have occurred. Therefore, in order to reveal the generation mechanism of large earthquakes at the plate boundaries, it is necessary to clarify slip deficit rate distributions. In addition, as seen in long-term slow slip events, there are significant temporal changes in the slip deficit rate distributions. In this study, we determined the slip deficit rate distribution along the whole Japan islands for each year from 1996 to 2010 (whole period of GEONET operated by GSI before the 2011 Tohoku earthquake) using the inversion method, and compared each other to investigate their temporal changes.

For calculating the deformation fields in Japan, we used the daily coordinates of F3 solutions of GSI. We obtained daily time series data considering the movements of the continental plates against reference frame and removing the offsets and postseismic effects due to nearby earthquakes. We then derived horizontal rate fields in Japan for each year by least-squares fittings. For reflecting the geometry of the plate boundaries, we used the plate model (Baba et al., 2005) incorporated in JIVSM (Koketsu et al., 2012). The Green’s functions were calculated using the frequency-wavenumber method (Zhu and Rivera, 2002). We performed slip deficit inversions using the method of Yoshida et al. (1996).

The slip deficit rate distributions derived from the inversions were consistent with previous studies and the plate convergence rates. In addition, known long-term slow slip events were found in the temporal changes of the slip deficit rate distributions. Furthermore, we can see the temporal changes in the Hokkaido and Kanto regions, which suggest variations of plate coupling in these regions. The zones of large slip deficit rate in the distributions look corresponding to the source regions of past megathrust earthquakes in seismic supercycles. These correspondences are significant not only in Earth science but also in seismic hazard assessments.

KEYWORDS: Japan islands, GPS, slip deficit, megathrust earthquake, seismic supercycle
Including geodesy and non-traditional seismic radiation in seismic hazard assessment in New Zealand

B. Fry¹, L. Wallace², J. Haines³, D. Rhoades⁴, H. Kao⁵, M. Gerstenberger⁶

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² Research Scientist, University of Texas, U.S.A.. E-mail:lwallace@utexas.edu
³ Emeritus Scientist, GNS Science, New Zealand. E-mail:j.haines@gns.cri.nz
⁴ Principle Scientist, GNS Science, New Zealand. E-mail: d.rhoades@gns.cri.nz
⁵ Seismologist, Natural Resources Canada, Canada. E-mail:honn.kao@nrcan-rncan.gc.ca
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ABSTRACT

At present, geodetic measurements in New Zealand are used to produce strain budgets to distribute hazard between mapped and unmapped faults. We have also used GPS estimates of interseismic locking to inform subduction interface earthquake hazard in the national seismic hazard model. In the foreseeable future, we intend to incorporate geodetic constraints into both scenario based and probabilistic seismic hazard. We are also investigating inclusion of GPS strain models into hybrid models based on earthquake catalogues. By mathematically combining GPS based information with smoothed seismicity models or earthquake clustering models we can capture different scales of the seismic process and improve the forecasting ability. In this talk, we will present an example from 2013 to highlight current research that is directed toward these two goals. We will focus on the southern Hikurangi margin, where GPS inversion identifies a strong degree of interseismic coupling updip from a large slow slip (SSE) event that occurred during 2013. The deep (30-50 km) long-term Kapiti SSE that began in January 2013 is equivalent to an Mw7.1 earthquake. Previous Kapiti SSEs occurred in 2003 and 2008. The 2013 event activated tremor-like energy release in at least two discrete regions around the SSE. We use an energy scanning approach (Kao and Shan, 2004; Liao et al., 2012) to search continuous data from 2013 for areas around the SSE that emitted seismic radiation, either from tectonic tremor or long-duration (~>20-50s) clustering. By using an energy-based approach, we forestall issues associated with the distinction of tremor and attenuated microseisms. We locate these events within a 3D model that encompasses the plate interface from the trench to aseismic depths. We map increased seismic energy release updip from the SSE with morphology ‘interlocking’ with an embayment of the SSE. We suggest that these results map a large-scale asperity on the plate interface. We further suggest that this type of mapping can be used to quantify the evolution of stress transfer from the SSE to the locked region, providing an a priori model for deterministic modeling of megathrust rupture. To aid in PSHA, future work will also be directed at using calculated stress perturbations from both the SSE and mapped areas of seismic radiation to test the usefulness of incorporating these effects into forecast models such as EEPAS.

KEYWORDS: SSE, PSHA, seismic tremor, subduction megathrust
Overview of shallow s-wave velocity structure in Taiwan estimated from microtremor

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ABSTRACT

Amplification of strong ground motion by top alluvium layer during an earthquake incurred damage frequently recorded in recent large earthquakes. The shallow subsurface structure plays an important role for site amplification effects. Thus, the seismic wave simulation and ground motion prediction by numerical modeling include subsurface model is necessary in seismic hazard analysis in the future.

We already conducted more than one hundred and twenty microtremor array measurements and about four thousands microtremor survey points throughout Taiwan. The S-wave velocity structures were estimated from the surface to a depth of several hundred meters determined by the array radius. The Maximum Likelihood Method of Frequency-Wavenumber (F-K) analyses were used to obtain phase velocity dispersion curves. Both S-wave velocity and thickness was estimated by Genetic Algorithm (GA) searching for the inversion of the dispersion curves with the suitable initial models. The final best fit models checked by stochastic least square inversion of the fundamental Rayleigh waves. Based on that the H/V ratios confirmed with the theoretical SH wave transfer functions, the GA-Haskell method was developed to simulate H/V ratios and estimate shallow velocity structures. The capability of this method was tested and confirmed in the microtremor research of Taipei area. The microtremor survey may provide a convenient and quick solution to mapping the shallow subsurface structure in Taiwan.

KEYWORDS: microtremor, Frequency- Wavenumber, Genetic Algorithm, subsurface structure
Modeling of the subsurface structure from the seismic bedrock to the ground surface for a broadband strong motion evaluation

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ABSTRACT

Sophisticated predictions of strong ground motion are vital when constructing structure models that enable us to evaluate broadband ground motion features. In this study, we have created a subsurface structure model applicable from seismic bedrock to ground surface for individual Japanese individual prefectures, e.g., Chiba and Ibaragi, in attempts to sophisticated subsurface structure models. An essential issue in sophisticated prediction of strong ground motion is constructing structure models that enable us to evaluate broadband ground motion in a range from 0.1 to 10 seconds. It then becomes essential to integrate subsurface model and deep structure models, which used to be modeled separately, to enable us to reproduce observation data. Previous studies do not seem to have verified ground motion in 3D structure models. We therefore prepared an initial structure model for entire prefectural areas.

Using the initial structure model's initial values, we obtained S-wave ground velocity, Q values and amplification features, i.e., spectral amplification factors, from seismic data at seismic observation points from K-NET, KiK-net, JMA, municipalities, and from numerous array and single-point survey data on microtremors collected area-wise. We worked out area-wise interpolation and created subsurface structure models from seismic bedrock to ground surface in 250-meter meshes. In creating the above subsurface structure model, we verified results at each stage in reference to seismic observation and site amplification by using one-dimensional(1D) multiple reflection for periods shorter than two seconds and referencing seismic observation data by using the finite difference for periods longer than two seconds in order to check whether created models were more sophisticated than previous structure models.

The final goal of this study is to facilitate and promote studies creating new structure models based on the above subsurface structure models, so we decided to construct standard structure models for predicting broadband ground motion in Japan and to make them available to the general public. This paper focuses on results of our study on standard structure models for test sites in Chiba and Ibaragi Prefectures.

KEYWORDS: Broadband strong motion evaluation, Microtremor observation, Borehole data, Joint inversion, S-wave velocity.
Multi-method noise-based imaging of an earthquake prone valley, lower North Island, New Zealand

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ABSTRACT

Basin-scale and crustal scale imaging of New Zealand has been accomplished on multiple scales with multiple methods including those providing information on isotropic and anisotropic velocity as well as attenuation. We will briefly discuss these efforts and provide a review of passive imaging shear-wave velocity structure in an area of dense urbanization. Wellington, the capital of New Zealand is a densely populated urban area located at the boundary of the convergent Australian and Pacific plates. It is prone to the effects of both large strike-slip and large subduction earthquakes. The city lies on the edge of a funnel shaped basin and is underlain by the strike-slip Wellington Fault. The fault has average single event displacements of approximately 5 meters for surface-rupturing events. These events represent a significant seismic hazard. In order to accurately model wave propagation resulting from earthquake scenarios derived from geological mapping and calculations of synthetic seismicity, we must accurately know the basin geometry and velocity structure. Geotechnical data in the basin is sparse and insufficient to provide a full 3D basin model. The dense human development precludes the use of active source seismics for imaging. We therefore apply noise-based, passive seismic imaging to define velocity structure and basin geometry. We use 3 separate noise-based techniques which provide complementary sensitivities. Early work (Kaiser and Louie) used the linear-array method REMI to map shallow velocity structure. Shallow velocity estimation was later improved by a densification of measurements with the SPAC method (Stephenson). Lastly, we deployed eight 40 second and six 1 second seismometers to record both earthquake and ambient noise data. Cross-correlation functions from the ambient noise data were used to determine surface wave dispersion from every 2-station pair. The resulting dispersion curves have been inverted with a non-linear scheme using the neighborhood sampler to calculate multiple, path-averaged 1D Vs profiles of intermediate depths down to contact with effective bedrock. These velocity profiles have been integrated with existing geotechnical and geological data to generate a comprehensive basin model. Concurrent work is focused on modeling complex wave propagation through this model, including the effects of the basin's drastic bounding topography.

KEYWORDS: basin imaging, scenario-based seismic hazard, ambient noise, tomography, shear-wave velocity
Estimations of Vs30 in Taiwan

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ABSTRACT

The growth of population and urbanization make more people concentrating in big cities in the past few decades. Those big cities are usually located on a place covered by fertile deposits and extended abundant water. The tendency of concentration of large population and development of buildings has increased the vulnerability to seismic hazard. It has been recognized that the seismic response is largely influenced by geological conditions at the location of a building, that is, the so-called site effect. Vs30, which is the average S-wave velocity in the top 30 meter, is a widely used parameter for defining seismic amplification in earthquake engineering.

Several studies had estimate seismic site conditions (site classification or Vs30) for the free-field stations of Taiwan Strong Motion Instrumentation Program (TSMIP) in Taiwan (Kuo, 1992, 1993, 1994; Phung et al., 2006; Chiou et al., 2008; Lee et al., 2001, 2008; Wald and Allen, 2007; Kuo et al., 2012). After Chi-Chi earthquake, the Central Weather Bureau (CWB) and the National Center for Research on Earthquake Engineering (NCREE) started to launch a project of investigating the site conditions for free-field TSMIP stations by logging. Kuo et al. (2012) arranged those velocity data measured by a PS-logging system and also used an accurate extrapolation to calculate the Vs30 at all drilled stations. The Engineering Geological Database for TSMIP (EGDT) was then constructed and adopted by the well-known Next Generation of Attenuation (NGA) ground motion modeling project. Otherwise, Chiou et al. (2008), Lee et al. (2008), and Wald and Allen (2007) estimated the Vs30 in Taiwan using the correlations between measured Vs30 and elevation, geological conditions, and topographic slope, respectively. The measured Vs30 used in those studies is also a part of the EGDT. Accordingly, we examined the estimated Vs30 from those studies by comparing with the later measured Vs30 to discuss the accuracy of those estimation approaches.

KEYWORDS: Vs30, Taiwan, PS-logging, TSMIP, EGDT
The Development of Ground-Motion Prediction Equation Incorporating Ground-Motion Simulation

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ABSTRACT

Strong-motion instruments have been in place in Taiwan since 1991 and have produced a large amount of observed data, including the most valuable data from the 1999 Chi-Chi earthquake. However, data for earthquakes with a magnitude greater than 6.5 is still lacking. Most Ground-Motion Prediction Equations (GMPEs) have been derived from regression analysis using large sets of observed data called empirical GMPEs. For a regional GMPE model, it may lack large magnitude and near field data which may cause bias of the predictions.

Recent development of physics-based numerical simulations of earthquakes has been greatly improved by taking into account the source, path, and site effects. This may help to further improve the development of GMPEs.

In this study, we implement ground motion simulation to provide a large number of simulated data which fill the lack part of the observed data. With the combination of observed data and simulated data we could be better to re-evaluate the current GMPEs in Taiwan. Finally, we generate an updated version of GMPEs which incorporating the observed data and simulated data together and could provide more reliable ground-motion predictions value for near field and large magnitude earthquakes.

KEYWORDS: GMPE, Ground motion simulation
A new ground motion prediction equation for Japan

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ABSTRACT

In this study we suggest a new ground motion prediction equation for Japan using the strong motion records including those from the 2011 Tohoku-oki earthquake. Target strong-motion parameters are JMA seismic intensity, peak ground acceleration, peak ground velocity and 5% damped acceleration spectra whose periods between 0.05 and 10 seconds. The number of earthquakes was 333 and strong-motion records was 21,681. We first determined a simple base model with moment magnitude and the shortest distance from the source fault as parameters. In order to avoid overestimating amplitude at moment magnitude (Mw) larger than 8, we introduced a quadratic magnitude term with a complete amplitude saturation at some Mw. We then adopt additional correction terms corresponding to amplification by deep sediments or shallow soft soils, and anomalous seismic intensity distribution in order to improve prediction. As an overall feature, our new model can explain strong motion records of the 2011 Tohoku-oki earthquake of Mw9 well. However, the uncertainty of the prediction at near source region for large earthquakes (distance<30km, Mw>7) and long-period ground motions from mega-earthquakes still remains because these records were quite limited.

KEYWORDS: Ground motion prediction equation, the 2011 Tohoku-oki earthquake, seismic hazard assessment, site amplification, anomalous seismic intensity distribution.
Recent efforts in empirical ground motion prediction in New Zealand

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ABSTRACT

This presentation discusses recent empirical ground motion modelling efforts in New Zealand. Firstly, the active shallow crustal and subduction interface and slab ground motion prediction equations (GMPEs) which are employed in the 2010 update of the national seismic hazard model (NSHM) are discussed. Other NZ-specific GMPEs developed, but not incorporated in the 2010 update are then discussed, in particular, the active shallow crustal model of Bradley (2010). A brief comparison of the NZ-specific GMPEs with the near-source ground motions recorded in the Canterbury earthquakes is then presented, given that these recordings collectively provide a significant increase in observed strong motions in the NZ catalogue. The ground motion prediction expert elicitation process that was undertaken following the Canterbury earthquakes for active shallow crustal earthquakes is then discussed. Finally, ongoing GMPE-related activities are discussed including: ground motion and metadata database refinement, improved site characterization of strong motion station, and predictions for subduction zone earthquakes.

KEYWORDS: New Zealand ground motion prediction, 2010-2011 Canterbury earthquakes; Ground motion expert elicitation.
Earthquake scenario simulations for active faults and seismogenic structures in Taiwan

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ABSTRACT

We perform earthquake scenario simulations for active faults and seismogenic structures in Taiwan based on fully 3D topography and subsurface structures. For the scenario source models, we digitize 20 active faults and seismogenic structures in Taiwan. Then, each fault plane is divided into 3 x 3 km² subfaults to consider finite-fault rupture approach. In the first phase of simulation, a simplified source rupture model is considered which assumes homogeneous slip distribution on the fault plane. For the path effects, we use spectral-element method to simulate the seismic wave propagation of the scenario earthquakes. The SEM mesh model built for Taiwan contains currently available relevant seismological and geological information, including a large-scale velocity model, sedimentary plains, surface topography, basin geometry and its 3-D wave-speed heterogeneity. The size of the region is 279.27 km x 428.42 km horizontally and +3.93 km to -110.00 km vertically. The average distance between Gauss-Lobatto-Legendre grid points in the horizontal direction is 136 m at the surface. This SEM mesh model is sufficient to resolve topography and tomography data for simulations accurate up to 1.0 Hz. Earthquake scenario simulation results show that the PGA value are usually larger than 1g in the area near the fault plane. In addition, the PGA are further amplified due to low wave speed material, such as in the Western Plain, Ilan Plain, Longitudinal Valley and Taipei Basin. The second phase of scenario earthquake study will consider characterized source model which has heterogeneous rupture with asperities and background slips on the fault plane. This phase is planned to accomplish before the end of next year.

KEYWORDS: Earthquake scenario simulation, active faults, seismogenic structures, computational seismology
Ground motion simulation for large earthquakes along Ryukyu Trench offshore Taiwan

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ABSTRACT

Large earthquakes resulted from rupture along the thrust-type fault boundary at the Ryukyu Trench between the downgoing oceanic Philippine Sea Plate and the overriding Eurasian Plate, causing potential of widespread shaking and tectonic deformation. Historically, this region has experienced a large earthquake with magnitude about 8.0 on June 5, 1920. We discussed and implemented ground motion simulation with various characterized source models to understand possible impact of induced strong motion. Seismic intensity map from historical document shows that the earthquake shook all over the mainland Taiwan, especially the north area of Hualien, where the earthquake occurred nearby. No doubt northeast Taiwan area is also under inevitable threat from strong ground motions generated by future large earthquakes along the subducting plate boundary. Along the subduction zone of Ryukyu Trench, a great earthquake was known from 1920 written literature, seismologists and geophysicists thus recognized the potential for future great earthquakes. After the 1920 event, it has no such great event occurred in the similar region during the period of digital seismic observation so far. Thus, not only study for historical earthquakes is an important work for extending the knowledge into the past to spur and guide seismic hazard reduction efforts but it is worth to validate intensity using seismological bulletin records and produce the possible strong motions on some specifically pivotal sites, such as critical metropolitan. Utilizing simulation methods of deterministic method for low frequency and the stochastic method for high frequency, the broadband-frequency ground motion time history could be obtained. We build up characterized source models and tuned source parameters to catch optimal explanation with respect to the historical seismic intensity. The shaking level from simulation for the other metropolitan areas will also be helpful for the advanced assessment of seismic hazard and the mitigation of seismic risk.

KEYWORDS: Ground motion simulation, subduction zone, seismic hazard
Finite-difference simulation of long-period ground motion for the Nankai Trough earthquakes

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ABSTRACT

Large interplate earthquakes such as the Nankai Trough earthquakes in southwest Japan potentially cause damages to high-rise and large-scale structures due to long-period ground motions. The long-period ground motions are amplified particularly on sedimentary basins, where big cities have been established. Therefore it is important to evaluate long-period ground motions as well as strong motions and tsunami for the anticipated large earthquakes.

We evaluate long-period ground motions associated with the Nankai Trough earthquakes (M8~9) by the finite difference method (FDM) using “characterized source model” and the 3-D underground structure model. The parameters of the characterized source model are determined based on a “recipe” for predicting strong ground motion [Earthquake Research Committee (ERC), 2009]. To understand a variation of long-period ground motions caused by the uncertainty of the source model, we construct various source models (~400 scenarios) assuming various possible source parameters, including rupture area, asperity configuration, and hypocenter location. We apply the system called GMS (Ground Motion Simulator) for simulating the seismic wave propagation based on 3-D FDM scheme using discontinuous grids (Aoi and Fujiwara, 1999) to our study. The underground structure model used in the FD simulation is the Japan integrated velocity structure model (ERC, 2012).

Simulated peak ground velocity (PGV) and velocity response spectra (Sv) show a large variation at each site. The scenarios with wider source area have larger PGV and Sv than those with smaller source area. We select some specific scenarios that correspond to representative (e.g. average, average+1) response spectra of the simulation results at each site. The selected scenarios vary from site to site. In addition, we evaluate the hazard curves and maps for PGV and Sv using the simulation results by assuming the occurrence probability of each scenario. The PGV and Sv distribution maps for low conditional exceedance probability clearly show that the long-period ground motions are amplified at sedimentary basins.

KEYWORDS: Nankai Trough, long-period ground motion, megathrust earthquake, finite difference method.
Employing multiple approaches to simulate ground motions for scenario events

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I present an overview of the multiple approaches currently undertaken by myself and colleagues from New Zealand institutes (GNS Science, University of Canterbury) and USGS (collaboration with Brad Aagaard) to simulate ground motions for past and future large earthquakes in New Zealand.

For past earthquake case studies, ground motion modeling in “response mode” for fast characterization of recent large NZ earthquakes has been essentially computed using the fast Discrete Wavenumber approach for the rather low frequency range of 0.1 to 1 Hz. (eg Holden, 2011). In a second stage, ground motion modeling is extended to a broader frequency range based on detailed kinematic fault model (B. Bradley (following the approach of Graves and Pitarka, 2010), Holden 2014 (following a stochastic approach (Atkinson et al., 2009)), Kaiser (high-frequency scattering theory)) or dynamic fault modeling (B. Aagaard)).

Potential large earthquake sources for New Zealand are the Alpine Fault (South Island) and the Hikurangi subduction zone (North Island). Preliminary ground motion estimates have been modeled based on characterized source models as well as historical slip histories from relevant past large world earthquakes and employing the empirical Green’s function approach as well as the finite fault stochastic approach. I will also mention studies focusing on the Wellington region: finite difference simulations of M6.7 scenario earthquakes on the Wellington fault (Benites and Olsen, 2005), and a better characterization of the earthquake risk and impact in Wellington through the “It’s Our Fault” project (http://www.gns.cri.nz/Home/IOF/It-s-Our-Fault).

It is worth noting that the modeling of these large events is ongoing work as progress is being made on better source characterization and regional geophysical characterization (Work by M. Reyners, B. Fry and colleagues (GNS Science) for New Zealand in general and B. Bradley and colleagues (University of Canterbury) for the Canterbury region).

KEYWORDS: ground-motion modeling, Canterbury, Alpine Fault, Hikurangi, Wellington.
Probabilistic seismic hazard assessment for Taiwan:

Implementation of the TEM parameters

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ABSTRACT

We assess probabilistic seismic hazard for the Taiwan region based on the state-of-the-art achievements of Taiwan Earthquake Model (TEM). According to the information in respect of tectonic setting, geology, geomorphology, and earthquake catalog, several categories of seismogenic source types are identified and corresponding seismicity rates are evaluated. By further implementing ground motion prediction equations for different sources and site conditions, probabilistic seismic hazard is assessed. The obtained high hazards is mainly contributed by the crustal active faults with short recurrence intervals. Since this assessment is widely applied for Taiwan, when the information on vulnerability (fragility curve) and exposure (distribution of structures and population) is considered, probabilistic seismic risk map could be further assessed. The results would be a benefit to decision-makers and public officials for hazard mitigation.

KEYWORDS: Probabilistic seismic hazard assessment, hazard map, hazard curve, Taiwan.
Some clues for approaching Japanese PSHA maps by OpenQuake

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ABSTRACT

An on-going mission of the National Seismic Hazard Maps for Japan has been carrying out after the 1995 Kobe Earthquake. An open-web system of Japan Seismic Hazard Information Station, J-SHIS, provides the all of information related seismic hazard assessment (SHA) (Fujiwara et al., 2009). The authorized new knowledge has been annually updated by J-SHIS. The 2012 Japanese probabilistic SHA model was accordingly implemented on OpenQuake-engine by the Global Earthquake Model foundation (GEM) in 2013. The OpenQuake, an open-source software package powered by modern Python technology, summarized probabilistic SHA and risk assessment methodologies with the state of the art (Monelli et al., 2012, Pagani et al., 2014).

More than 10 regional models include Japanese have been implemented on OpenQuake and the more on the way. The Japanese PSHA map produced by OpenQuake was generally comparable to the original J-SHIS maps but differences were recognized within a couple dozen of percentage in somewhere. It is really hard to find bugs in the huge packages either OpenQuake or J-SHIS that were made by totally different scientific groups with different technologies.

This study tries to use OpenQuake to approach J-SHIS maps and the presentation will raises the questions and reports their progress.

Some clues are possibly obtained from the following approaching ways:

1) Implementation of Ground Motion Prediction Equation (Si and Midorikawa 1999);
2) Performance hazard curve comparisons at given sites for selected single Earthquake source typologies;
3) Performance hazard curve comparisons at given sites for all of sources include rectangular faults (about 358), non-rectangular faults (14), discretized faults (1858), and discretized sources (686), gridded seismicity (31,963).

Applying the most complex Japanese model to carefully checkup OpenQuake will increase the interest of OpenQuake and benefit Japanese PSHA researchers and other users.

Acknowledgement: We thank Dr. D. Monelli, M. Pagani for their cooperation.

KEYWORDS: Seismic Hazard Assessment, OpenQuake, GEM, J-SHIS
Rethinking PSHA

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ABSTRACT

Since the early 1980s seismic hazard assessment in New Zealand has been based on Probabilistic Seismic Hazard Analysis (PSHA). The most recent version of the New Zealand National Seismic Hazard Model, a PSHA model, was published by Stirling et al, in 2012. This model follows standard PSHA principals and combines a nation-wide model of active faults with a gridded point-source model based on the earthquake catalogue since 1840. These models are coupled with the ground-motion prediction equation of McVerry et al (2006). Additionally, we have developed a time-dependent clustering-based PSHA model for the Canterbury region (Gerstenberger et al, 2014) in response to the Canterbury earthquake sequence.

We are now in the process of revising that national model. In this process we are investigating several of the fundamental assumptions in traditional PSHA and in how we modelled hazard in the past. For this project, we have three main focuses: 1) how do we design an optimal combination of multiple sources of information to produce the best forecast of earthquake rates in the next 50 years: can we improve upon a simple hybrid of fault sources and background sources, and can we better handle the uncertainties in the data and models (e.g., fault segmentation, frequency-magnitude distributions, time-dependence & clustering, low strain-rate areas, and subduction zone modelling)? 2) developing revised and new ground-motion predictions models including better capturing of epistemic uncertainty – a key focus in this work is developing a new strong ground motion catalogue for model development; and 3) how can we best quantify if changes we have made in our modelling are truly improvements? Throughout this process we are working toward incorporating numerical modelling results from physics based synthetic seismicity and ground-motion models.

KEYWORDS: PSHA, time-dependence, uncertainty, New Zealand, ground-motion prediction
Current Status of Taiwan Earthquake Loss Estimation System

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ABSTRACT

"Taiwan Earthquake Loss Estimation System (TELES)" was developed by the National Center for Research on Earthquake Engineering in Taiwan. Since the software was announced in year 2003, it already has many practical applications, such as assistance in proposing disaster reduction plans for central and local governments through a scenario-based approach, in prioritizing seismic retrofit sequence of existing highway/railway bridges, and in calculating insurance premium for residential houses through probabilistic seismic risk assessment, and so on. Not only the software architecture but also the database and analysis models have been improved gradually. The database, analysis models and software architecture are the key elements in seismic disaster simulation; therefore, this presentation illustrates the current status of TELES in these aspects.

Finding reliable data-sources, transforming the data-sources into useful database, calibrating and updating the existing database, improving the data quality inside the database, etc are briefly explained. Analysis models for potential seismic hazards, damage assessment of buildings, bridges and buried pipelines have played important roles in previous applications. It is also noted that extension the damage assessment of individual facilities to system serviceability analysis after a devastating earthquake will be emphasized in the future development. Last but not least, in order to accelerate the applications and to provide user-friendly interface, revising the software architecture of TELES is required. The term TELES now represents a family of earthquake loss estimation systems. For example, T-gbs, T-highway and T-water are systems derived from the same architecture, and they are suitable for loss estimation of general building stocks, highway systems and potable water systems, respectively. All the systems in TELES may work together or stand-alone depending on the user needs, and they follow the same data-flow rules. Individual systems may be maintained by different researchers with special domain knowledge. Hopefully it will accelerate the progress of seismic disaster simulation technology in Taiwan.

KEYWORDS: seismic disaster simulation, database, analysis model, software
Seismic risk analysis based on national seismic hazard maps for Japan

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ABSTRACT

NIED is publishing "The National Seismic Hazard Maps for Japan" on the web site named "J-SHIS" for the purpose of seismic disaster mitigation. When social impact caused by seismic hazard can be properly illustrated, it is easier for the users obtaining a clear picture of earthquake disaster and developing measures against it. From this perspective, NIED has been studying quantification of the seismic risk based on the seismic hazard maps.

The targets in the first step are damage of buildings which are the most basic social infrastructure and casualties caused by the building damage. Building damage is affected by not only intensity of ground motion but also building structure, building code, and so on. Casualties are said to be strongly correlated to building damage and accordingly affected by population movement.

The seismic risk analysis based on "The National Seismic Hazard Maps for Japan" was carried out and the various results could be obtained. One obtained result, for instance, was that the expected value of totally damaged buildings for 30 years was about 407,000 and 60% of the damages was caused by category-1 earthquakes (mega earthquakes in subduction zones). It is also possible considering policies for disaster mitigation in the seismic risk analysis. It is expected that this kind of analysis will be effectively used for policymaking.

KEYWORDS: National Seismic Hazard Map, building damage, casualties, seismic risk
Riskscape and PSHA Applications in New Zealand

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ABSTRACT

PSHA is used as the basis for a wide range of down-stream applications in earthquake engineering. This presentation will outline two main applications of PSHA in New Zealand, namely defining seismic loading standards for the New Zealand building code, and for underpinning seismic loss/risk assessment using the Riskscape multi-hazard risk assessment platform.

The National Seismic Hazard Model for New Zealand, based on PSHA methodology, is used as the basis for defining the national seismic hazard zone factor maps for the current structural design standard for New Zealand (NZS 1170). Seismic zonation in New Zealand is defined by the Z factor, which is used to scale normalized response spectra for a given location. The Z factor is defined as 0.5 times the 0.5s spectral acceleration for a probability of exceedence of 10% in 50 years on a soft-soil site. This approach allows the design level motions for a given building to be determined quickly for any location in New Zealand.

Riskscape is multi-hazard risk assessment system, run as a joint venture between GNS Science and the National Institute of Water & Atmospheric Research (NIWA). The primary goal of Riskscape is to convert existing hazard knowledge into likely consequences, such as damage and replacement costs, casualties, disruption and number of people that could be affected. Consequences are presented in a common platform across all natural hazards and can then form the basis of prudent planning and worthwhile risk-mitigation measures that link directly to the severity of the risks. Riskscape aims to provide a decision support tool which can be applied across a region for use by emergency, asset, and environmental managers. Riskscape will not only benefit these agencies through supporting planning and investment decision-making prior to a natural disaster, but also support emergency managers and government agencies with rapid estimates of the consequences and disruption following a natural disaster.

KEYWORDS: PSHA, Risk Assessment, Building Code
PSHA applications and its social scientific approach

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ABSTRACT

NIED keeps developing mobile applications and web services in order to realize DRR for the society. As introductions, applications and service are picked up below, which use J-SHIS Web APIs: PSHA data distribution format of speedy, simple, universal Restful APIs on the web.

1. Moshiyure (If earthquake occurs, what will happen to myself?): Selfie app on earthquake damages.
   It is an iOS application visualizing earthquake awareness and to promote appropriate action. A selfie shot will be taken and the damage possibility layered above using location information obtained from GPS, etc.

2. Seismic Hazard Karte: PSHA multi-index summary as a web service.
   It is a summary service of PSHA for every mesh. Arbitrary places can be searched and the diagnosis of the earthquake hazard about the place can be drawn up. A result displays many indices, such as various subsurface structure information, hazard curves, probability, etc. as one page A4 sheet using many charts and graphics.

   The J-SHIS application service enables browsing of the latest PSHM, SESM, Site Amplification map, deep subsurface structure map, and for each 250m mesh, information delivered by APIs.

After release of these services, check and analysis process is started for verification. One research shows only 11% people get already prepared confidently for earthquake, while 63% people feel that it is possible to occur earthquake anywhere anytime in Japan (n=2,004). This result supports there is a big gap between knowing hazard to get action to prepare for disaster as Gardner (2008) mentioned. It is always important to consider users properly when any services are provided. User domains in the society vary by each attribution as a matter of course in the case of PSHA applications. In this context, this social scientific approach to know human beings and society will be expected for each applications treating PSHA.

KEYWORDS: Application, PSHA, IT tools.
Ground motion simulation of the 1909 Taipei historical earthquake

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ABSTRACT

The 1909 Taipei earthquake(M6.8) was located beneath the Taipei Metropolitan Area(TMA), the possible seismic hazard similar to the 1909 Taipei earthquake would require special attention. According to the hypocenter relocated from the historical archived travel times of 1909 Taipei earthquake(Kanamori et. al., 2012) we simulated ground motions in TMA by using Spectral Element Method(SEM). A 3D velocity structure with topography and sediment layers in Taipei basin was also included in simulation works.

As the results of point-source simulations, the tension type focal mechanism may cause larger ground motions than the subduction zone type mechanism. The higher peak-ground-motion values occurred in the western part of Taipei basin with both two types of focal mechanism.

SEM could provide us good prediction of low frequency ground motions. For higher frequency components, we chose a recently happened deep event in Taipei basin as the empirical Green’s function(EGFM) for the 1909 Taipei earthquake. By combining the lower and higher frequency components, we expect to obtain the expecting PGA to give the comparison to the corresponding 1909 historical intensity map and literature damaging patterns.

KEYWORDS: 1909 Taipei earthquake, SEM, EGFM, hybrid simulation
New Attenuation Relationship for peak ground acceleration and response spectra of normal faulting events in the northeast offshore Taiwan

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2 Department of Earth Sciences, National Central University, Taiwan
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ABSTRACT

The normal faulting earthquakes showing larger peak ground motion acceleration (PGA) has been discussed recently. To evaluate the possibility of risk related to the normal faulting earthquakes occurred in the Ryukyu Arc and the Okinawa Trough, we developed the Ground Motion Prediction Equation (GMPE) for PGA and response spectra (Sa) with the data of normal faulting events in the northeast offshore Taiwan. In the analysis, 1084 data of 13 normal faulting earthquakes with Mw 4~6 at depths less than 35 km were used. The new attenuation considered the seismic moment magnitude (Mw), hypocentral distance, focal depth and site effect which quantified with Vs30. The resultant attenuation relationship shows that the normal faulting earthquake generates stronger Sa which is not adopted for attenuation equation that usually used in Taiwan. The new GMPE for PGA do not reveal higher values for normal faulting earthquakes with Mw 4~6 analyzed in this study. However, higher predicted values were shown for Mw > 6, corresponding to the observed data catalogued in Next Generation Attenuation (NGA). To enhance the accuracy of Sa and PGA prediction of normal faulting earthquakes with Mw > 6, analyzing comprehensive data worldwide, particularly the normal faulting events of Japan should be considered further.

KEYWORDS: normal fault, ground motion prediction equation, Sa, PGA
The Empirical Equation with a New Definition of Effective Shaking Duration for Taiwan Earthquakes

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ABSTRACT

The duration of strong shaking is particularly important in assessing building performance and also assessing potential landslide and liquefaction hazards. The product of this investigation has the potential to be useful in reducing losses. In this study, we analyzed the acceleration seismograms of Taiwan Strong Motion Network to characterize the strong shaking duration that associated with earthquake source, propagation path and site effect. This paper proposes a new definition for the strong shaking duration called “effective shaking duration” in consideration of amplitude and energy factors. We calculated the strong shaking duration for 495 events in Taiwan area from 1994 to 2012 within magnitude of $M_L > 5.0$ and within depth $< 50 km$ (inter-plate events). Using a nonlinear regression procedure, we, thus, obtained an empirical equation of strong shaking duration with function of earthquake magnitude, distance and site condition. The result shows that the shaking duration significantly to increase with magnitude, and also to decrease with distance and $V_{s-30}$ value ($V_{s-30}$ reflects the shallow geologic condition of the top 30m from ground). The empirical equation can be applicable to estimate the strong shaking duration for the criteria earthquakes ($M_L > 5.0$, depth$<50 km$) in Taiwan. The empirical equation derived from massive dataset of Taiwan strong motion network could provide the reference to the global community on the ground shaking duration estimation in ground motion prediction of future earthquakes.

KEYWORDS: strong shaking duration; effective shaking duration; hazards; empirical equations; site condition
Jet streams anomalies as possible short-term precursors of earthquakes with M>6.0

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ABSTRACT

Satellite data of thermal images revealed the existence of thermal fields, connected with big linear structures and systems of crust faults. The measuring height of outgoing longwave radiation (OLR) is located to the range of jet stream. This work describes a possible link between strong earthquakes and jet streams in two regions. The front or tail ends of jet groups maintain their position for 6 or more hours in the vicinity of epicenters of strong (M > 6.0) earthquakes in 2006-2010. The probability of observing a stationary jet stream behavior is estimated in 93.6% of the cases on one six-hour map and in 26.7% of cases - on two adjacent maps. The median of distribution of distances between epicenters and the relevant positions of jet stream corresponds to 36.5 km. Estimates of cumulative probability of realization of prediction were 24.2% for 10 days, 48.4% for 20 days, 66.1% for 30 days.

Keywords: earthquake, epicenter, jet stream, precursory anomaly.

Ps.1. This paper had been published on


2. The predicted examples

(a) M6.1 Italy earthquake (M6.1 2012/05/20 44.800N 11.192E 5.1km) Prediction:2012/03/20~2012/04/20

http://ireport.cnn.com/docs/DOC-764800

(b) M7.8 Iran earthquake (2013/04/16 28.107N 62.053E 82.0km) Prediction:2013/01/14~2013/02/04 eastern Iran(28.0N61.3E)M>6.0 100%

http://ireport.cnn.com/docs/DOC-910919
Evaluation of strong ground motions for the Wenchuan and Lushan earthquakes based on Empirical methods

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ABSTRACT

Site effect is an important factor affecting strong ground motion. The evaluation of site effect can be done by using either theoretical methods or empirical methods if the detailed information of soil profiles is available, but will be difficult when such information is not available. Since the detailed soil profiles are not available for many observation stations in the world, it is necessary to have a method to evaluate site effect for such observation stations. In this study, we suggest a method to estimate amplification factors for observation stations without detailed soil profiles by using empirical methods. In the method, firstly we use a GMPE defined on hard rock site proposed by Si et al. (2013a) to predict ground motions on bedrock with Vs about 2 km/s, then the predicted ground motions are corrected to sites with arbitrary Vs30 and bedrock depth based on the evaluation equation of amplification factor for spectral acceleration proposed by Si et al. (2013b).

The method is applied to the 2008 Mw7.9 Wenchuan and the 2013 Mw6.6 Lushan earthquakes. The predicted spectral accelerations on hard rock by the GMPE of Si et al. (2013a) are compared with the observations during the Wenchuan and Lushan earthquakes, and it is found that the observations for both the earthquakes are well consistent with predictions. The results show that the GMPE developed in Japan can be thought as the average ground motions for the two earthquakes. Thus, we then computed ground motions on surface layer with Vs30 of 500 m/s, and bedrock depth of 100 m. The results are compared with the observations on soil observation stations, and found that the predictions are also well consistent with the observations. This reveals that the assumed Vs30 and bedrock depth may be adequate as the average ones for the observation stations recorded the Wenchuan and Lushan earthquakes. Finally, soil parameters for several observation stations are estimated by fitting predicted amplification factors to the residuals between observations and predictions by the GMPE on hard rock. The results implied that the method suggested in this study is useful for the rough estimates of soil parameters.

KEYWORDS: Hard rock, Ground motion prediction equation, Spectral acceleration amplification, Evaluation equation for amplification factor, GMRotI50, Vs30RT.
Shallow s-wave velocity structure of the western coastal plain of Taiwan estimated from microtremor array

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ABSTRACT

The shallow S-wave velocity structures of the western plain of Taiwan were estimated by twenty-four microtremor array measurements. The largest radius of each array ranged from 32 meters to 70 meters. The Maximum Likelihood Method of Frequency-Wavenumber (F-K) analyses were used to obtain phase velocity dispersion curves. Both S-wave velocity and thickness was estimated by Genetic Algorithm (GA) searching for the inversion of the dispersion curves with the suitable initial models. The final best fit models confirmed by stochastic least square inversion of the fundamental Rayleigh waves.

We assumed the S-wave velocity of the engineering bedrock to be 600 m/s, the depths of the substructure are between 27m and 338m gradually increasing from eastern foot of mountain to western coastline. The results of very shallow part are in good agreement with the suspension PS-logging (EGDT, Engineering Geological Database for TSMIP) data. The pattern of the depth contour is also corresponding with the geological and the geophysical information. However, we only analyzed half of the microtremor arrays so far, the more inversion result will provide us more detail information of the subsurface structure.

KEYWORDS: velocity structures, microtremor array, Frequency-Wavenumber, Genetic Algorithm
Review the 1906 Meishan earthquake and Chiayi transfer zone in central Taiwan

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ABSTRACT

The Chiayi transfer zone is the major segment boundary of the fold and thrust belt in central Taiwan which separates the Changhua-Chelungpu faults and Muchiliao-Liuchia faults. In this transfer zone several active faults, including Meishan fault, Kukeng fault, Chiayi fault, and Chiuchungkeng fault, were developed to accommodate the ca. 3 cm/yr shortening.

The Chiayi fault, ca. 30 km in length, is a blind listric thrust which deformed ca. 35000 bp lateritic terraces. The Chiuchungkeng fault, ca. 17km in length, is a low angel thrust cut the 18540 bp terrace. Kukeng fault, ca. 17km in length, is strike slip fault which separate the Changhua fault and Chiuchungkeng fault. The 1906 Meishan earthquake (M7.1) resulted in a near 14 km surface rupture caused by activation of the right lateral Meishan fault. During 1999 earthquake the Meishan fault is also the southern ending boundary of the surface deformation. The seismic profiles show the Meishan fault could extend eastward and becomes a blind fault beneath the Chiuchungkeng fault. The total length is ca. 30 km and high angle dipping to the south. Variation of crust strength from north to the south and the preexisting normal faults are the major mechanisms of developing the Chiayi transfer zone and active faults in this area.
Digitization and processing of historical seismograms in Taiwan

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ABSTRACT

A data processing procedure for the historical seismograms of the CWB was present. Instrumental observations in the Taiwan area began on December 19, 1897, when a Gray-Milne seismograph was installed at Taipei. Subsequently after another has installed Omori horizontal seismograph, Omori tremometer, Strong-motion seismograph, Wiechert seismograph, Portable seismograph, Acceleration seismograph, etc., and recorded a large number of seismograms. The Data-base of Historical Seismograms in Taiwan (Cheng et al., 2014) using digital image files to replace microfilm store historical seismograms. To obtain the corrected data with equal time intervals, the following steps were performed on the image of seismogram: (1) Digitizing, (2) Correction of arm length, (3) Equal spacing interpolation, (4) Baseline correction, (5) Instrument correction, and (6) Bandpass filter. The original analog seismic records processed through the six steps above, we can get the actual ground displacement waveform.

KEYWORDS: historical seismogram, digitization.
2014
Taiwan-Japan-New Zealand Seismic Hazard Assessment Meeting
Field Geology Guidebook
TAROKO NATIONAL PARK
AND ACTIVE PLATE BOUNDARY

2014/05/21 – 2014/05/23
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Taroko National Park

Taroko National Park, situated in the eastern part of the Taiwan and established on November 28, 1986, covers more than 92,000 hectares in the northern section of the Central Mountain Range. This park features high mountains and sheer gorges. Many of its peaks tower above 3,000m in elevation, with many natural wonders. The spectacular Taroko Gorge and the scenic beauty of Liwu River can be conveniently viewed from the Central Cross-Island Highway. The varied mountain peaks, numerous waterfalls, diverse plant forms and animal life, together with the indigenous Taroko people, create the rich texture of this unique natural ecosystem.

~Taroko National Park Official Web page~

The Penglai Orogeny occurred 4 million years ago, was caused by the collision of the Philippine Sea Plate and the Eurasian Plate. At that time, thick layers of calcareous rock that had been raised from the marine depths during earlier orogenies were now gradually pushed high above the ocean surface to form lofty peaks. During this period of immense tectonic forces, the high pressures and temperatures of compression folded and metamorphosed the original rock (limestone) turning it to marble. At present, this region is still being uplifted at the rate of 0.5cm a year. The area has experienced both geologic uplifting and river erosion by the Liwu River. This area is unique for its marble gorge that occasionally forms hundreds of meters high, a phenomenon seldom found elsewhere in the world.

~Taroko National Park Official Web page~

The gorge itself was carved into the marble by the erosive power of the Liwu River. In addition, there are known to be jade in this gorge. This jade is only found in Taiwan and the jade from this area supplies the jade market in Hualien. These mountains can be seen from rafting (a common activity during summer months in Taroko Gorge) through the rivers.

~Taroko National Park Wikipedia Web page~

Reference

Taroko National Park Official Web Page:
http://www.taroko.gov.tw/English/

Taroko National Park Wikipedia Web page:
Figure 1: Tunnel of Nine Turns (九曲洞, Jiuqu Dong) trail, two kilometers in length, is the most elite section of Taroko Gorge, tight trails, Alpine, melancholy, that is looking down the wild water Liwu River (立霧溪). Road is wide and flat, and is a popular recreational trail and excellent outdoor geological classrooms.

Figure 2: The Liwu River, is a located in Taiwan Hualian County's well-known rivers, cutting out the gap over more than 1,000 meters of Taroko Gorge is famous for. Liwu River of about 55 km, watershed area of 616 km², with an average slope of 1:32. Built a number of bridges, in which Chingwun Bridge is the start of the Taroko Gorge, source of the Liwu River from the Centre mountains over 3,000 meters above sea level until it flows into the Pacific Ocean. River is rapids and forms many attractions of waterfalls.
Sequence of Duluanshan Formation, Volcanic Arc, in Eastern Taiwan

Duluanshan formation is major including volcanic breccia, volcanic conglomerate, tuff, conglomerate, tuffaceous sandstone and limestone, even with thin lava flows. It is a product of the eruption of the volcanic arcs. The average thickness of formation is about 400 – 500 meters but the thickness variation is considerable throughout, some parts are up to 1,000 meters or more. Because the changes of lithology and occurrence are large, it can be further broken down, depending on their lithological and occurrence, into "Shihmen Volcanic Breccia" and "Shihtiping Tuff" and "Kangkou Limestone" three rocks.

In the middle part of the Coastal Range, volcanic rock has gone through three phase developments of deep sea, coastal and land:

1. Deep sea eruption phase: About 20 million years ago in the Pacific Coast range volcano beneath the sea, because the crater-overlying water pressure was too large, volcanic eruptions were dominated by lava flows. During eruption processing it produces some pillow breccia and glass clastic rock (in Changhung Bridge).

2. Coastal eruption phase: Volcanos gradually grow up, when they grew to hundreds of meters above the crater depth, shallow (generally, about 500 meters deep), less pressure overlying the crater, eruptions of the volcano started to be dramatic, resulting in large amounts of volcanic ash and volcanic breccia. From lava flows to the volcanic rock stage, undersea volcanoes has grown to a shallow-water environment (in Shihtiping).

3. Land eruption phase: Lithology change from volcanic breccia to Kangkou limestone of Duluanshan formation represents another environmental change. In volcano inactive period, the sea form massive reefs, such as Ludao Island and Lanyu Island, eruption of the volcano is no longer near coral reefs in the sea. It began to form limestone, suggesting volcanoes of the Coastal Range are no longer active, the time in 5 - 4 million years ago (in Changhung Bridge).

Reference

Figure 3: Changhung Bridge south bank next to the Hsiukuluan River, riparian cliffs on both sides is huge volcanic rock composed of volcanic breccia blocks. The Hsiukuluan River piled up huge blocks of limestone rock in, come from Kangkou limestone outcrop on the both sides foothills of Changhung Bridge. Limestone is formed by many bio-shell rock and examined many kinds of fossils can be found, such as coral, flinging balls of algae and foraminifers from, is a creature of living near the crater.

Figure 4: Shihtiping in Hualien County is the Eastern Coast precious coral coast. Coral reef originally grew on the soft tuff, and the coral reef platform was formed on tuff since sea erosion, uplift of the crust. On second, the entire Shihtiping region is an area of marine terraces, coastline is well developed, wave-cut platform, the uplifted Coral reef, sea groove, sea cliff, especially the pothole can be called Taiwan's first.
Active Plate Boundary in Eastern Taiwan: Chihshang Fault

GPS crustal deformation measurement displays the Taitung Longitudinal Valley on either side about 3 cm per year relative displacement. Over one-third of 8 cm per year of the plate contraction is concentrated in this one 5-10 kilometers in width and 150 kilometers in length on the Taitung Longitudinal Valley.

Further, this displacement of 3 cm per year, mainly on the Huatung Valley, there is a suture zone, known as "Longitudinal Valley fault". Longitudinal Valley fault is roughly divided into Hualien, Kuangfu, Yuli, Chihshang and Taitung fault segments.

Reference

Figure 5: Chihshang Fault causes surface broken, including stonewall broken, drain deformed etc. At the present, fault creeping behaviour clearly prevails on the Chihshang Fault zone, where no large earthquake has occurred since 1951 and earthquake activity remains minor. A new major decrease in fault slip velocity would probably announce a new stage of fault locking and accumulating compressive stress, and hence an increasing earthquake hazard.

Figure 6: Yuli Bridge is located at the junction of the Eurasian Plate and the Philippine Sea plate, squeeze plate movement, not only the bridge uplift, also caused uplift pier No. 17, 18, 19. Yuli Bridge to watch from a distance, showing no contour deformation on the railing, an annual rate of 2-3 centimeters continued to rise among this scene became a wholly Taiwan's only remaining "grow taller" bridge. Institute of Earth Sciences are located at both ends of the bridge erection of monitoring instruments, intended for the collection of data of plate movement, for academic research purposes.