The 2nd International Workshop on Seismic Observation in Deep Borehole and Its Applications

Construction of System for Seismic Observation in Deep Borehole (SODB)

- Development of Multi-depth, High-temperature/pressure resistance seismometer

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At Niigata Institute of Technology

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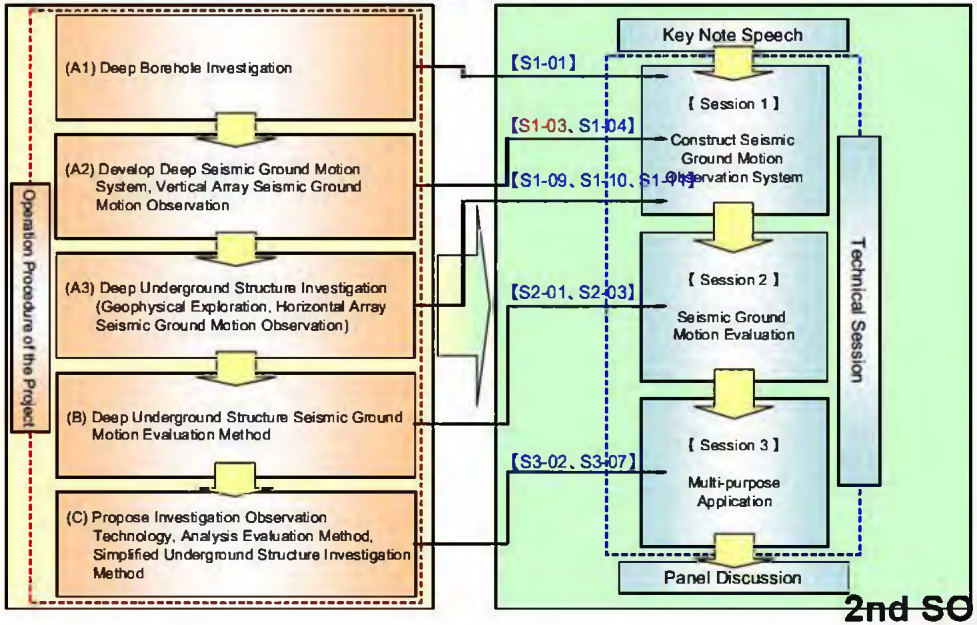
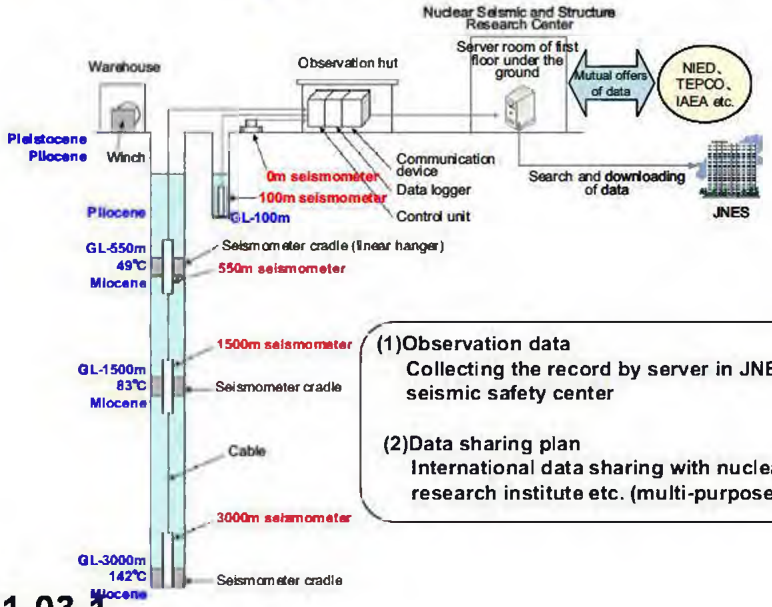
Japan Nuclear Energy Safety Organization (JNES)

Contents

Relationships between Results of the Support Organization in the Project and Sessions of this Workshop



Overview of system of SODB



(1)Observation data
Collecting the record by server in JNES Kashiwazaki seismic safety center

(2)Data sharing plan
International data sharing with nuclear organization, research institute etc. (multi-purpose usage of data)

1. Objective of this project

Objective

- ○Development of SODB technology
  Applicable to sites with thick sediment and/or irregular structure
- ○Seismic observation technology
  site effect and propagation property from deep underground
- ⇒Observation under high temp. and pressure
- ○Multi-usage of data by SOBD
  (e.g., auto scram, real time application to earthq. disaster)

Key points for development

- P1 : High temp. and high pressure resistant seismometer
- P 2 : High sensitive and strong motion seismometer with broad band frequency response
- P3 : Multi depth borehole seismometer and installation technique

Required items for seism. Obs.

- ○High temp.(150℃), high press. (40MPa) : design
- ○Collection of microtremor (10μga), and/or micro earthquake data
  ⇒ Estimation of underground structure
- ○Collection of strong motion data (up to 1000 gal) with broad band frequency range (0.1 to 50 Hz)
  ⇒ Site effect and propagation property from deep underground

Construction of new system for SOBD (The first development in the world)

International sharing of data by SODB

4

2. Over view of technology for seismic observation in deep borehole

Specification of observation system

(Ⅰ)Specification of seismometer

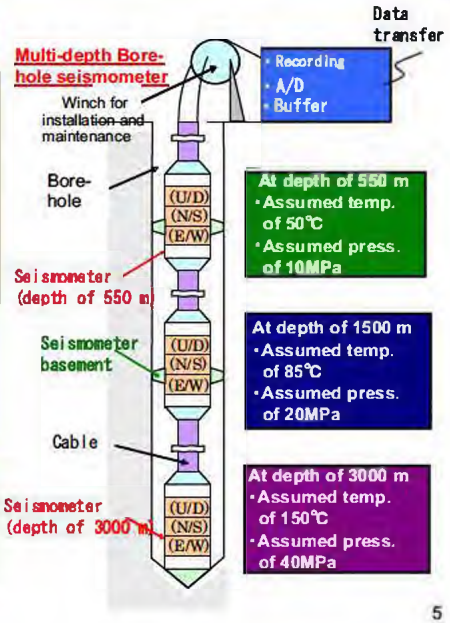
Ⅰ1 High temp. and press. : 150℃ and 40MPa
Ⅰ2 1 3 components (vertical and horizontal 2 comp.)
Ⅰ2 2 Freq. response : constant at 1to 50 Hz
resolution:10 ^{5}gal (at 1Hz), S/N :100dB以上、
Max accerelation: ±1 000gal
Ⅰ3 Specification of cable
temp.:150℃、pressure:40MPa
tensile load:up to 3tf (multi channel:at least 18 chs.)

(Ⅱ)Specification of seismometer basement

Applicable to contacting to borehole at any depths
Stability of contact (stable up to 20 Hz)
Applicable to seismometer maintenance
(designed but practically confirmed when maintenance)

(Ⅲ) Specification of recorder

Sampling rate: higher than 200 Hz and continuous recording with UPS
Online real time data transfer system



5

■Instrument design and confirmation test ①

Tools	Required design	Tests to confirm required design	Remarks
Seismo-meter (I-1)High temp.& pressure	Temperature:150℃	Heating test up to 200 ℃ by electric furnace	32 days
	Pressure: 30MPa	Pressurization test up to 50 MPa	Seismometer probe (case)
	Acceleration test for high temperature	Periodic temperature changing test between -10 and 120 ℃	Periodic:½day during10 days
	Test against high temp. and pressure	Long term field test in borehole under high temp. (120 ℃,10Mpa)	3 months
Seismo-meter (I-2) Frequency resp.	Freq. Res. :0.1 to 50 Hz	Confirmation by electrical signal (Comparison of in and out put signals)	Freq.Res. :0.1 to 50 Hz
	Resolution:10^{-5} gal (at 1 Hz)	Field experiments under low noise area. Comparing microtremor recorded by seismometer (VSE15D) and developed seismometer	Resolution:10^{-5} gal (at 1 Hz)
	Max. Acc. : greater than 2000 gal	In-house test by shaker	Max. Acc. : greater than 2000 gal

■Instrument design and confirmation test ②

Tools	Required design	Tests to confirm required design	Remarks
(I-3) Cable	Designed tensile strength: 3tf	Tensile loading test up to 3tf of cable unit (cable with cable head)	
	Cross talk test for multi-channel cable	Checking of signal interaction for any pairs of channels	
(II) Seismo-meter basement	Stable contact to bore-hole Freq. range: 0.1 to 50 Hz	Comparison of records: Bottom seismometer and seismometer on basement in middle part in borehole	

7

3. Key points for development of observation tools

I-1:High temp.and pressure seismometer (1/2)

■Design for high temp.

Basic design:

electric circuit: surface, pendulum: underground

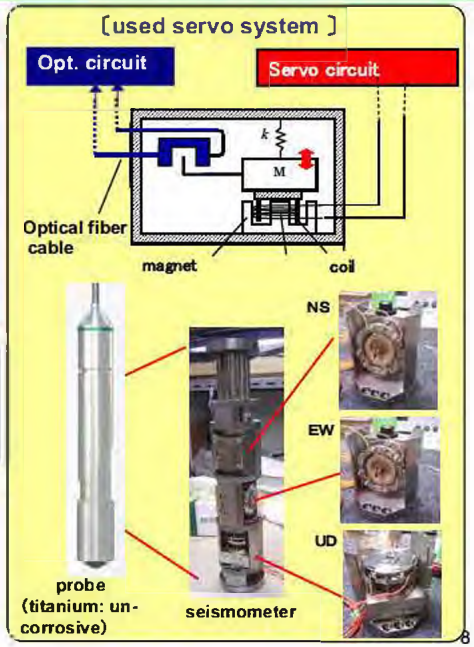
- Separating the electric circuit in seismometer from pendulum.
- Signal transfer by optical fiber

High temp. test for individual parts and unit as seismometer

- Test for seismometer parts up to 200℃ by electric furnace
- Long term test for seismometer unit at borehole under high temp. (resistant to high temp. and corrosion

■Design for high pressure

- Use of high pressure resistant probe covering seismometer
- high pressure test of probe by pressurization pool



I-1:High temp. and pressure seismometer(2/2)

■Acceleration test to for high temp. and pressure

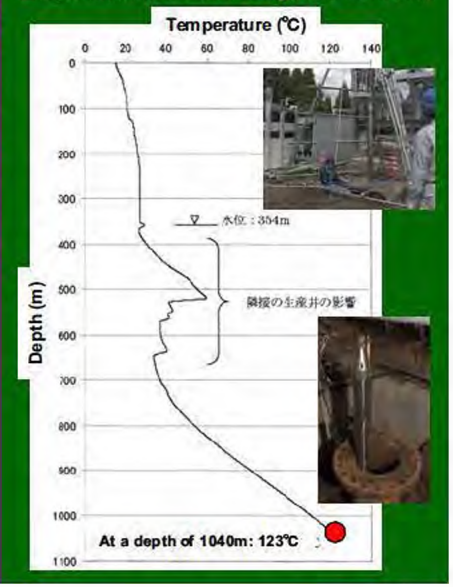
〔test room〕

〔borehole seismometer〕

〔Pressurization pool〕

〔seismometer probe〕

■Experiment in borehole at high heart flow area



I-2: Broad-band, High Sensitive and strong –motion seismometer

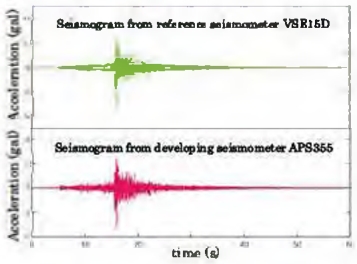
Microtremor to strong motion at broad-band frequency range

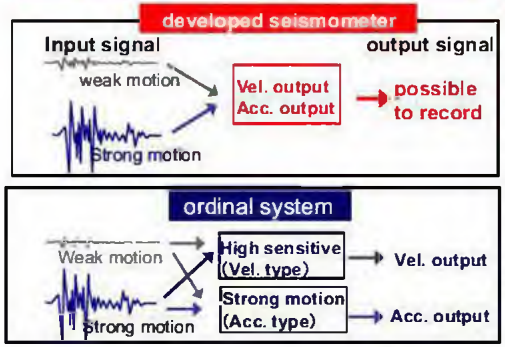
Broad-band : 0.1 to 50Hz

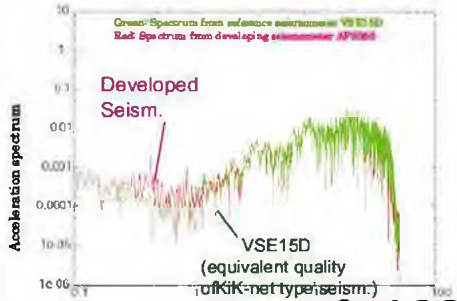
High sensitive: 10^{-5}gal (at 1Hz)

S/N : 100dB

⇒ Equivalent quality to Hi-net and KiK-net type seismometer



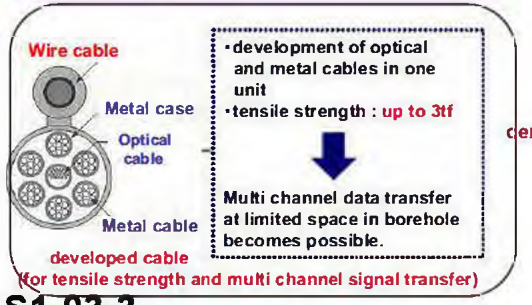




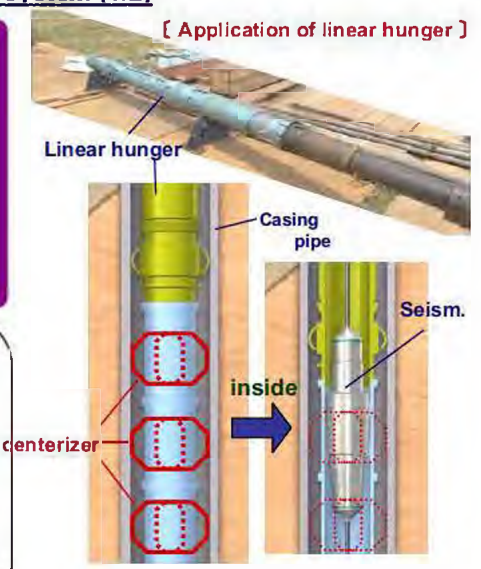
II: Multi-depth seismometer installation system (1/2)

■characteristics

1) Multi-seismometers installation in one borehole
   maintenance of seismometer: possible
2) Installation at any depths
   ⇒ possible by use of oil drilling tool (Linear hunger)
3) Reducing contact noise of seismometer to borehole by centerizer



〔 Application of linear hunger 〕



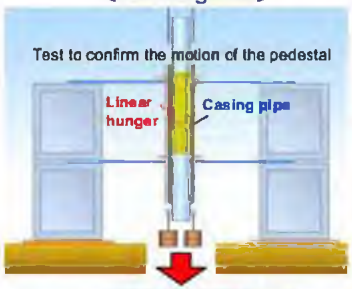
II: Multi-depth seismometer installation system (2/2)

■Field experiment for checking stability of seismometer contact

(1) Loading test of linear hunger
- Confirming the stability of contact to borehole

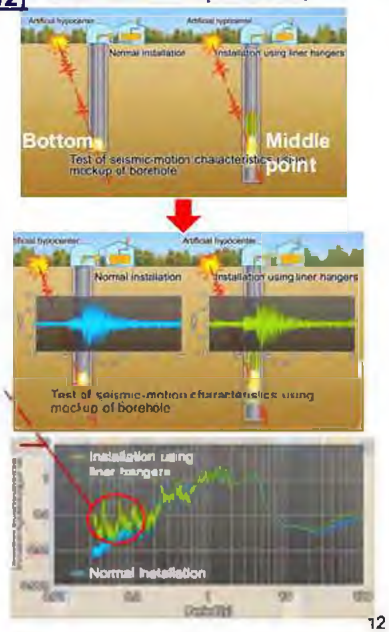
(2) Effect of seismometer basement on records
- Confirming equivalence of event records independent of seismometer basement

〔Loading test〕



Similar spectra between 0.1 to 20 Hz

〔Method of experiment〕



Summary of instrument design and confirmation tests ①

Tools	Required design	Tests to confirm required design	Practical design after tests
Seismo-meter (I-1)High temp.& pressure	Temperature:150℃	○	
	Pressure:30MPa	○	
	Acceleration test for high temperature	○	
	Test against high temp. and pressure	○	
Seismo-meter (I-2) Frequency resp.	Freq. Res.:0.1-50 Hz	○	
	Resolution:10^{-5} gal (at 1 Hz)	○	
	Max. Acc. : greater than 2000 gal	Difficult satisfying with resolution	Design change Max. Acc. :up to 1000 gal

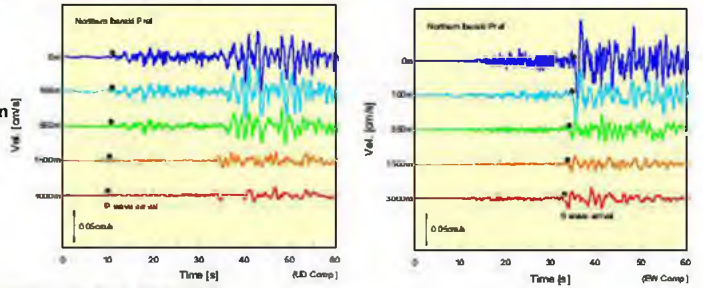
Summary of instrument design and confirmation tests ②

(I-3) Cable	Designed tensile strength: 3tf	○	
	Cross talk test for multi-channel cable	Cross talk is negligible	
(II) Seismo-meter basement	Stable contact to bore-hole Freq. range: 0.1 to 50 Hz	Stable up to 20Hz	Correction necessary above 20 Hz ranges.

4. Examples of collection data

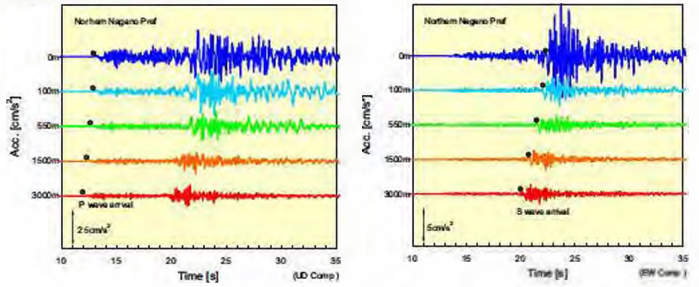
Event 1 (Northern Ibaraki earthquake)

Mj=5.2
Epi. Dist.= 233.2 km
Hypo. Dist.=233.3 km
depth=7.2 km



Event 2 (Northern Nagano earthquake)

Mj=5.2
Epi. Dist.= 60.0 km
Hypo. Dist.=60.6 km
depth=8.5km



JNES 原子力安全基盤機構

5. Summary and future problems

■Summary

JNES constructed the system for seismic observation in deep borehole. This system includes following three remarkable points for the first development in the world.

- Seismometer applicable under high temperature (up to 150℃) and high pressure (up to 40 MPa)
- Seismometer recordable from microtremor to strong motion over broad-band frequency range (0.1 to 50 Hz)
- Multi-seismometer installation technique in one borehole

■Future Problem

- Deformation of cable causes high frequency noise record (NS component record at a depth of 1500 m)
  → Re-consideration of the length of cable when installing process
- Confirming possibility of seismometer maintenance
- Long term verification test of this observation (How long recordable by this system ?)

16