Topic	**Record examples of underground nuclear explosions**
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1 Record examples of underground nuclear explosions between 1978 and 1993 within the teleseismic distance range

Below, seismic records of underground nuclear explosions (UNEs) at 5 weapon test sites and from a peaceful nuclear explosion (PNE) are shown. All records were made in the distance range D > 30° by vertical-component seismographs at station GRA1 of the Gräfenberg broadband array in Germany. The original BB records were filtered in the short-period range (WWSSN-SP simulation filter). The time scale is given in the records. The amplitudes have been normalized and the records are presented in Figure 1 in the following order:

No.	Date	Time	Latitude [deg]	Longitude [deg]	Depth [km]	m_b	Location (Code Name)	D [deg]	Reference
1	1988-12-17	04:18:09.2	49.879	78.924	0	5.9	Semipalatinsk	42.34	UK AWE (1990)
2	1993-10-05	01:59:56.68	41.6322	88.6886	0	5.9	Lop Nor	52.49	ISC (2001)
3	1988-12-04	05:19:53.3	73.3660	55.0010	0	5.9	Novaya Zemlya	30.32	Richards (2000)
4	1988-10-13	14:00:00.08	37.0890	-116.0493	0	5.9	Nevada Test Site (Dalhart)	81.83	ISC (2001)
5	1987-11-19	16:31:00.2	-21.845	-138.941	0	5.7	Mururoa	143.58	UK AWE (1993)
6	1978-10-08	00:00:00.0	61.55	112.85	1.545	5.2	PNE, USSR / Siberia (Vyatka)	52.78	Sultanov et al. (1999)

D is the distance to the reference site of the Gräfenberg Array GRA1.The estimated yields for these explosions range between approximately 20 and 150 kt TNT for the weapon tests and is about 15 kt TNT for the PNE (No. 6).

With the exception of the Mururoa test all other records show a clear positive (compressional) first arrival. This should be expected from explosions at all distances and azimuths. For the Mururoa the waveform is influenced by the caustic in the core distance range near D = 145° and therefore the onset polarity can not be read reliably. Note the remarkable differences in P waveforms, which are rather short and simple for events No. 1, 2, 5 and 6 but much more complex and longer for events No. 3 and 4. This is mainly due to the specific geology and/or complex topography at the test sites in Nevada and on Novaya Zemlya. However, for event No. 3 we observe later P energy in an epicentral distance of about 30º due to the upper mantle triplications and for event No. 5 the distinguished onsets are later PKP-type onsets (see

Schlittenhardt, 1996). More waveform data from UNEs can be retrieved from the PIDC Nuclear Explosion Database (see IS 10.3).

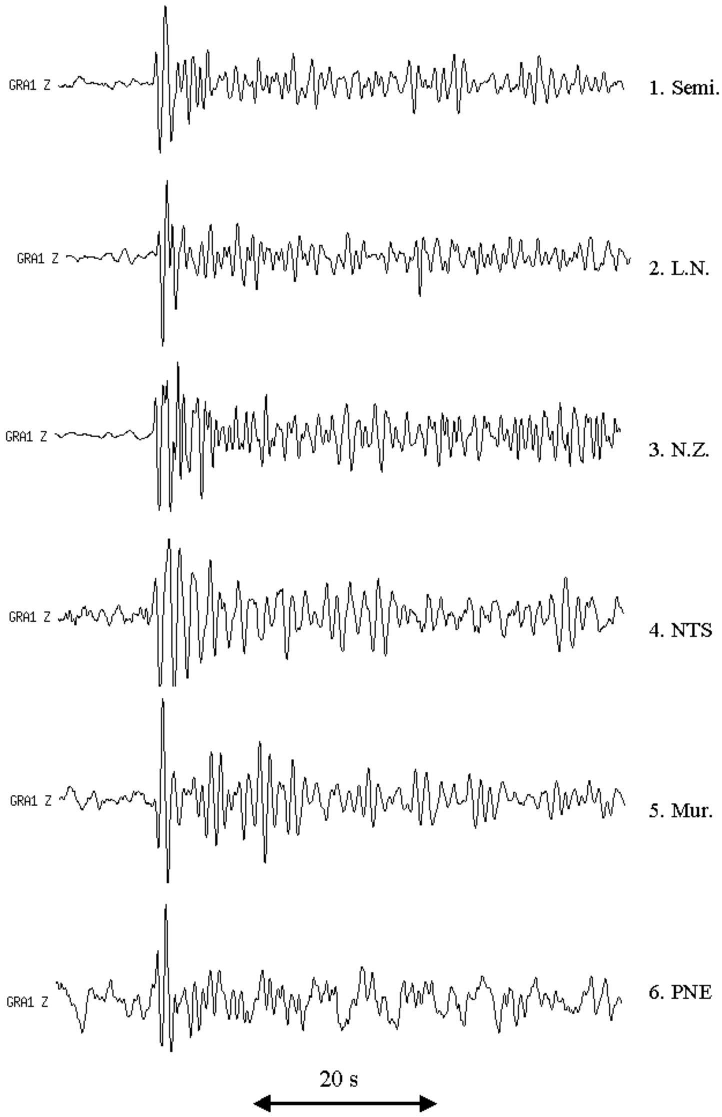

Figure 1 Short-period filtered seismograms (WWSSN-SP simulation filter) recorded at station GRA1 of the Gräfenberg broadband array in Germany from underground nuclear explosions in six different areas. For source parameters and distances to GRA1 see list above.

2 Records of the nuclear-weapon tests of India and Pakistan

Figures 2 and 3 show vertical component records of broadband stations of the German Regional Seismography Network (GRSN) from the underground nuclear weapons tests of India and Pakistan in 1998. All records were filtered narrowband in the short-period range around 1 Hz and sorted according to the epicentral distance. The source parameters are:

India: 1998-11-05, 10:13:44.2, 27.0780°N, 71.7190°E, depth 0 km, mb 5.2 (Barker et al., 1999) with epicentral distance and backazimuth from GRFO: D = 50.99° and BAZ = 92.94°.

Pakistan: 1998-05-30, 06:54:54.87, 28.4434°N, 63.7375°E, depth 0 km; mb 4.7 (ISC, 2001) with epicentral distance and backazimuth from GRFO: D = 44.91° and BAZ = 98.12°.

The P-wave onsets are generally simple. However, they are masked by noise at the more noisy stations. Surface-wave amplitudes were very weak and could not be analyzed at this large distance.

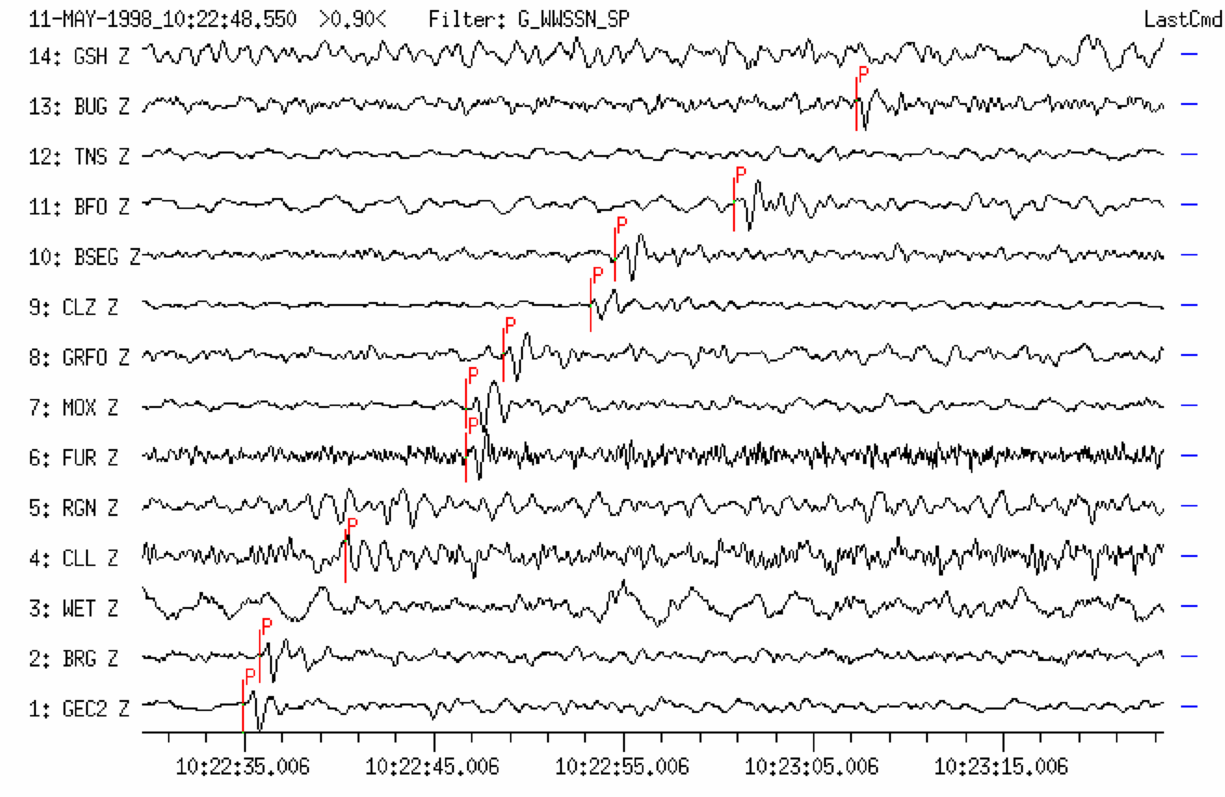

Figure 2 Records of the Indian underground nuclear test on 11 May 1998. For source parameters see above. The broadband records were filtered with the WWSSN-SP response. Typical for explosions are the compressional first onset polarities at stations with high SNR.

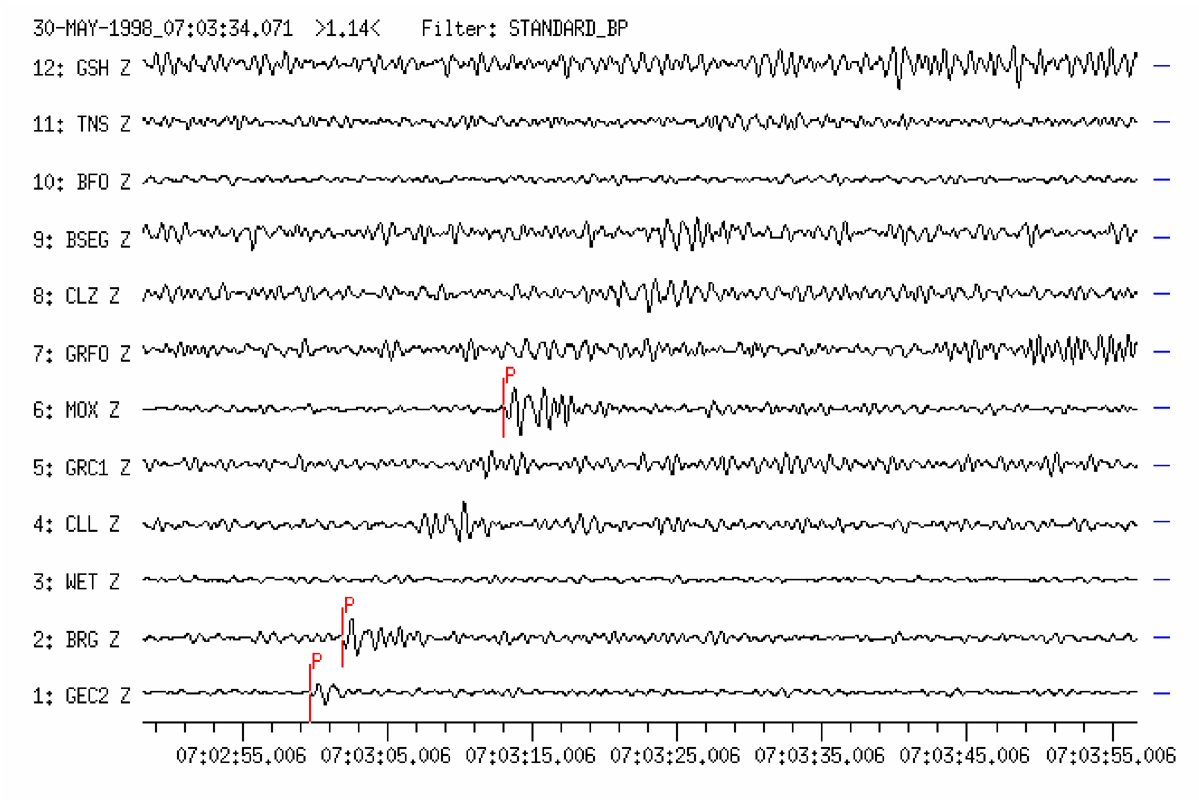

Figure 3 Records of the Pakistani underground nuclear test of 30 May 1998. For source parameters see above. The broadband records were filtered with a short-period band-pass filter (0.8 to 1.2 Hz), which has a smaller (about 0.5 octaves) bandwidth than the WWSSN-SP filter (about 1 octave). It results in a better SNR, however it is not possible to read reliable first motion polarities. In addition, the seismograms are disturbed by energy of an aftershock sequence of an earthquake in the Afghanistan-Tajikistan border region (see, e.g., Kværna et al., 2002). Note the apparently negative first onsets at stations BRG and MOX! For related discussions see 4.2 in Chapter 4 of this Manual.

3 Records of underground nuclear explosions in the regional distance range (7° < D ≤ 30°)

At shorter distances (D ≤ 30°) records from underground nuclear explosions (UNE) still contain a rather large amount of high-frequent energy. This is mainly due to the difference in the source process as compared to earthquakes (see Fig. 3.5 and the related discussions in 3.1.1.3). Two examples are shown below.

3.1 UNE at the Northern Novaya Zemlya Test Site

Source data: 1990-10-24, 14:57:58.5, 73.3310°N, 54.7570°E, depth 0 km, mb 5.7 (Richards, 2000)

The distances to the recording stations shown in Fig. 4 are: D = 9.99° (ARCES), 15.98° (FINES), 20.41° (NORES) and 30.40° (GERES).

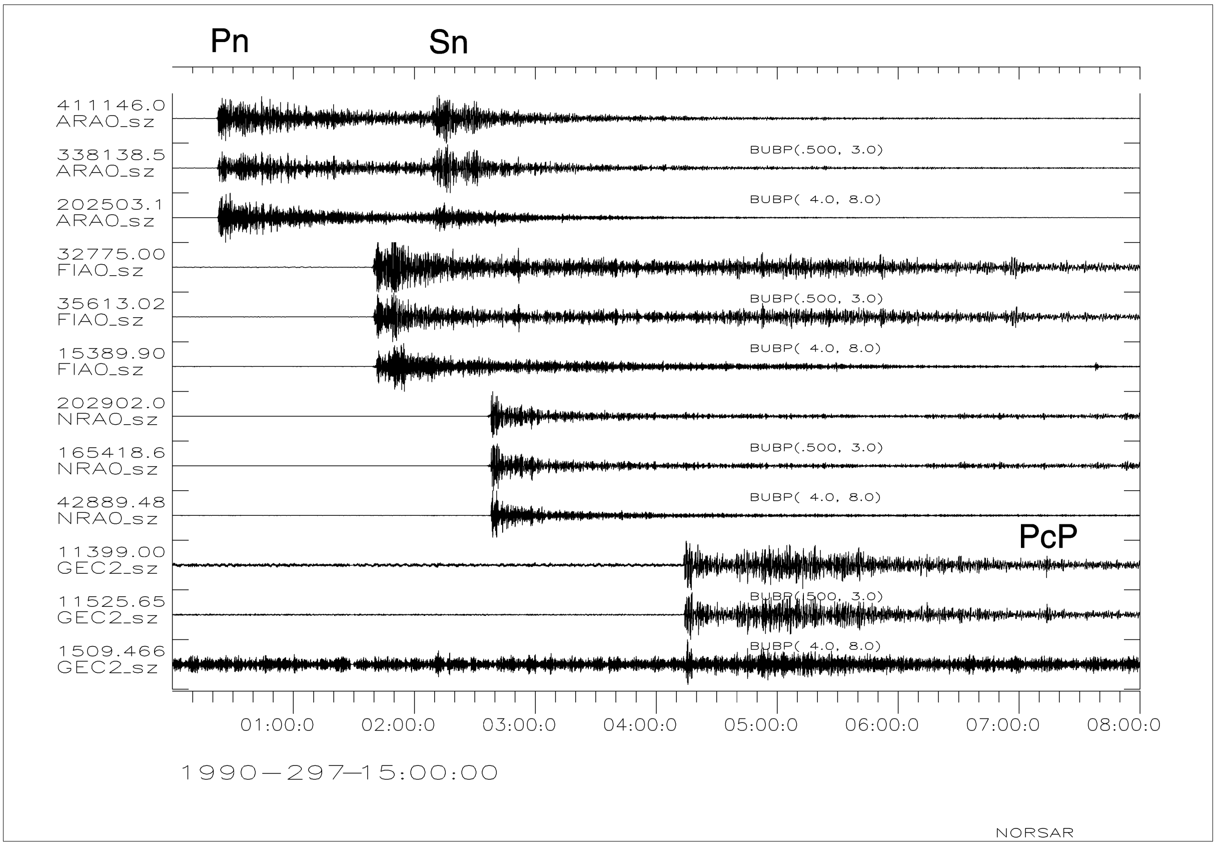

Figure 4 Records of the key stations ARA0, FIA0, NRA0 and GEC2 of the small aperture short-period arrays ARCES, FINES, NORES and GERES from the Novaya Zemlya test of 24 October 1990. These arrays are specialized for regional signals and ARCES, FINES and GERES are part of the International Monitoring System (IMS) under the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna. Shown are the vertical component records a) unfiltered, b) band-pass filtered between 0.5 and 3 Hz, c) band-pass filtered between 4 and 8 Hz. Note the relatively strong high-frequent energy that is well developed in the P-wave group up to 30° distance but no longer visible above the level of signal coda for S waves beyond 10° distance. S waves are stronger attenuated then P waves. At GEC2 the core reflection PcP is nicely visible and the P-wave coda is dominated by energy scattered in the uppermost mantle. Each trace is normalized by its maximum amplitude, which is given in digital counts together with the channel name. The time axis is labeled at each minute after 15:00:00 with 10 s between two ticks.

3.2 UNE of India in 1998

In Figure 2 we showed data of the Indian UNE of 5 May 1998 as observed in Europe. This event could also be observed at a regional distance at the Pakistani station NIL (Figure 5).

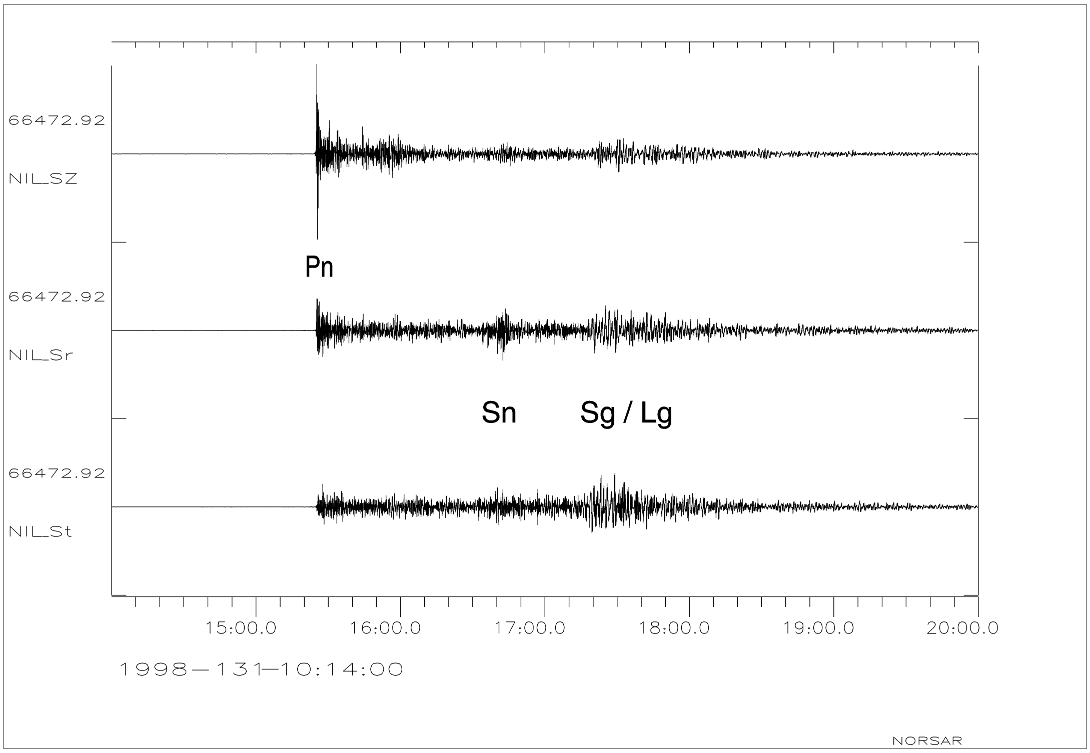

Figure 5 Z-R-T rotated three-component record at the IRIS/IDA station NIL, Pakistan. The epicentral distance to the Indian test site is about 740 km; the amplitudes are normalized by the largest signal, which is given in counts at each channel name; shown are unfiltered data. Note the strong P- but weak S-wave arrivals. The time axis is labelled for each minute after 10:14:00 with 10 s between two ticks.

References (see References under Miscellaneous in Volume 2)