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Earthquakes in Cretaceous Granites Associated with North Korean Nuclear Tests

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Abstract

The goal of this study was to examine the danger of six North Korean underground nuclear tests to the regional safety associated with deadly earthquakes and volcanoes. Geological instabilities at Cretaceous granites were triggered by North Korean nuclear tests to induce the enhanced seismic impacts on earthquakes in China, Russia, Japan, Taiwan (China), South Korea, USA, Ecuador, Vanuatu, Indonesia, and Mexico after lag times between the nuclear test site and individual epicenters. It is urgent to prohibit North Korean nuclear tests for the regional stability of surrounding countries with Cretaceous granites.

Keywords

Earthquake, North Korean, Underground Nuclear Test, Cretaceous, Granite

1. Introduction

Nuclear testing has often been used as an indicator of scientific and military strength, and many nuclear weapons states publicly declared their nuclear status by means of a nuclear test [1]. North Korea conducted six underground nuclear tests at the Punggae-ri test site (41.2977 N 129.0147 E) [2], which occurred at various depths (310 - 1340 m) of Mt. Manthap (2205 m), consisting of Cretaceous granite, during the years of 2006 till 2017. The first nuclear crisis occurred when the International Atomic Energy Agency (IAEA) found a discrepancy in the initial report of North Korea, which refused IAEA special inspection in an announcement of its intent to withdraw from the Nuclear Nonproliferation Treaty (NPT) in 1993. A second nuclear crisis occurred when its uranium enrichment program was revealed in 2002, which implied that North Korea has already established their nuclear capability, as indicated by the frequent earthquakes with 49 events in 2002 with 15 events in 1990. The first underground

nuclear test (Oct 2006) occurred which was subsequently followed by 55 earthquakes. The second nuclear test (May 2009) (82 earthquakes), third nuclear test (Feb 2013) (136 earthquakes), fourth nuclear test (Jan 2016) (50 earthquakes), fifth nuclear test (Sep 2016) (633 earthquakes), and sixth nuclear test (Sep 2017) showed that the number of earthquake events (≥ M 2.0) in the Korean Peninsula during 1990 to 2016 (available from Korean Meteorological Administration (KMA)) tremendously increased from 15 in 1990 to 633 in 2016, as shown in Figure 1. The novelty of the present study was to show the impacts of underground nuclear tests on earthquakes of surrounding countries.

The case of the Chinese Tangshan 1976 earthquake (M7.8) which caused 800,000 deaths [3] implied that the underground nuclear testing above 100 - 150 kt might cause a strong and deadly earthquake at a location as far as 11,000 km away from the test site, while major cities in China, Russia, Japan, Taiwan (China), and South Korea are located within 3000 km region from the underground nuclear test site of Punggae-ri in North Korea. Cretaceous granites in USA and Mexico showed earthquakes in Montana, California, and Mexico after the sixth North Korean underground nuclear test with yield exceeding 100 kt (50 - 300 kt).

The purpose of the present study was to investigate the impacts of six North Korean nuclear tests on corresponding earthquakes in China, Russia, Japan, Taiwan (China), Indonesia, Vanuatu, South Korea, USA, Ecuador, and Mexico.

2. Impacts of North Korean Underground Nuclear Tests

Recently, there was a landslide that caused 140 deaths at Mao in Sichuan in China on June 24, 2017, M 5.7 at Niigata of Japan in June 25, 2017, M 5.7 at western Montana of USA in July 06, 2017. M 8.1 hit Mexico off the southern coast causing 100 deaths in September 08, 2017, followed by M 7.1 which killed 370 people in September 19, 2017. Such locations all consist of Cretaceous granites like the Punggae-ri nuclear test site in North Korea. At Sichuan in China, 68,712 people were killed by an earthquake with M 8.0 in 2008 while 11 people were killed at Niigata in Japan by an earthquake of M 6.6 in 2007. The Sichuan and Niigata earthquakes occurred 578 and 277 days after the first nuclear test by North Korea, respectively. In addition, the Montana earthquake happened 297 days after the fifth test, and the Oaxaca and Puebla earthquakes in Mexico took place 5 and 16 days after the sixth test by North Korea, correspondingly. The geological distributions of Cretaceous granite in surrounding countries might amplify the seismic energies due to the constructive interference of the same Cretaceous granites in resonance between the North Korean nuclear test site and epicenters. North Korean nuclear tests have coincidently caused instabilities in fragile terrains in China, Japan, Russia, North Korea, South Korea, USA, Ecuador, and Mexico in the form of powerful earthquakes and volcanoes, as summarized in Table 1. Initial magnitudes at the nuclear test site of Punggae-ri in North Korea were mostly amplified due to their similar terrain consisting Cretaceous granites to cause enhanced frequency (υ) for amplification of seismic

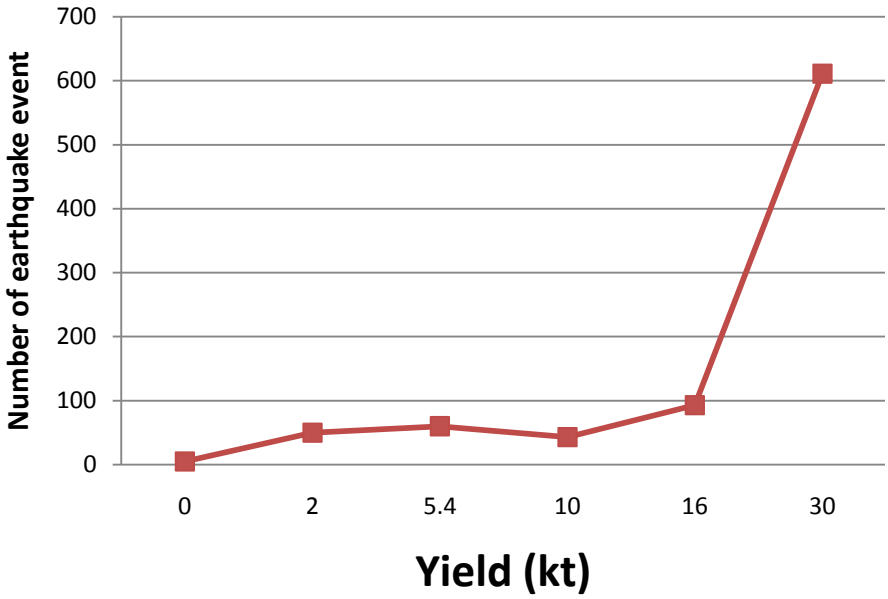

Figure 1. Number of earthquake events in the Korean Peninsula versus the yield (kt) of underground nuclear tests by North Korea. The first test in 2006 showed the earthquake magnitude of M 3.9 with yield of 0.2 - 2 kt, the second test of M 4.5 and 2 - 5.4 kt in 2009, the third test of M 4.9 and 6 - 16 kt in 2013, the fourth test of M 4.8 and 7 - 10 kt in January of 2016, the fifth test of M 5.04 and 20 - 30 kt in September of 2016, and the sixth test of M 5.7 - 6.4 and 50 - 300 kt in September of 2017.

energy (E) in Planck-Einstein relation ($E = h\upsilon$) with Planck constant (h) [4]. The distribution pattern of earthquakes in China, Russia, Japan, South Korea, USA, Ecuador, and Mexico were not uniform but randomly oriented throughout underground tests with various lag times from 3 days (Gyeongju, South Korea) and 5 days (Oaxaca, Mexico) to 676 days (Fukushima, Japan), as shown in **Table 1**. It was thus difficult to locate epicenters in advance although main shocks were observed in the terrains of Cretaceous granite and aftershocks at Cretaceous/Jurassic granites.

3. Earthquakes at Cretaceous Granites in Surrounding Countries

It is interesting to note that the earthquake magnitudes at epicenters consisted of Cretaceous granites were always greater than those of the nuclear test site at Punggae-ri in North Korea ; First test (M 3.9) while Kuril Islands in Russia (M 8.1), Sichuan in China (M 8.0), Pyeongchang in South Korea (M 4.8), Second test (M 4.5) while Yunnan in China (M 5.7) and Fukushima in Japan (M 9.1), Third test (M 4.9) while Kamchatka (M 8.3) and Vladivostok (M 6.3) in Russia, and Niigata in Japan (M 6.6), Fourth test (M 4.8) while Kaotsiung in Taiwan (China) (M 6.4), Kumamoto in Japan (M 7.0), Muisne in Ecuador (M 7.8), and Ulsan in South Korea (M 5.0), Fifth test (M 5.03) while Gyeongju in South Korea (M 5.8), Sixth test (M 5.7 ~ 6.4) while Oaxaca (M 8.1, M 7.2) and Puebla (M 7.1) in Mexico, Tafea in Vanuatu (M 6.4), and Iwate in Japan (M 6.1). Therefore, the

Table 1. Earthquakes and volcanoes correspondingly induced by six North Korean nuclear tests.

North Korean Nuclear Tests [5]				Earthquake			Volcano			
							Japan		Russia	
Sequence	Date	Yield (kt)	Magnitude (M)	Date	Location	Magnitude (M)	Date	Loation	Date	Location (Kamchatka)
1	2006.10.09	0.2 - 2	3.9	2007.01.13	Kuril Islands, Russia	8.1	2008.02.21	Anatahan, Mariana Islands	2007/2008	Bezymianny
							2008.07.12	Mount Meakan, Hokkaido		
				2007.01.20	Pyeongchang, South Korea	4.8				
				2007.07.16	Niigata, Japan	6.6	2009.03.10	Sakurajima, Kagoshima	2008	Koryaksky
				2008.05.12	Sichuan, China	7.9				
2	2009.05.25	2 - 5.4	4.5	2009.07.09	Yunnan, China	5.7	2009/2011	Mount Aso, Kumamoto	2009/2010/2012	Bezymianny
							2009 2010	Mount Meakan, Hokkaido		
				2010.04.14	Yushu, China	6.9	2011/2012/2013	Sakurajima, Kagoshima	2010.08	Gorely
				2011.04.11	Fukushima, Japan	9.1	2010/2013	Miyakejima, Honshu	2011.02	Kizimen
									2011.03	Karymsky
									2012.11.27	Tolbachik
3	2013.02.12	6 - 16	4.9				2013.06.04	Kikai Caldera, Ryukyu Islands	2013.01.10	
				2013.03.03	Yunnan, China	5.5	2013.07	Sakurajima, Kagoshima		Kizimen
							2014.09.27	Mount Ontake, Honshu		
				2013.04.20	Ya'an, China	6.9	2014/2015	Nishinoshima, Tokyo	2013.11.29	Klyucheskaya Sopka
				2013.05.24	Kamchatka Peninsula, Russia	8.3	2015	Iwo Jima, Tokyo		
				2013.07.22	Dingxi, China	5.9	2015.05.22	Mount Hakone, Kanagawa		
				2014.05.24	Yingjiang, China	5.6	2015.06.19	Kuchinoerabu—jima, Kagoshima	2014.01.26	Gorely
							2015.08.16	Sakurajima, Kagoshima		
				2014.08.03	Ludian, China	6.1	2015.08.31	Mount Meaken, Hokkaido		

Continued

				2016.01.20	Qinghai, Hongtu, Northern Qinghai	5.9	2015			
				2016.02.06	Tainan, Taiwan (China)	6.4		Mount Aso, Kumamoto	2016.02.02	Karymsky
				2016.03.17	Western Sichuan, China	4.8				
				2016.04.16	Kumamoto, Japan	7.0	2016.03.08			
4	2016.01.06	7 - 10	4.8		Muisne, Ecuador	7.8				
				2016.04.19	Gyang Kar, China	4.4	2016.05.06	Mount Niigata-Yakeyama, Honshu		
				2016.06.25	Southern Xinjiang, China	4.2				
				2016.07.05	Ulsan, South Korea	5.0			2016.04.24	Klyuchevskaya Sopka
				2016.07.31	Guang Xi, China	5.0	2016.07.26	Sakurajima, Kagoshima		
				2016.08.13	Yunnan, China	4.7				
				2016.09.12	Gyeongju, South Korea	5.8			2016.10.01	Shiveluch
				2016.09.23	Rulong, Sichuan, China	5.3	2016.10.08	Mount Aso, Kumamoto	2016.10.08	Karymsky
				2016.10.06	Kaotsiung, Taiwan (China)	5.7				
				2016.10.17	Dartang, China	5.9				
5	2016.09.09	20 - 30	5.04	2016.10.17	Southern Qinghai, China	4.5			2016.12.15	Bezymianny
				2016.10.19	Hujizhen, China	4.9			2017.03.08	Kambalny
				2016.11.25	Xinjiang Uygur, China	6.5	2017.03.31	Suwanose jima, Ryukyu Islands		
				2017.06.24	Sichuan, China	Landslide			2017.03.09	Bezymianny
				2017.06.25	Niigata, Japan	5.7				
				2017.07.18	Nikol'skoye, Russia	7.8				

Continued

				2017.09.09	Oaxaca, Mexico	8.1	-	-	-	-
				2017.09.19	Puebla, Mexico	7.1	-	-	-	-
				2017.09.20	Los Angeles, USA	3.6	-	-	-	-
				2017.09.20	Taitung, Taiwan (China)	5.7	-	-	-	-
6	2017.09.03	50 - 300	5.7 ~ 6.4		Iwate, Japan	6.1	-	-	-	-
				2017.09.21	Tafea, Vanuatu	6.4	-	-	-	-
					Java Sea, Indonesia	5.7	-	-	-	-
				2017.09.22	Ferndale, California, USA	5.7	-	-	-	-
				2018.02.16	Oaxaca, Mexico	7.2	-	-	-	-

constructive interference in resonance among the same material of cretaceous granite (Kgr) between the North Korean nuclear test site of Punggae-ri and individual epicenters might induce the enhanced frequency for higher earthquake magnitudes. Since the yield of the North Korean underground nuclear test was further increased from the fifth one of 20 ~ 30 kt to the sixth one of 50 to 300 kt with 120 kt [5], surrounding countries in **Table 1** might suffer catastrophic damage by the amplified energy during the seismic propagation through terrains of Cretaceous or Jurassic granites. The following areas consist of Cretaceous granite ; Sichuan [6], South China [7], North China [8], North East China [9], Western Yunnan China [10], North-Asian Russia [11], parts of Taiwan (China), most of Kyushu, Honshu, and Fukushima of Japan (http://www.fukushima-blog.com/article-the-geology-of-fukushima-88575278.html) with Cretaceous granites. There are wide locations in the USA and Mexico where Cretaceous granites are found (http://goo.gl/images/DJ6VGM), such as the Brooks Range of northern Alaska [12], Sierra-Nevada batholith, Cretaceous plutons of San Diego in southern California [13], Idaho batholiths [14], Washington (Coast Plutonic Complex), Oregon (Klamath Mtns.), Montana (Boulder batholiths) [15], Mexico (Guerrero Composite, Mixteca, Cortes, Parral, Central, Oaxaquia, Caborca) [16]. As a result, at least 100 people were killed by the most powerful earthquake (M 8.1) to hit Mexico in a century at Oaxaca [CNN, September 9, 2017]. Furthermore, the 7.1 earthquake devastated Central Mexico killing at least 370 people by shaking activated faults associated with the sixth North Korean test.

It is most likely that the USA, particularly the states of Alaska, Nevada, Idaho,

Washington, Oregon, Montana, and California, can be in danger due to earthquakes induced by North Korean underground nuclear tests. This is seen in the recent earthquake (M 5.7) in western Montana in July 06, 2017, M 3.6 at Los Angeles in September 19, and M 5.7 in Ferndale in California in September 22, 2017, 297 days after the fifth underground nuclear, and 16 and 19 days after the sixth test by North Korea, respectively. Therefore, it could be very dangerous since North Korea attempted the sixth nuclear test with yield of 50 - 300 kt impacting all over the surrounding counties including the USA and Mexico. Since North Korea conducted the sixth nuclear test close to the earthquake magnitude of 6.4 or yield of 120 kt [17], as conducted by China at Lop Nor nuclear Xingjiang in October 6 of 1993, a few disastrous accidents could be expected as follows; 1) Mt. Baekdu erupted in AD 946 might erupt again causing volcanic plumes with toxic gases of H_2S, SO_2, HF, HCl, H_2SO_4 and hot magma (700˚C ~ 1500˚C) damaging the surroundings including China, North Korea, Russia, and Japan in accordance with seasonal wind directions. 2) Earthquakes could be observed in neighboring countries in China (Bejing, Changchun, Chongging, Darlin, Dunhua, Harbin, Sichuan, Shenyang, Tianjin, Hong Kong, Guangdong), Russia (Vladivostok, Khttabarovsk, Sikhote-Alinsky/Badzhalsky) [11], Japan (Fukushima, Hiroshima, Nagoya, Kyoto, Osaka, Kobe, Nagasaki, Fukuoka, Kumamoto, Sapporo, Sendai, Niigata, Kyushu) (http://www.fukushima-blog.com/article-the-geology-of-fukushima-88575278.html), North Korea (Pyeongyang, Haeju, Ongjin, Gaesong, Sinpo, Hamhung, Chosan, Heungnam, Wonsan, Chongjin, Sariwon), and South Korea (Seoul, Busan, Gyeongju, Incheon, Sogcho, Gangneung, Uljin, Suwon, Daejeon, Daegu, Youngju, Ulsan, Gimcheon, Gwangju). Several states of USA with Cretaceous granites might experience earthquakes such as Alaska, Washington, Oregon, Montana, Idaho, Nevada, and California (http://goo.gl/images/DJ6VGM) as well as Mexico and Ecuador.

4. Earthquakes by the North Korean Hydrogen Bomb Test

Seismic energies caused by a hydrogen bomb explosion in the sixth North Korean nuclear test with yield of 50 to 300 kt, have been released and then channeled through in The Pacific *Ring of Fire*, compared to being narrowly channeled to the East Sea at Gyeongju of South Korea during the fifth test with yield of 20 to 30 kt. Initial explosive force after the sixth test might have been propagated from North Korea to Russian Kamchatka Peninsula reaching the Pacific Plate, which might have activated the tectonic boundary between the small and unstable Cocos Plate and North American Plate to induce extensive damage. More than 100 people died at Oaxaca in Mexico, 12,540 km away, 5 days after the sixth nuclear test. Furthermore, M 7.1 at Puebla in Mexico killed more than 370 people 16 days. In addition the M 7.2 earthquake occurred in Oaxaca 163 days after the same sixth nuclear test.

Since North Asian Russia, Japan, USA, and Mexico are located on multi tectonic plates (Russia-Kamchatka 3, Japan 6, USA 3, Mexico 3) and enormous

volcanoes (Kamchatka 29, Japan 108, USA 65, Mexico 42), any minor stimulation of either Cretaceous or Jurassic granites by North Korean nuclear tests at the present Pungae-ri test site, might activate geothermal systems to cause deadly damage in China, Russia, Taiwan (China), Japan, South Korea, North Korea, The USA, Ecuador, and Mexico as shown in Table 1. Alarmingly, several states of The USA including Alaska, Washington, Oregon, Montana, Idaho, Nevada, and California are within 11,000 km distance, and have Cretaceous granite terrains similar to the North Korean nuclear test site associated with the constructive interference of resonance for a higher magnitude of earthquake. Mexico showed the strongest earthquakes with magnitudes of 8.1, 7.1 and 7.2 occurring 5, 16 and 163 days after the sixth nuclear test. Therefore, it is urgent to prohibit further North Korean nuclear tests to prevent high casualties in surrounding countries.

5. Conclusion

The present study showed that the explosive powers of North Korean underground nuclear tests at Punggae-ri have coincidently impacted on earthquakes in China, Russia, South Korea, Japan, Taiwan (China), USA, Ecuador, Vanuatu, Indonesia, and Mexico. The number of earthquake events (≥M 2.0) in the Korean Peninsula tremendously increased from 15 in 1990 without the nuclear test to 633 in 2016 with the fifth nuclear test. Therefore, the underground nuclear tests by North Korea are dangerous to surrounding countries with deadly earthquakes. Geological instabilities in terrains of Cretaceous granite were triggered by North Korean nuclear tests to induce the enhanced seismic impacts in earthquakes in surrounding countries after lag times between the North Korean underground nuclear test site and individual epicenters ranging from 3 (Gyeongju, South Korea) and 5 (Oaxaca, Mexico) to 676 days (Fukushima, Japan). There was recently (02/16/18) an earthquake (M 7.2) in Oaxaca of Mexico whose terrain is also composed of Cretaceous granites. It is therefore urgent to prohibit North Korean nuclear tests for the regional stability of surrounding countries with Cretaceous granites.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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