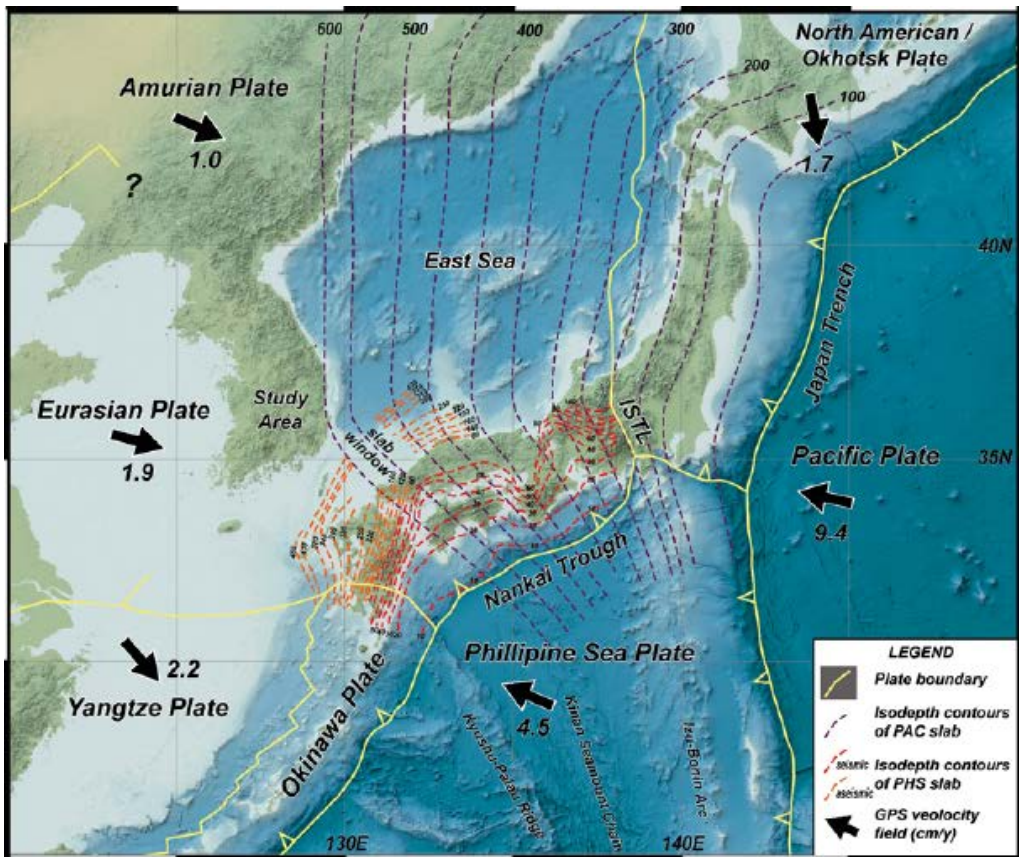
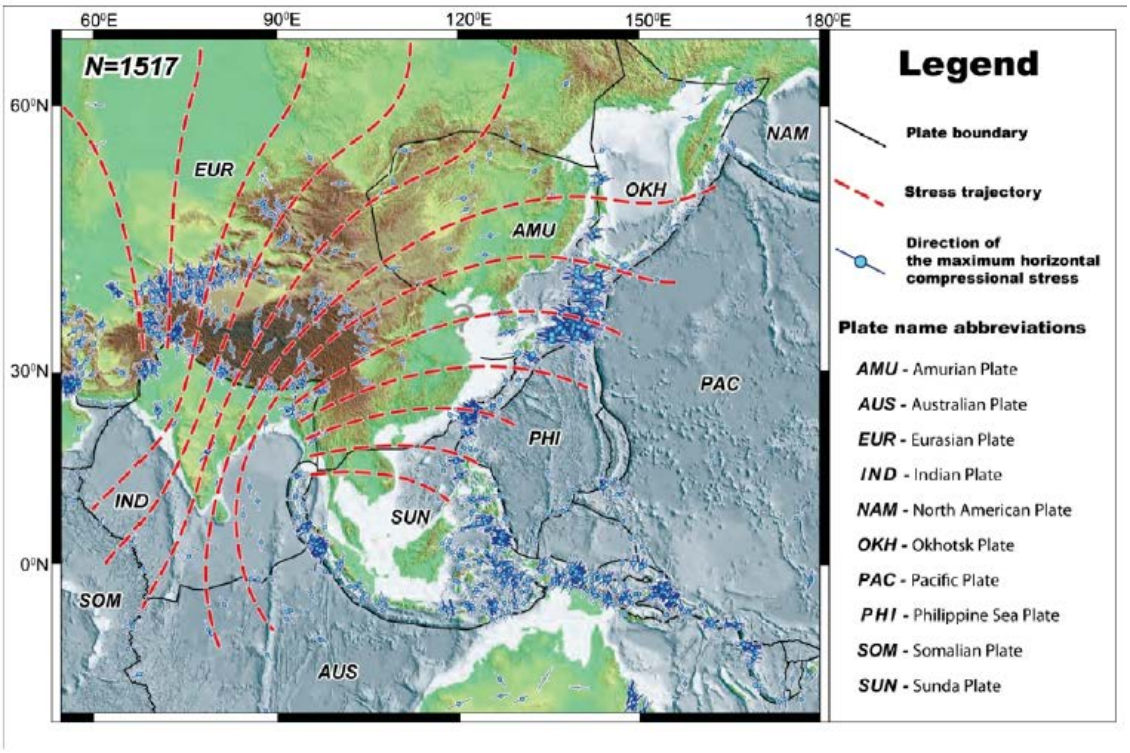
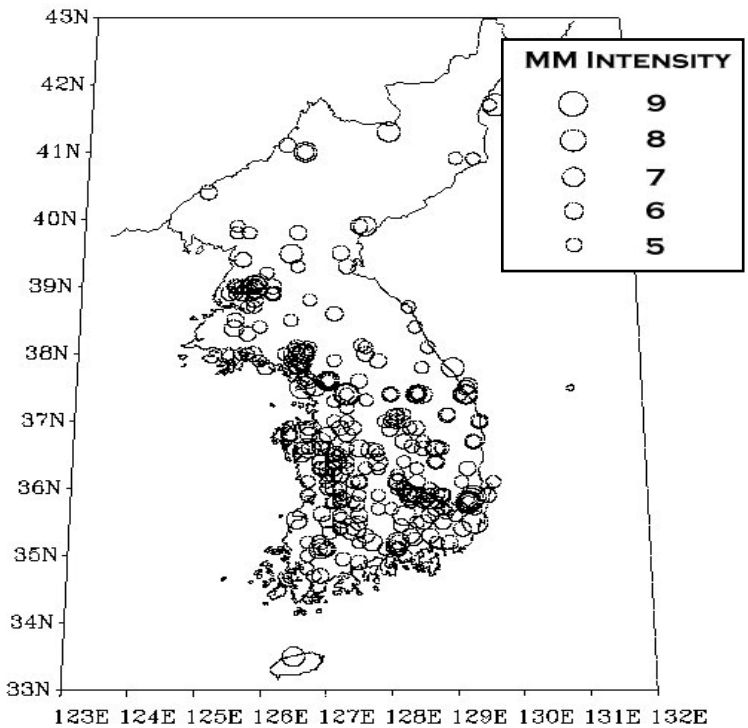
Earthquakes in Korea : tectonic setting of east asia



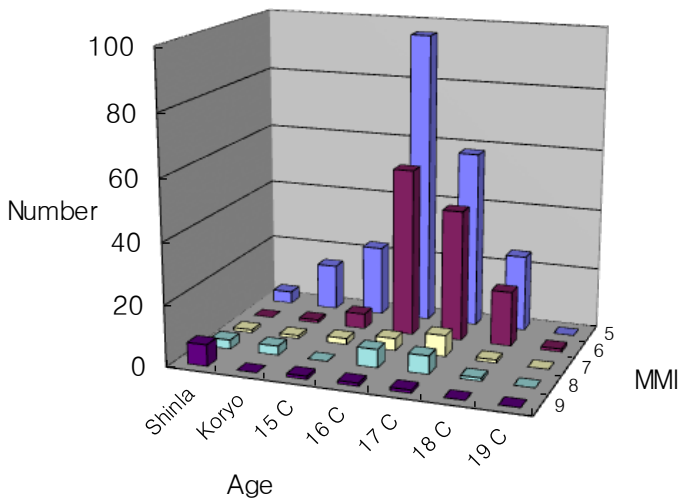


EQs in Korea (AD2 ~ 1904) : intensity

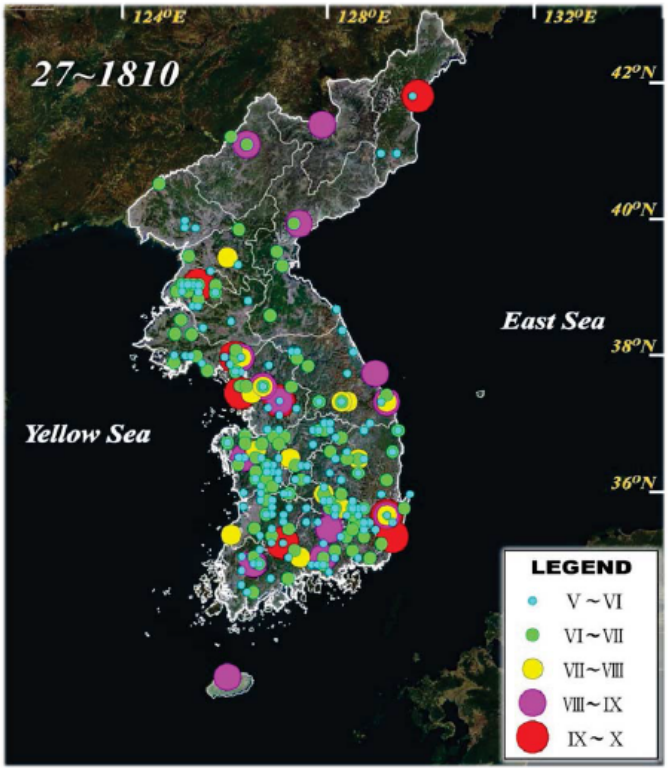


Number of felt earthquakes in historical literature : about 1800

Number of earthquakes with MMI ≥ VII (*M*L ≥ 5.5) : about 40 with damages casualties



Historical Earthquakes
: At least 1,800 felt earthquakes since AD 27



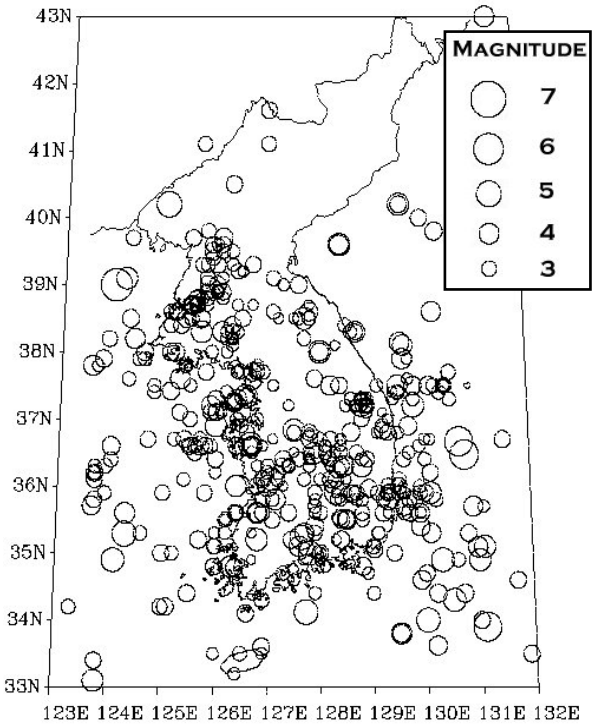
Major Events

1) **AD 779, Gyeongju**
(the Silla Dynasty)
- IX (MM Scale), M6.7~7.0
- Killed ca. 100 people
- The worst casualties in history

2) **AD 1643, Korean Peninsula**
(the Joseon Dynasty)
- Occurred pervasively in whole country
- Ground cracks & Water gush (Ulsan)
- Rampart breaks (e.g.Daegu)

3) Other M6.0 over events
- AD 1518, Seoul
- AD 1597, Samsu
- AD 1810, Cheongjin

EQs in Korea (1905 ~ 1999) : magnitude

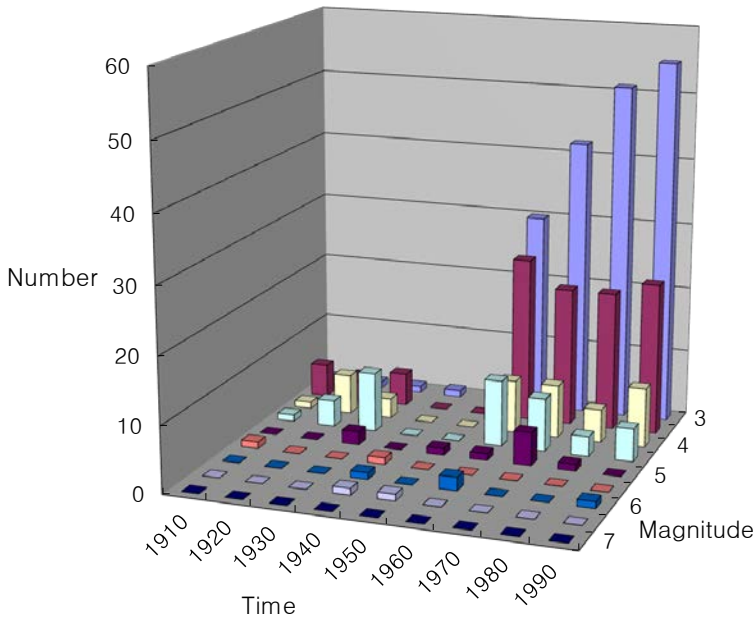


Number of earthquakes with *M*L ≥ 4.0

occurring on land : about 50

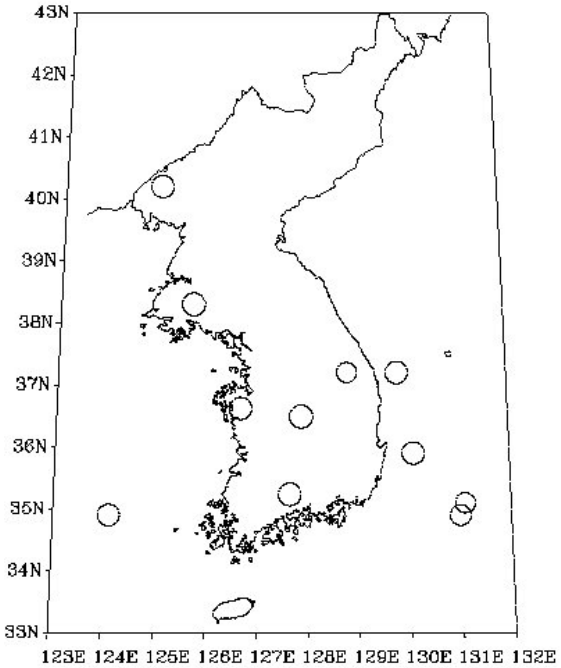
Number of earthquakes with *M*L ≥ 5.0

occurring on land : about 7

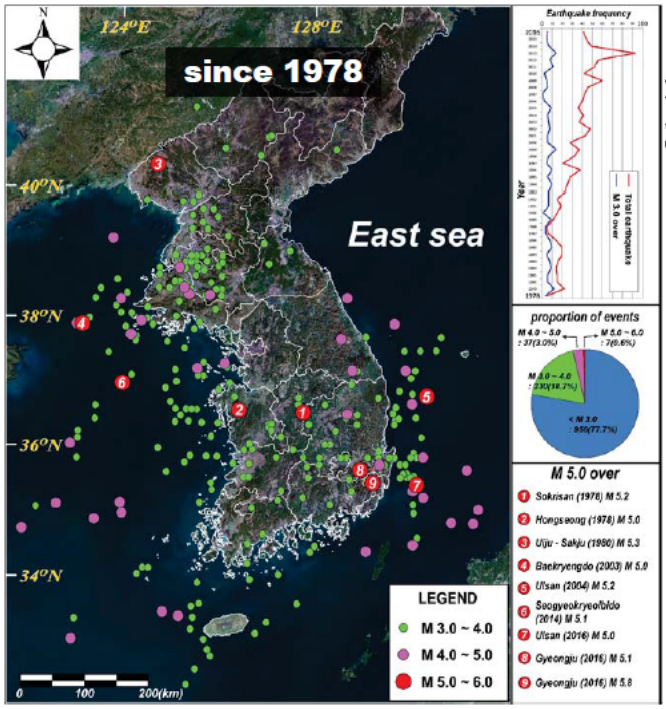


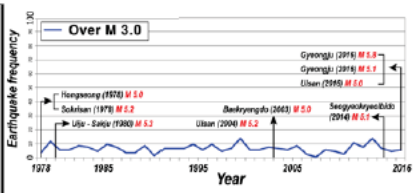
Inland earthquakes greater than M=4.5 in Korea

- 쌍계사 지진 (1936) M=5.1
- 평양 지진 (1952) M=6.2
- 속리산 지진 (1978) M=5.2
- 홍성 지진 (1978) M=5.0
- 삭주 지진 (1980) M=5.0
- 포항 지진 (1981) M=5.0
- 사리원 지진 (1982) M=5.1
- 울진 지진 (1982) M=5.0
- 울산 지진 (1994) M=4.6
- 울산 지진 (1994) M=4.5
- 홍도 지진 (1994) M=4.9
- 영월 지진 (1996) M=4.5
- 백령도지진 (2003) M=5.0
- 울진지진 (2004) M=5.2
- 경주지진 (2016) M = 5.8

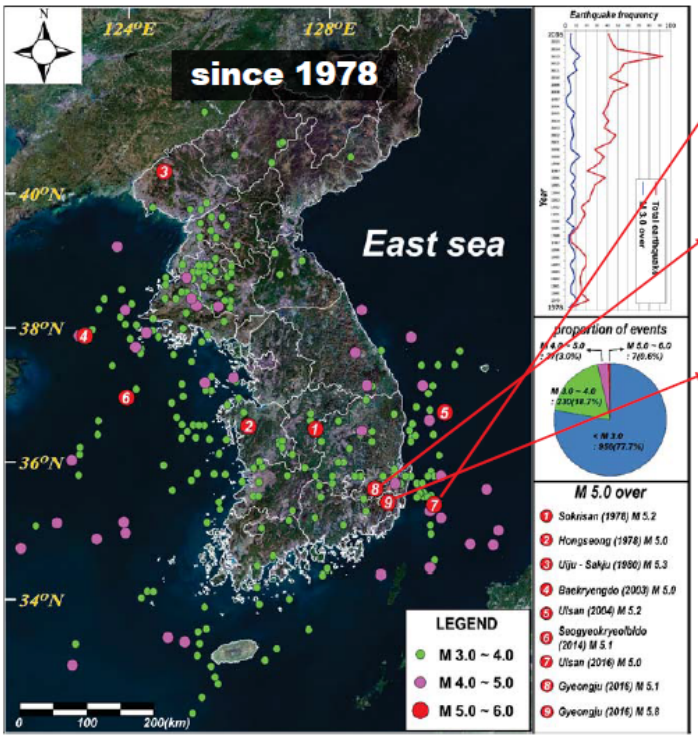


Instrumental Earthquakes
: Gyeongju Earthquakes (2016. 07. 05 ~ present)





		KMA	JMA		China
		M	Md	Mv	Ms
1936	Ssanggyesa	-	5.1	-	
1952	Pyongannam-do	-	6.3	-	6.3
1978	Mt. Sokli	5.2	5.0	-	4.7
1978	Hongsung	5.0	5.0	-	4.2
1980	Uiju	5.3	5.5	-	5.3
1982	Anak	4.5	5.8	-	5.3
1996	Yeongweol	4.5	-	5.6	4.7
2004	Offshore Uljin	5.2	-	5.1	4.9
2007	Mt Odae	4.8	-	5.0	4.6



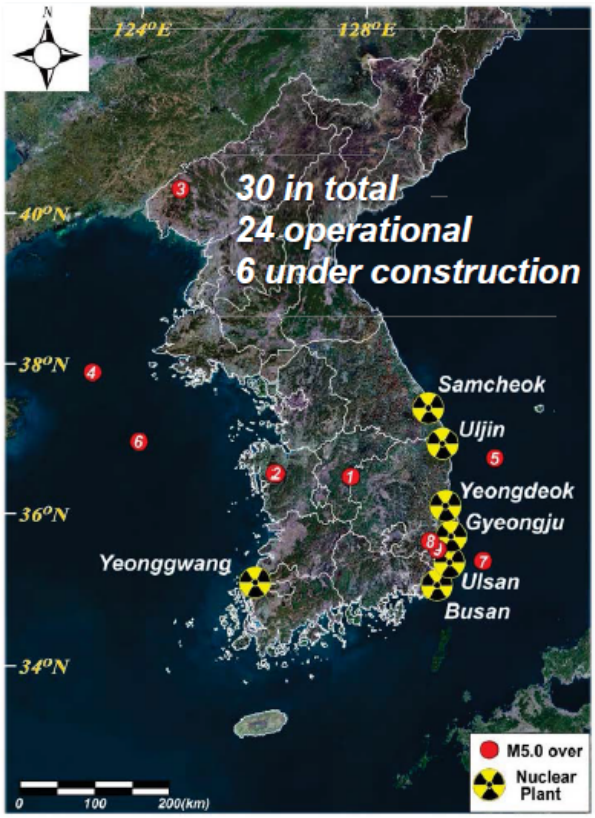
7 *Ulsan Earthquake M5.0 (2016. 07.05)*

8 *Gyeongju Earthquake M5.1 (2016. 09.12)*

9 *Gyeongju Earthquake M5.8 (2016. 09.12)*

● *Gyeongju Earthquake M4.5 (2016. 09.21)*

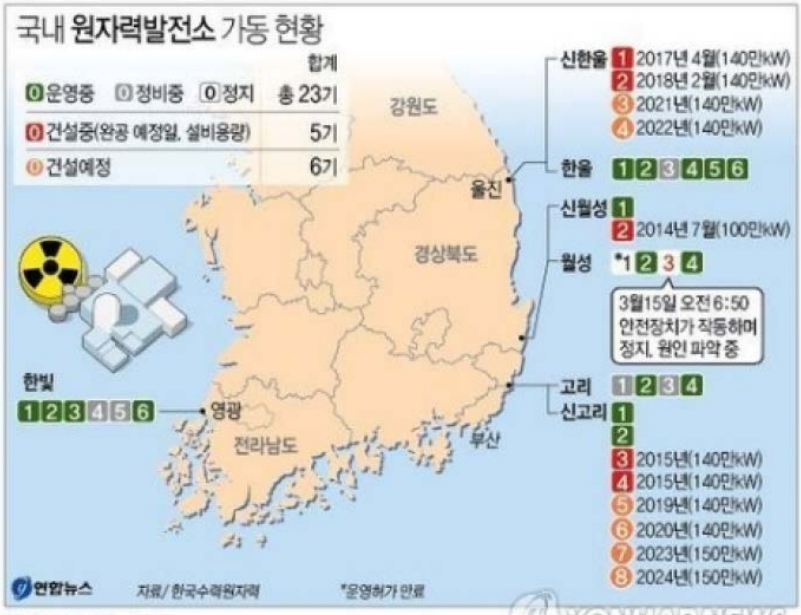
Recent earthquakes are the warning to our safety frigidity !



World's Top 10 Regions having densely concentrated Nuclear Power Plants

① Korea (Gori) : 8 plants	3.8 millions of people
② Canada (Bruce) 8 plants	30 thousands
③ Korea (Hanul) 6 plants	50 thousands
④ Korea (Hanbit) 6 plants	140 thousands
⑤ Ukraine (Zaporizhya) 6 plants	320 thousands
⑥ France (Granville) 6 plants	460 thousands
⑦ Korea (Wolsong) 6 plants	1.3 millions
⑧ China (Qin shan) 7 plants	1.3 millions
⑨ Canada (Pickering) 6 plants	2.2 millions
⑩ India (Rajasthan) 6 plants	460 thousands

The most densely concentrated area in the world !

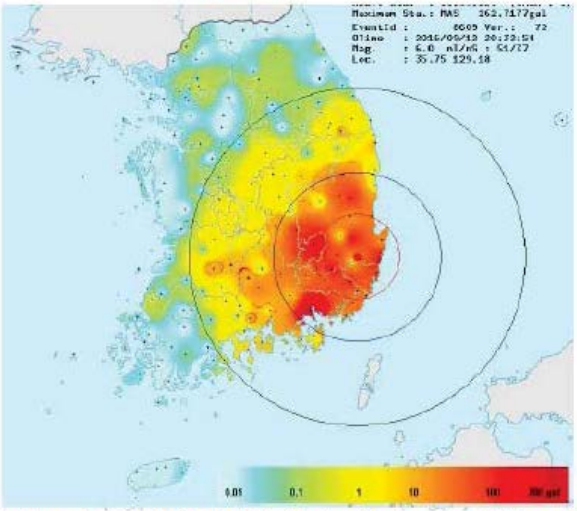


김토일 기자 / 20140315
@yonhap_graphics(트위터)

Kyungju EQ (2016, 9.12)

• Gyeong-Ju Quake M= 5.2/5.8, 09/12/2016

The first (pre-) shock: M_L 5.2, 19:44
The main shock: M_L 5.8, 20:32
Focal depth: 13km (relatively deep)



Steel Structures & Seismic Design Lab, Dept. of Arch and Arch Engrg, SNU

Magnitude reported

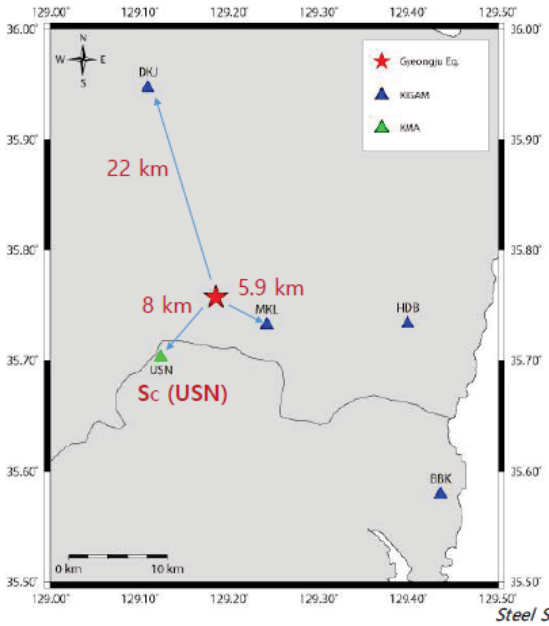
$$\log(E) = 11.8 + 1.5M_L;\ E = 10^{11.8+1.5M_L}\ (ergs) \qquad (1)$$

$$M_W = (2/3)\log(M_0) - 10.7;\ M_0(seismic\ moment) = 10^{16.05+1.5M_W}\ (dyne) \qquad (2)$$

The main shock: M_L 5.8
Focal depth: 13km

⇨

The main shock: Mw 5.36
Focal depth: 15km
(per Prof. YH Kim, SNU)



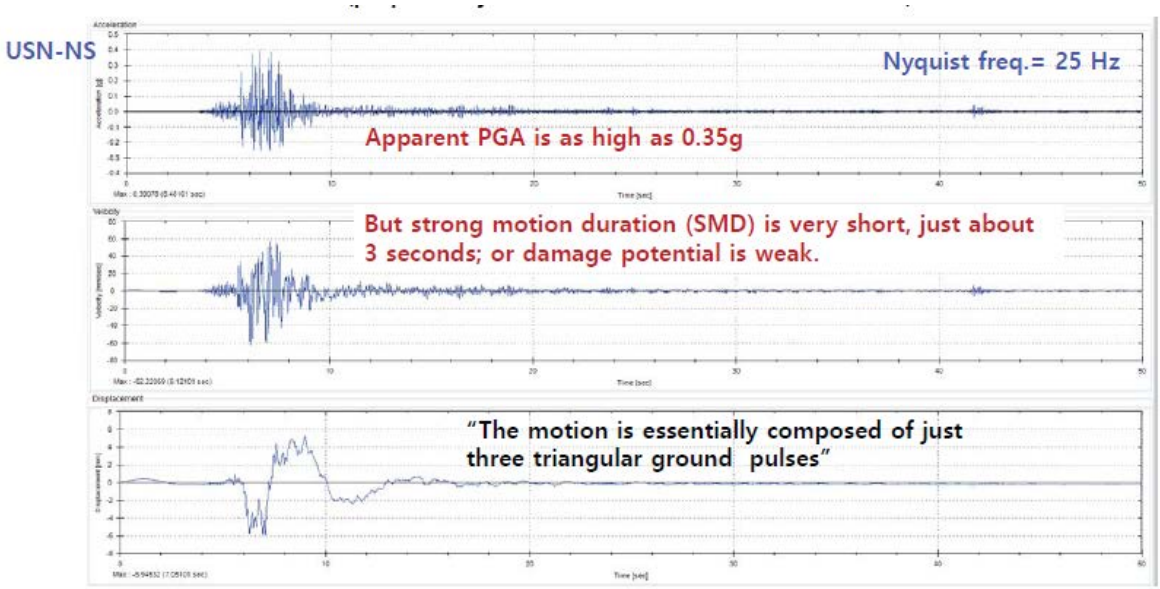
Three stations near the epicenter available

관측소명	위도	경도	가속도센서	기록계
MKL	35.7322	129.2420	ES-T	Q330
USN	35.7024	129.1232	ES-T	Q730
DKJ	35.9468	129.1089	CMG-5T	Q330HRS

"S_B (MKL, DKJ) or S_C (USN) soil condition speculated"

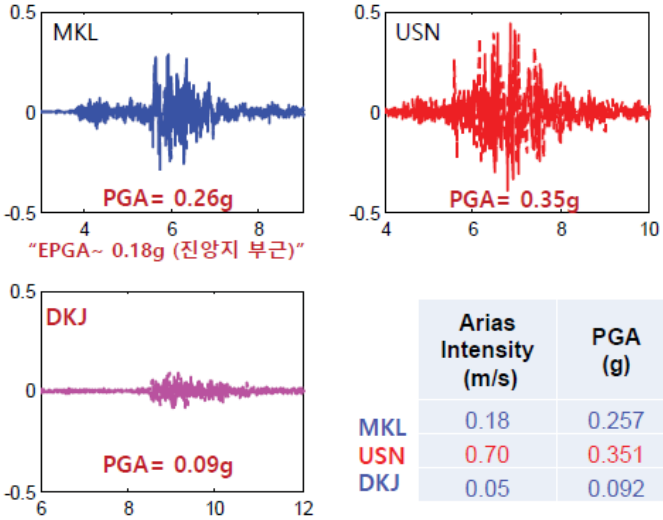
Steel Structures & Seismic Design Lab, Dept. of Arch and Arch Engrg, SNU

Quite high PGA, but the duration is short.



Steel Structures & Seismic Design Lab, Dept. of Arch and Arch Engrg, SNU

Nyquist freq.= 25 Hz



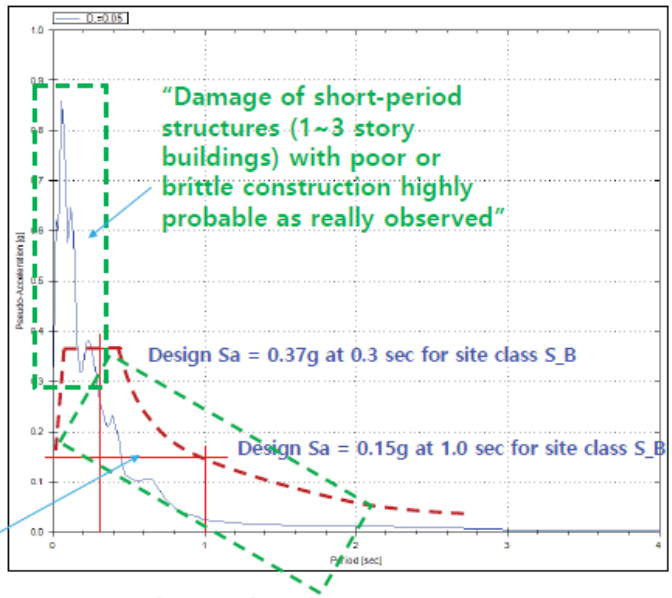
	Arias Intensity (m/s)	PGA (g)
MKL	0.18	0.257
USN	0.70	0.351
DKJ	0.05	0.092

"Apparent magnitude of PGA is a weak damage indicator"

"Amplitude, strong motion duration and frequency contents should considered all together"

MKL-EW

Comparison of elastic spectral acceleration caused by 912 Geong-Ju EQ with KBC (S_B) spectrum



"Damage of building structures of average construction with periods longer than 0.3~0.4 sec. difficult to occur"

Pseudo-acceleration Response Spectrum

Show window shattered

Unreinforced block wall fallen down

Typical corner cracking at opening

Failure in an already poor (non-engineered) construction

Damage observed in a 3-story RC Building (Ulju, Ulsan)_ ceiling and brick wall failure

The most impressive failure mode_ "short-column" shear failure

1952 M 6.2 EQ near Pyung-Yang "during Korea War"

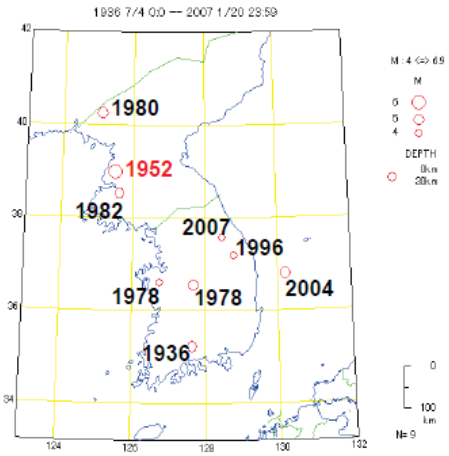
- Known during the technical meeting between south and north Korean seismologists for the KEDO program (supporting program for north Korea's NPP) once promoted but now halted
- Seismic design is one of the top priority issues in any nuclear power plant construction
- The information following is based on the presentation made by Drs. TS Kang and MS Jeon (former KIGAM researchers) at the EESK symposium last year: "Seismological evaluation of major earthquakes in Korean peninsular and seismic safety of building and civil structures", Feb. 23, 2016
- The occurrence of this major EQ was not well recognized probably due to the turmoil during the war, but...

Epicenter location reported by USGS

- Date and Time
  - 1952-03-19 09:04:18 (UTC)
  - 1952-03-19 18:04:18 (Local Time)
- Epicenter (USGS)
  - 38.872°N, 125.834°E
  - Nearby cities
    - Chung-HWA: 3 km
    - Pyung-Yang: 19 km
    - Sariwon: 41 km
  - Focal depth : 35.0 km (estimate; appear to be rather deep, less damaging)
- Magnitude reported by various researchers based on measured records: M= 6.2~6.5

  RUSSIA_ Rustanovich et al.(1963): M=6.3
  CHINA_中国国家地震局科技情報中心(1987) Ms=6.5
  Yuche Li (2001): M=6.5
  JAPAN_Ishikawa et al.(2008): Md=6.5
  USA_ USGS Mw 6.3
  KOREA_ Kang (2011) Mw 6.2

"100 or 1000 times more meaningful than historical EQs since this is instrumental"



(Ishikawa et al., 2008)

SOURCE: the presentation made by Drs. TS Kang and MS Jeon at the EESK symposium last year: "Seismological evaluation of major earthquakes in Korean peninsular and seismic safety of building and civil structures", Feb. 23, 2016

2017 포항 지진의 개요

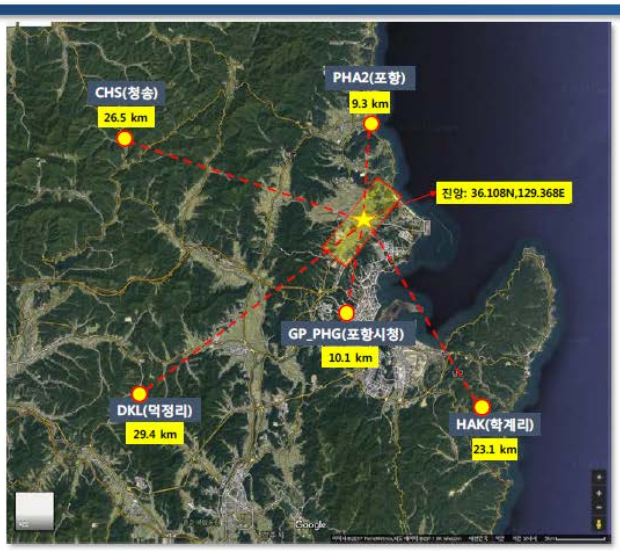
- 2017년 11월 15일, 수요일
  14시 29분 31초 (KST)

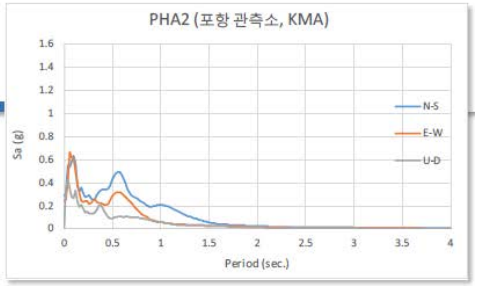
- 진앙: 36.10°N, 129.37°E
  경북 포항시 북구 북쪽 6km 지역,
  진원 깊이 3.5 km.

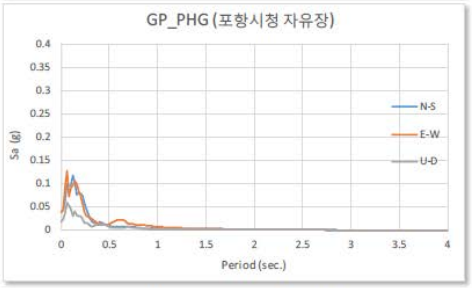
- M_L 5.4: 계측된 국내 지진 중에서
  2번째로 큰 지진 (2016 경주
  지진이 최대 지진 M_L 5.8)

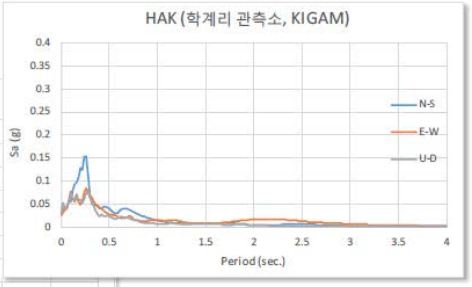
- 강진지속시간: 약 4~6 초.

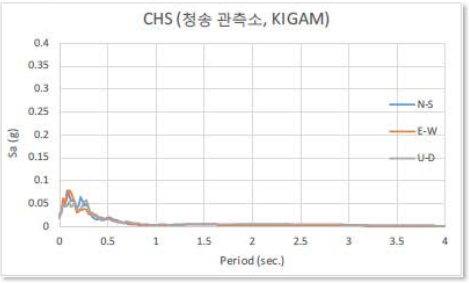
응답 스펙트럼

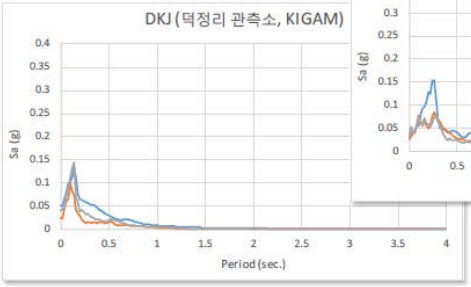




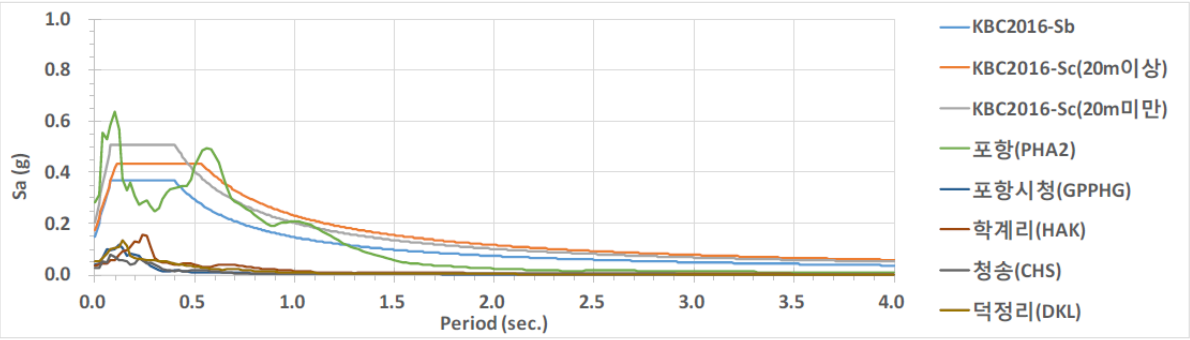








❑ KBC 2016 설계스펙트럼 비교



❑ 포항(PHA2) 관측소 기록은 설계 지진력을 초과했는가?

- 포항(PHA2) 관측소 기록은 지반운동예측식의 모든 범위를 벗어남. 관측값을 재점검 할 필요가 있음.
- 0초~0.14초, 0.5초~0.7초 주기에서 설계스펙트럼(Sc-20m미만)을 초과했음.
- 설계스펙트럼은 불확실성이 큰 지진파의 통계적 예측 임. 따라서, 하나의 계측값이 짧은 구간에서 평균+1σ 를 벗어났다고 통계적 예측이 틀렸다고 할 수 없음.

❑ 외부 마감재 (조적)

5층 이하 필로티 건물

❑ 내진설계 오류: 기둥의 취성파괴, 연약층

❑ 구조설계 기준 미준수: 구조안전에 대한 책임감 결여

❑ 내진보강 미적용 교사동