

# Appendix 12B. Nuclear explosions, 1945–2006

VITALY FEDCHENKO and RAGNHILD FERM HELLGREN\*

## I. Introduction

In October 2006 the Democratic People’s Republic of Korea (DPRK, or North Korea) conducted a nuclear test explosion, the first nuclear explosion recorded since those conducted by India and Pakistan in 1998. This appendix presents a brief discussion of the North Korean explosion, in particular how international researchers have sought to determine its nature, location and yield based on the available data, and then presents data on all the nuclear explosions conducted since 1945.

## II. The nuclear test in North Korea

On 9 October 2006 the Korean Central News Agency (KCNA) reported that North Korea had on that day successfully conducted an underground nuclear test explosion ‘under secure conditions’.<sup>1</sup> North Korea had announced on 3 October its intention to conduct a nuclear test.<sup>2</sup> The Chinese Government was given 20 minutes’ prior warning of the test and was informed that the explosion’s yield would be 4 kilotons.<sup>3</sup>

Following the 9 October announcement, numerous measurements and studies were carried out by governmental and independent experts outside North Korea to determine whether there had been an explosion and, if so, its nature, location and actual yield. A seismic event was recorded by several monitoring networks at 01:35 UTC on 9 October 2006, originating 70 kilometres north of the city of Kimchaek in North Korea’s North Hamgyong province. The wave patterns recorded at monitoring stations and the depth of the event (less than 1 km) indicate that it was an explosion rather than an earthquake. Data on the seismic magnitude of the event were used to estimate the yield of the explosion, although the lack of information on the geology of the test site affects the reliability of such estimates.<sup>4</sup> Based on the seismic data, the governments of France, South Korea and the United States, along with independent researchers, concluded with a high degree of certainty that there had been an explo-

<sup>1</sup> Korean Central News Agency, ‘DPRK successfully conducts underground nuclear test’, Pyongyang, 9 Oct. 2006, URL <<http://www.kcna.co.jp/item/2006/200610/news10/10.htm>>.

<sup>2</sup> Korean Central News Agency, ‘DPRK foreign ministry clarifies stand on new measure to bolster war deterrent’, Pyongyang, 3 Oct. 2006, URL <<http://www.kcna.co.jp/item/2006/200610/news10/04.htm>>.

<sup>3</sup> CNN, ‘North Korea claims nuclear test’, 9 Oct. 2006, URL <<http://www.cnn.com/2006/WORLD/asiapcf/10/08/korea.nuclear.test/>>; and Linzer, D., ‘Low yield of blast surprises analysts’, *Washington Post*, 10 Oct. 2006.

<sup>4</sup> US National Academy of Sciences, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* (National Academy Press: Washington, DC, 2002), URL <<http://www.nap.edu/catalog/10471.html>>, pp. 41–42.

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sion and that its yield was well below 1 kt.<sup>5</sup> Different estimates of the time, location and size of the 9 October explosion are given in table 12B.1.

Seismic data alone are insufficient to confirm that an underground explosion is nuclear. Immediately after the 3 October announcement by North Korea, the USA deployed its WC-135W Constant Phoenix atmospheric collection aircraft,<sup>6</sup> which is normally used for collection of particulate and gaseous effluents and debris in support of the 1963 Partial Test-Ban Treaty.<sup>7</sup> Based on analysis of atmospheric radioactive debris collected by the aircraft, the US Government announced on 16 October that the event had been a nuclear explosion.<sup>8</sup> This was corroborated by the findings of South Korea and, later, the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO).<sup>9</sup> Analysis of the debris also indicated that the test used plutonium, which was confirmed by North Korean officials.<sup>10</sup>

The extent to which the North Korean nuclear test was successful is uncertain. The discrepancy between the pre-announced yield of 4 kt and the estimated actual yield of less than 1 kt made some experts speculate that the test ended in a ‘fizzle’—that is, an inefficient detonation releasing less explosive energy than expected. As reported in the South Korean press, a North Korean diplomat acknowledged that the test was ‘smaller in scale than expected’.<sup>11</sup> However, even the predicted yield was several times smaller than that expected from a basic plutonium weapon design.

### III. Estimated number of nuclear explosions, 1945–2006

Table 12B.2 lists the known nuclear explosions to date, including nuclear tests conducted in nuclear weapon test programmes, explosions carried out for peaceful purposes and the two nuclear bombs dropped on Hiroshima and Nagasaki in August

<sup>5</sup> Garwin, R. L. and von Hippel, F. N., ‘A technical analysis of North Korea’s Oct. 9 nuclear test’, *Arms Control Today*, Nov. 2006. An early official Russian estimate that the yield was 5–15 kt was dismissed by US Government officials as inaccurate. It was identical to an estimate reportedly given to Russia by North Korea in the run-up to the test. Chanlett-Avery, E. and Squassoni, S., *North Korea’s Nuclear Test: Motivations, Implications, and U.S. Options*, US Library of Congress, Congressional Research Service (CRS) Report for Congress RL33709 (CRS: Washington, DC, 4 Oct. 2006), URL <<http://fpc.state.gov/fpc/75427.htm>>; and Linzer (note 3).

<sup>6</sup> Chin, T., ‘Seoul’s intelligence capabilities “a total failure”’, *Korea Herald*, 18 Oct. 2006.

<sup>7</sup> US Department of the Air Force, ‘WC-135 Constant Phoenix’, Fact sheet, Oct. 2005, URL <<http://www.af.mil/factsheets/factsheet.asp?fsID=192>>. The Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (Partial Test-Ban Treaty) was opened for signature on 5 Aug. 1963 and entered into force on 10 Oct. 1963. For the text of the treaty see URL <<http://www.state.gov/t/ac/trt/4797.htm>>. For a description of the treaty and a list of the signatories and parties see annex A in this volume.

<sup>8</sup> Office of the Director of National Intelligence, ‘Statement by the Office of the Director of National Intelligence on the North Korea nuclear test’, News release, 16 Oct. 2006, URL <[http://www.dni.gov/announcements/20061016\\_release.pdf](http://www.dni.gov/announcements/20061016_release.pdf)>. Collection and analysis of atmospheric debris are not an entirely reliable way to establish that an underground nuclear explosion has occurred. On-site inspection would probably be needed to establish with absolute certainty that the North Korean test was nuclear.

<sup>9</sup> ‘S. Korean gov’t officially confirms N. Korea’s nuclear test’, *Yonhap News*, 25 Oct. 2006; ‘ROK confirms radiation level normal following Pyongyang’s nuke test’, *Yonhap News*, 25 Oct. 2006; and US Defense Treaty Readiness Inspection Program, ‘CTBTO observatory detects radioactive materials from DPRK nuclear test’, *Weekly Treaty Review*, 5–11 Jan. 2007, URL <[http://dtirp.dtra.mil/tic/WTR/wtr\\_11jan07.pdf](http://dtirp.dtra.mil/tic/WTR/wtr_11jan07.pdf)>, p. 19.

<sup>10</sup> Shanker, T. and Sanger, D. E., ‘North Korean fuel identified as plutonium’, *New York Times*, 17 Oct. 2006; and Hecker, S. S., ‘Report on North Korean nuclear program’, Nautilus Institute, Policy Forum Online 06-97A, 15 Nov. 2006, URL <<http://www.nautilus.org/fora/security/0697Hecker.html>>.

<sup>11</sup> MacAskill, E., ‘Diplomat says test was smaller than expected’, *The Guardian*, 11 Oct. 2006.

**Table 12B.1.** Data on North Korea's nuclear explosion, 9 October 2006

Source <sup>a</sup>	Origin time (UTC)	Latitude (degrees)	Longitude (degrees)	Error margin <sup>b</sup>	Body wave magnitude <sup>c</sup>
IDC <sup>d</sup>	01:35.27.6	41.3119 N	129.0189 E	±20.6 km	4.1
NEIC	01:35.28	41.29 N	129.09 E	± 8.1 km	4.3
CEME	01:35.26.0	41.31 N	128.96 E	..	4.0
KIGAM	01:35	40.81 N	129.10 E	..	3.9

UTC = Coordinated Universal Time; .. = Data not available.

<sup>a</sup> Because of differences between estimates, particularly regarding the precise site of the explosion, data from 4 sources—1 internationally recognized body and 3 national bodies—are provided for comparison. IDC = Comprehensive Nuclear Test-Ban Treaty Organization (CTBTO) International Data Centre, Vienna; NEIC = US Geological Survey (USGS), National Earthquake Information Center, Denver, Colorado; CEME = Geophysical Service of the Russian Academy of Sciences, Central Experimental Methodical Expedition; KIGAM = Korea Institute of Geoscience and Mineral Resources (South Korea).

<sup>b</sup> The error margins listed here are horizontal location errors provided by the data sources. See USGS Earthquake Hazards Program, 'Recent earthquakes—glossary', URL <<http://earthquake.usgs.gov/eqcenter/recenteqsus/glossary.htm>>.

<sup>c</sup> Body wave magnitude indicates the size of the event. In order to give a reasonably correct estimate of the yield of an underground explosion, detailed information is needed, e.g. on the geological conditions in the area where the explosion took place. Body wave magnitude is therefore an unambiguous way of giving the size of an explosion.

<sup>d</sup> The IDC was 'in a test and provisional operation mode only' and only 60% of the monitoring stations in the CTBTO's International Monitoring System were contributing data at the time of the event. 'North Korea: a real test for the CTBT verification system?', *CTBTO Spectrum*, no. 9 (Jan. 2007), pp. 24, 28, URL <[http://www.ctbto.org/reference/outreach/140207\\_spectrum9\\_web\\_final.pdf](http://www.ctbto.org/reference/outreach/140207_spectrum9_web_final.pdf)>.

*Sources:* **IDC data:** Swedish Defence Research Agency (FOI), Swedish National Data Centre, Information provided to the authors, Feb. 2007; **NEIC data:** NEIC, 'Magnitude 4.3: North Korea', Preliminary Earthquake Report, 8 Nov. 2006, URL <<http://earthquake.usgs.gov/eqcenter/equinthenews/2006/ustqab/>>; **CEME data:** CEME, 'Information message about underground nuclear explosion made by the Northern Korea on October 9, 2006', 9 Oct. 2006, URL <[http://www.ceme.gsras.ru/cgi-bin/info\\_quakee.pl?mode=1&id=84](http://www.ceme.gsras.ru/cgi-bin/info_quakee.pl?mode=1&id=84)>; **KIGAM data:** Lee, Y. W. and Ahn, J. H., [Seismic waves released: it is an explosion], *Chosun Ilbo*, 9 Oct. 2006, URL <<http://www.chosun.com/national/news/200610/200610090665.html>>; and Lee, J. N., Yonhap News, [KIGAM: 'official magnitude figure 3.58–3.7, no change'], *Hankyoreh*, 10 Oct. 2006.

1945. The totals also include tests for safety purposes carried out by France, the Soviet Union/Russia and the USA,<sup>12</sup> irrespective of the yield and of whether they caused a nuclear explosion. The tables do not include subcritical experiments. Simultaneous detonations, also called salvo explosions, were carried out by the USA (from 1963) and the Soviet Union (from 1965), mainly for economic reasons.<sup>13</sup> Of the Soviet tests, 20 per cent were salvo experiments, as were 6 per cent of the US tests.

<sup>12</sup> In a safety experiment, or a safety trial, more or less fully developed nuclear devices are subjected to simulated accident conditions. The nuclear weapon core is destroyed by conventional explosives with no or very small releases of fission energy. The UK also carried out numerous safety tests, but they are not included in table 12B.2 because of their high number.

<sup>13</sup> The Soviet Union conducted simultaneous tests including as many as 8 devices on 23 Aug. 1975 and on 24 Oct. 1990 (the last Soviet test).

**Table 12B.2.** Estimated number of nuclear explosions, 1945–2006

a = atmospheric (or in a few cases underwater); u = underground.

Year	USA <sup>a</sup>		USSR/ Russia		UK <sup>a</sup>		France		China		India		Pakistan		North Korea		Total
	a	u	a	u	a	u	a	u	a	u	a	u	a	u	a	u	
1945	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
1946	2 <sup>b</sup>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
1947	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1948	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
1949	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
1950	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1951	15	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	18
1952	10	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	11
1953	11	–	5	–	2	–	–	–	–	–	–	–	–	–	–	–	18
1954	6	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	16
1955	17 <sup>b</sup>	1	6 <sup>b</sup>	–	–	–	–	–	–	–	–	–	–	–	–	–	24
1956	18	–	9	–	6	–	–	–	–	–	–	–	–	–	–	–	33
1957	27	5	16 <sup>b</sup>	–	7	–	–	–	–	–	–	–	–	–	–	–	55
1958 <sup>c</sup>	62 <sup>d</sup>	15	34	–	5	–	–	–	–	–	–	–	–	–	–	–	116
1959 <sup>c</sup>	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1960 <sup>c</sup>	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	3
1961 <sup>c</sup>	–	10	58 <sup>b</sup>	1	–	–	1	1	–	–	–	–	–	–	–	–	71
1962	39 <sup>b</sup>	57	78	1	–	2	–	1	–	–	–	–	–	–	–	–	178
1963 <sup>e</sup>	4	43	–	–	–	–	–	3	–	–	–	–	–	–	–	–	50
1964	–	45	–	9	–	2	–	3	1	–	–	–	–	–	–	–	60
1965	–	38	–	14	–	1	–	4	1	–	–	–	–	–	–	–	58
1966	–	48	–	18	–	–	6	1	3	–	–	–	–	–	–	–	76
1967	–	42	–	17	–	–	3	–	2	–	–	–	–	–	–	–	64
1968	–	56	–	17	–	–	5	–	1	–	–	–	–	–	–	–	79
1969	–	46	–	19	–	–	–	–	1	1	–	–	–	–	–	–	67
1970	–	39	–	16	–	–	8	–	1	–	–	–	–	–	–	–	64
1971	–	24	–	23	–	–	5	–	1	–	–	–	–	–	–	–	53
1972	–	27	–	24	–	–	4	–	2	–	–	–	–	–	–	–	57
1973	–	24	–	17	–	–	6	–	1	–	–	–	–	–	–	–	48
1974	–	22	–	21	–	1	9	–	1	–	–	1	–	–	–	–	55
1975	–	22	–	19	–	–	–	2	–	1	–	–	–	–	–	–	44
1976	–	20	–	21	–	1	–	5	3	1	–	–	–	–	–	–	51
1977	–	20	–	24	–	–	–	9	1	–	–	–	–	–	–	–	54
1978	–	19	–	31	–	2	–	11	2	1	–	–	–	–	–	–	66
1979	–	15	–	31	–	1	–	10	1	–	–	–	–	–	–	–	58
1980	–	14	–	24	–	3	–	12	1	–	–	–	–	–	–	–	54
1981	–	16	–	21	–	1	–	12	–	–	–	–	–	–	–	–	50
1982	–	18	–	19	–	1	–	10	–	1	–	–	–	–	–	–	49
1983	–	18	–	25	–	1	–	9	–	2	–	–	–	–	–	–	55
1984	–	18	–	27	–	2	–	8	–	2	–	–	–	–	–	–	57
1985 <sup>f</sup>	–	17	–	10	–	1	–	8	–	–	–	–	–	–	–	–	36
1986 <sup>f</sup>	–	14	–	–	–	1	–	8	–	–	–	–	–	–	–	–	23
1987 <sup>f</sup>	–	14	–	23	–	1	–	8	–	1	–	–	–	–	–	–	47
1988	–	15	–	16	–	–	–	8	–	1	–	–	–	–	–	–	40
1989	–	11	–	7	–	1	–	9	–	–	–	–	–	–	–	–	28
1990	–	8	–	1	–	1	–	6	–	2	–	–	–	–	–	–	18

Year	USA <sup>a</sup>		USSR/ Russia		UK <sup>a</sup>		France		China		India		Pakistan		North Korea		Total
	a	u	a	u	a	u	a	u	a	u	a	u	a	u	a	u	
1991 <sup>g</sup>	–	7	–	–	–	1	–	6	–	–	–	–	–	–	–	–	14
1992 <sup>g</sup>	–	6	–	–	–	–	–	–	–	2	–	–	–	–	–	–	8
1993 <sup>g</sup>	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
1994 <sup>g</sup>	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2
1995 <sup>g</sup>	–	–	–	–	–	–	–	5	–	2	–	–	–	–	–	–	7
1996 <sup>g</sup>	–	–	–	–	–	–	–	1	–	2	–	–	–	–	–	–	3
1997	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
1998	–	–	–	–	–	–	–	–	–	–	–	–	2 <sup>h</sup>	–	2 <sup>h</sup>	–	4
1999	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
2000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
2001	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
2002	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
2003	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
2004	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
2005	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
2006	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
Subtotal	217	815	219	496	21	24	50	160	23	22	–	3	–	2	–	1	2 053
<b>Total</b>	<b>1 032</b>		<b>715</b>		<b>45</b>		<b>210</b>		<b>45</b>		<b>3</b>		<b>2</b>		<b>1</b>		

*Note:* For the purposes of this table ‘underground nuclear test’ is defined according to Section I, para. 2 of the 1990 Protocol to the 1974 US–Soviet Treaty on the Limitation of Underground Nuclear Weapon Tests (Threshold Test Ban Treaty, TTBT): ‘either a single underground nuclear explosion conducted at a test site, or two or more underground nuclear explosions conducted at a test site within an area delineated by a circle having a diameter of two kilometers and conducted within a total period of time of 0.1 second’. For the text of the TTBT and the Protocol see URL <<http://www.state.gov/t/ac/trt/5204.htm>>. ‘Underground nuclear explosion’ is defined according to the 1976 US–Soviet Treaty on Underground Nuclear Explosions for Peaceful Purposes (Peaceful Nuclear Explosions Treaty, PNET): ‘any individual or group underground nuclear explosion for peaceful purposes’ (Article II.a). ‘Group explosion’ is defined as ‘two or more individual explosions for which the time interval between successive individual explosions does not exceed five seconds and for which the emplacement points of all explosives can be interconnected by straight line segments, each of which joins two emplacement points and each of which does not exceed 40 kilometers’ (PNET, Article II.c). For the text of the PNET see URL <<http://www.state.gov/t/ac/trt/5182.htm>>. For brief descriptions of the TTBT and PNET see annex A in this volume.

<sup>a</sup> All British tests from 1962 were conducted jointly with the USA at the US Nevada Test Site but are listed only under ‘UK’ in this table. Thus, the number of US tests is higher than shown. Safety tests carried out by the UK are not included in the table.

<sup>b</sup> 1 of these tests was carried out under water.

<sup>c</sup> The UK, the Soviet Union and the USA observed a moratorium on testing from Nov. 1958 to Sep. 1961.

<sup>d</sup> 2 of these tests were carried out under water.

<sup>e</sup> On 5 Aug. 1963 the USSR, the UK and the USA signed the Partial Test-Ban Treaty (PTBT), prohibiting nuclear explosions in the atmosphere, in outer space and under water. It was subsequently opened for signature by all other states. For a description of the treaty and a list of the signatories and parties see annex A in this volume.

<sup>f</sup> The USSR observed a unilateral moratorium on testing between Aug. 1985 and Feb. 1987.

<sup>g</sup> The USSR and then Russia observed a moratorium on testing from Jan. 1991 and the USA from Oct. 1992, until they signed the Comprehensive Nuclear Test-Ban Treaty (CTBT);

France observed a similar moratorium from Apr. 1992 to Sep. 1995. The CTBT was opened for signature by all states on 24 Sep. 1996, and all 5 of the Non-Proliferation Treaty (NPT)-defined nuclear weapon states signed it on that day. It has not yet entered into force. For a brief description of the CTBT and lists of the states that have signed or ratified it see annex A in this volume.

<sup>h</sup> India's detonations on 11 and 13 May 1998 are listed as 1 test for each date. The 5 detonations by Pakistan on 28 May 1998 are also listed as 1 test.

*Sources:* Swedish Defence Research Agency (FOI), various estimates, including information from the CTBTO International Data Center; Reports from the Australian Seismological Centre, Australian Geological Survey Organisation, Canberra; US Department of Energy (DOE), *United States Nuclear Tests: July 1945 through September 1992* (DOE: Washington, DC, 1994); Norris, R. S., Burrows, A. S. and Fieldhouse, R. W., 'British, French and Chinese nuclear weapons', *Nuclear Weapons Databook, Vol. V* (Natural Resources Defense Council: Washington, DC, 1994); Direction des centres d'experimentations nucléaires (DIRCEN) and Commissariat à l'Énergie Atomique (CEA), *Assessment of French Nuclear Testing* (DIRCEN and CEA: Paris, 1998); Russian Ministry of Atomic Energy and Russian Ministry of Defense, *USSR Nuclear Weapons Tests and Peaceful Nuclear Explosions, 1949 through 1990* (All-Russian Research Institute of Experimental Physics, Russian Federal Nuclear Center (VNIIEF): Sarov, 1996); Natural Resources Defense Council, 'Archive of nuclear data', URL <<http://www.nrdc.org/nuclear/nudb/datainx.asp>>; and Swedish Defence Research Agency (FOI), Swedish National Data Centre, Information provided to the authors, Feb. 2007.