Hydrogeochemical anomalies associated with the 2017 M_W 5.5 Pohang earthquake in South Korea

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Approaches

Natural Influences

- Earthquakes
- Volcanic eruptions
- Cyclonic storms
- Floods
- Droughts
- Landslides

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"Changing original characteristics of subsurface groundwater system"

Approaches

Data and Methods

Time series data
- Groundwater level
- Temperature
- Electrical conductivity

Hydrochemistry
- Piper diagram
- Gibb's diagram
- Stiff diagram

Environmental Isotopes
- Radon
- Strontium

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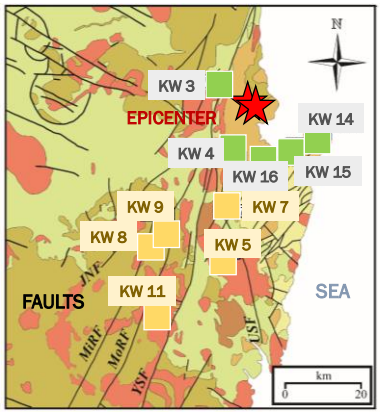
Statistical method (Principal component analysis)

Hydrogeochemical anomalies by 2017 Pohang earthquake



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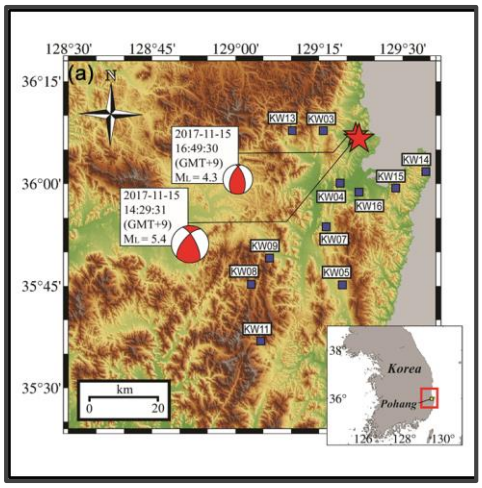
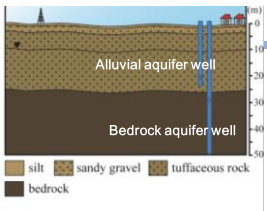
Study Site

POHANG, SOUTH KOREA





Groundwater well Information

Well ID	Latitude	Longitude	Well type	Sampling Depth
KW 3	36.13 N	129.26 E	Bedrock	25
KW 4	36.00 N	129.31 E	Alluvial, Bedrock	20, 35
KW 5	35.75 N	129.32 E	Alluvial, Bedrock	10, 35
KW 7	35.90 N	129.27 E	Alluvial, Bedrock	8, 50
KW 8	35.75 N	129.05 E	Alluvial, Bedrock	5, 50
KW 9	35.82 N	129.10 E	Alluvial, Bedrock	10, 50
KW11	35.62 N	129.08 E	Alluvial, Bedrock	10, 25
KW13	36.13 N	129.17 E	Alluvial, Bedrock	10, 50
KW14	36.03 N	129.57 E	Bedrock	50
KW15	35.99 N	129.48 E	Bedrock	30
KW16	35.98 N	129.37 E	Bedrock	26

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Study Site

The mainshock and aftershocks data (M_L≥3.5) of the Pohang earthquake

Date, time (KST)	M_W	Latitude	Longitude
2017-11-15, 14:29:31	***5.5***	***36.12 N***	***129.36 E***
2017-11-15, 14:32:59	***3.6***	***36.10 N***	***129.36 E***
2017-11-15, 15:09:49	3.5	36.09 N	129.34 E
2017-11-15, 16:49:30	4.3	36.12 N	129.36 E
2017-11-16, 09:02:42	3.6	36.12 N	129.37 E
2017-11-19, 23:45:47	3.5	36.12 N	129.36 E
2017-11-20, 06:05:15	3.6	36.14 N	129.36 E

† The red bold italics is the mainshock of the Pohang earthquakes.

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Objectives

This approach will be achieved via:

(1) Analyzing the time series data (groundwater level, temperature, and EC)

(2) Interpreting major ions for identifying hydrochemical characteristics in the study area by Piper diagram, Gibb's diagram, and Stiff diagram

(3) Applying the environmental isotopes (Strontium and Radon) for interpreting the response mechanism to seismic events

(4) Conducting statistical method (PCA) to support the hydrogeochemical results.

This study further aims to suggest the interpretation method of using those data in other earthquake-prone regions.

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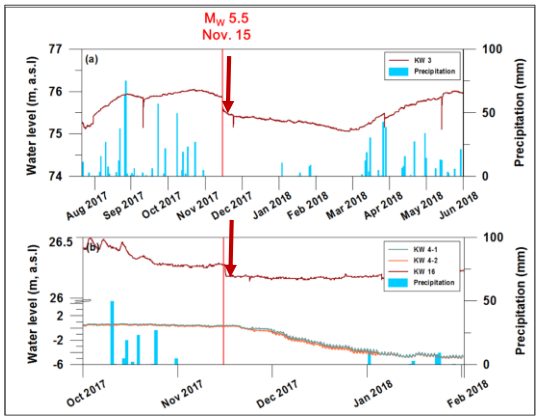
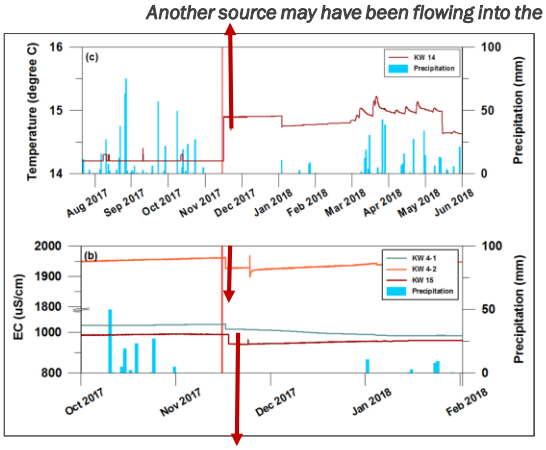
Results and Discussions - Time series data

Time series data (groundwater level, temperature, and EC)



In groundwater level data, decreasing patterns were detected in wells KW 3, KW 4-1, KW 4-2, and KW 16. These decreases could be explained by the influence of the earthquakes, as they were detected without precipitation events. Such abnormal decreases may be attributed to the opening of bedrock fractures or seawater intrusion (Fleeger et al., 1999; Kitagawa et al., 1996; Rojstaczer et al., 1995; Wakita, 1996; Wang et al., 2004; Wang and Chia, 2008; Werner et al., 2012).

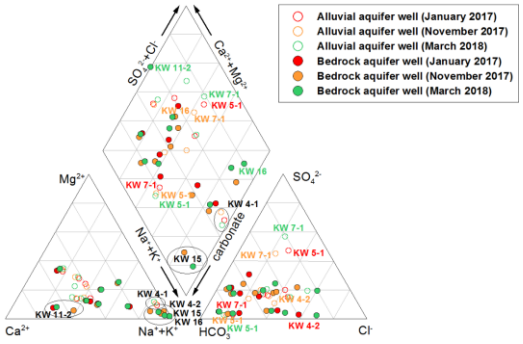
Another source may have been flowing into the well



Sharp decreases after the earthquake, which could be attributed to mixing with other water sources

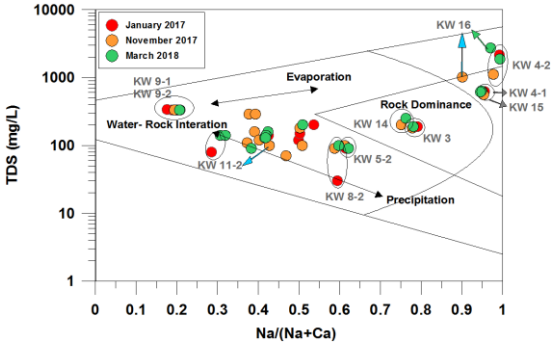
Results and Discussions – Major ions

< Piper diagram >



Ca-HCO_3 type
: indicates the chemical composition of shallow groundwater that interacts with sedimentary rocks

< Gibb's diagram >

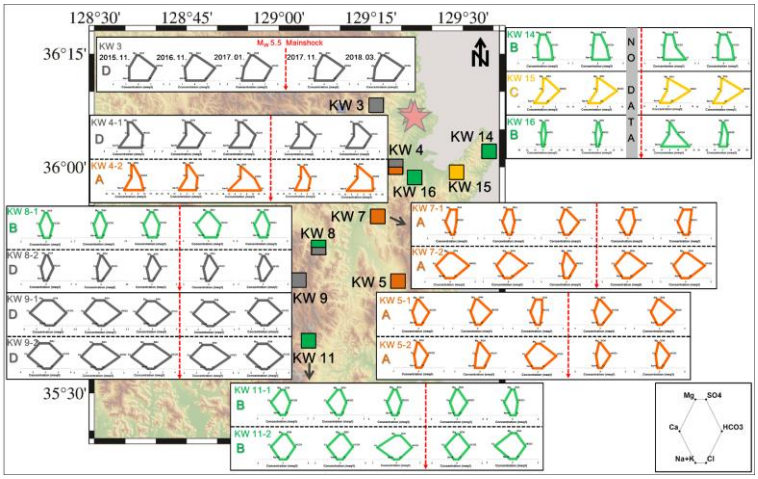


KW 4-2 and KW 16
: are showing increased salinity

KW 9-1 and KW 9-2 wells
: were mainly affected by the water-rock interactions

Results and Discussions – Major ions

< Stiff diagram >



(i) change before the main event
(KW 4-2, KW 5-1, KW 5-2, KW 7-1, and KW 7-2)
(marked as A)

(ii) recovery to original shape after a sudden change
(KW 8-1, KW 11-1, KW 11-2, KW 14 and KW 16)
(marked as B)

(iii) change after the main event
(KW 15)
(marked as C)

(iv) no change
(KW3, KW 4-1, KW 8-2, KW 9-1 and KW 9-2)
(marked as D)

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Results and Discussions – Environmental isotopes

< Strontium >

Well ID	2017.01		2017.11		2018.03	
	Sr (ppb)	$^{87}Sr/^{86}Sr$	Sr (ppb)	$^{87}Sr/^{86}Sr$	Sr (ppb)	$^{87}Sr/^{86}Sr$
KW 3	31.30	0.706575	82.50	0.706486	83.70	0.706491
KW 4-1	79.60	0.708188	196.00	0.708267	221.00	0.708306
KW 4-2	225.10	0.707283	265.30	0.707886	273.00	0.707417
KW 5-1	146.50	0.707610	101.10	0.706821	129.60	0.706883
KW 5-2	170.00	0.707356	72.40	0.705730	69.50	0.705915
KW 7-1	117.40	0.706590	165.40	0.707795	156.80	0.706518
KW 7-2	78.00	0.705688	159.70	0.707460	160.00	0.706086
KW 8-1	114.70	0.708231	164.50	0.708980	107.30	0.708892
KW 8-2	75.00	0.706177	69.90	0.706439	71.50	0.706189
KW 9-1	379.00	0.707919	407.30	0.708015	355.30	0.707856
KW 9-2	538.40	0.707469	532.10	0.708083	477.40	0.707539
KW 11-1	82.60	0.706385	72.60	0.706732	82.10	0.707103
KW 11-2	54.20	0.706122	28.80	0.706188	48.80	0.705562
KW 11-3	212.30	0.709625	125.40	0.706968	139.50	0.707051

: shift of $^{87}Sr/^{86}Sr$ ratios in some alluvial aquifer wells could be attributed to water-rock interactions

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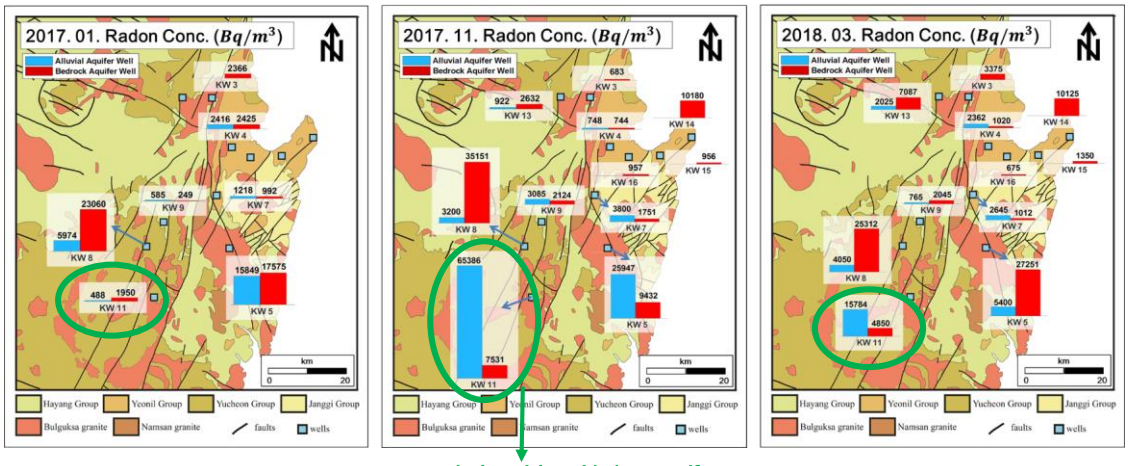
Results and Discussions – Environmental isotopes

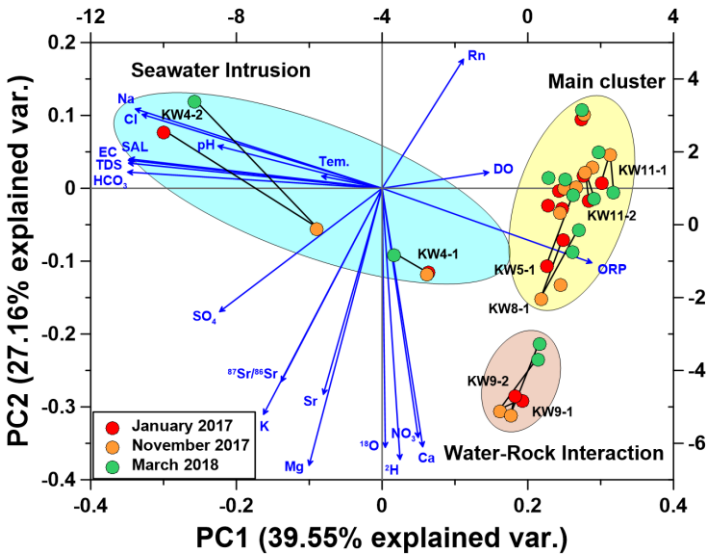
< Radon >



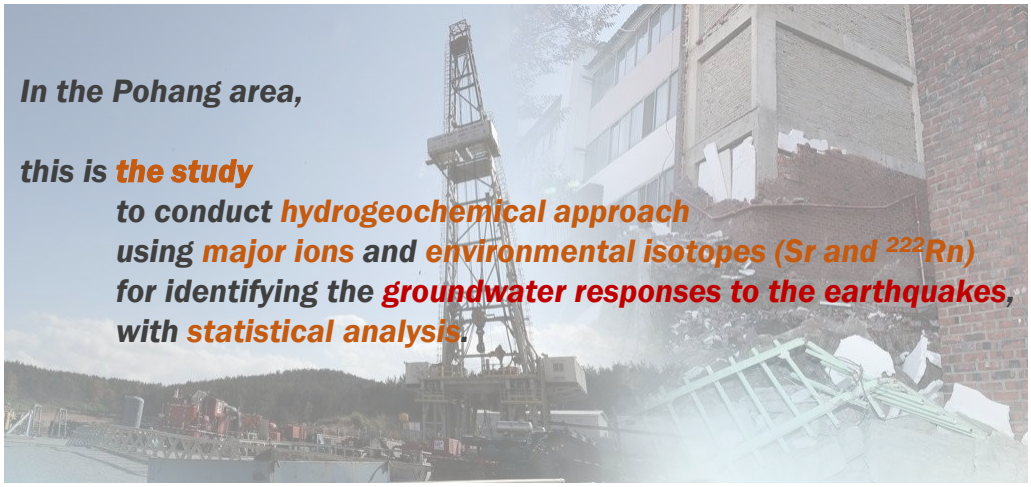
Active mixing with deep aquifer / Deep fluid upwelling

Results and Discussions – statistical methods

< PCA ***Principal component analysis*** **>**



Implications



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