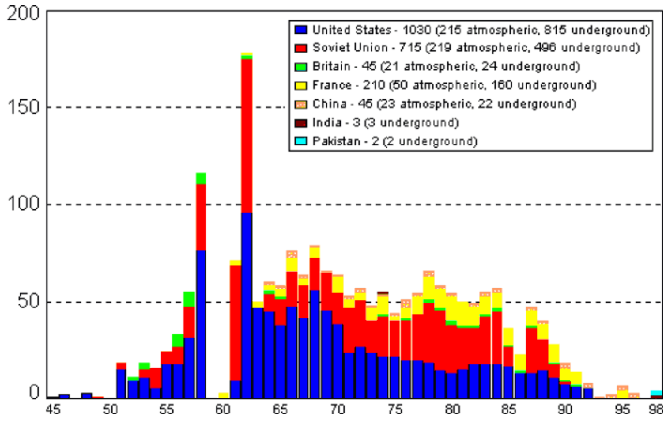
C2.5 Seismic detection of nuclear explosions

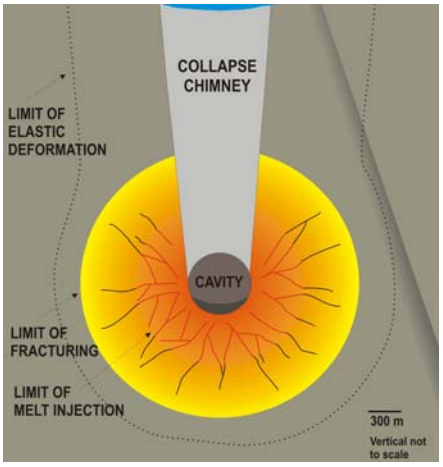
2.5.1 History

- From 1945 to 1957 nuclear weapons testing took place in the atmosphere.
- This led to increased radiation doses to civilian populations.



Nevada Test Site (NTS) http://www.answers.com/topic/nuclear-testing

- 1963 - Limited test ban treaty (LTBT) was also called the partial test ban treaty and forced many tests underground.
- France continued atmospheric nuclear testing until 1974 and China until 1980.
- Most testing after 1963 took place underground. Explosion forms a cavity underground, the roof of which usually collapses to form a rubble-filled chimney. Unless this is located at great depth, the chimney can breach the surface.



Nevada test site

- Verification through seismic monitoring.

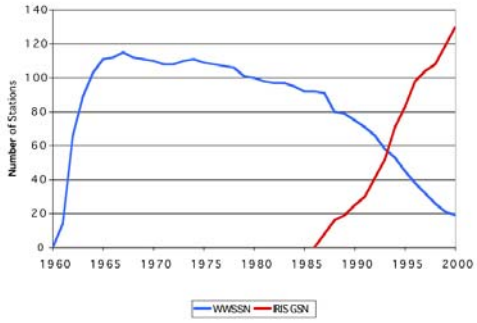
- Did South Africa conduct an atmospheric nuclear test in 1979? See details of the "Vela incident".

- Some test sites are clearly visible on satellite photographs on Google Earth and include

United States	Nevada Test site, Amchitka Island	
China	Lop Nur	
USSR	Semipalatinsk (in Kazakhstan) and	Nova Zemlaya
France	South Pacific	

- **W**orld **W**ide **S**tandardized **S**eismic **N**etwork (**WWSSN**) was deployed in the 1960's to monitor nuclear explosions. Had important side effect that it gave new seismic data that supported plate tectonics (e.g. sense of motion on transform faults).

- WWSSN now being replaced by Global Seismic Network (GSN).



- Vela Uniform project.
"*Vela Uniform incorporated seven underground nuclear tests in the continental United States and Alaska from October 1963 to July 1971. Seismic traces from multiple locations were analyzed for each of these events to develop methods for differentiating underground nuclear tests from other seismic events (such as earthquakes) and locating the test site.*" Wikipedia

  Project Longshot was part of the Vela Unifrom Project and involved an explosion on Amchitka Island in the Aleutian Islands of Alaska. It was used to study if a **subduction zone** could conceal a nuclear explosion. Explosion took place in 1965 with a yield of 70 kilotons. Slab caused early seismic arrivals because of it's high velocity (Carder et al., 1967)

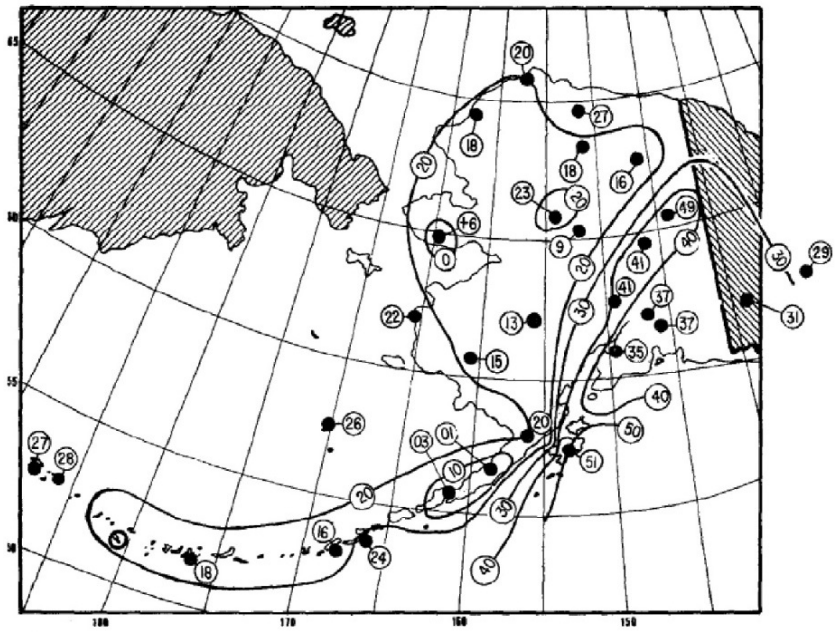
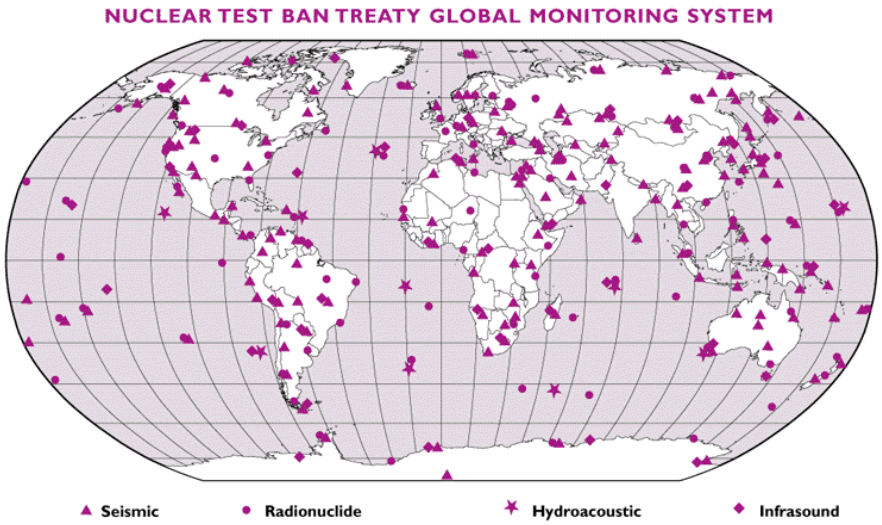


FIG. 10. Negative *P* residual contours in units of tenth seconds referred to *JB* surface-focus travel times. Reading from top down by 5° latitude zones and from left to right in each zone using residuals for reference: Barrow (20); Lay 18, Hughes (23), Tanana (9), Umiat (27), Anaktuvuk (18), Arctic (16), Circle Hot Springs (49); Cape Romanzoff (22), Nome (+6), Bethel (15), Tatalina (13), Anchorage (35), McKinley (S41), College (N41), Black Rapids (N37), Paxson (S37), Burwash (31), White Horse (29); St. Paul Island (26), Cold Bay (03), Port Heiden (01), Brooks (20), Kodiak (51); Attu (27), Shemya (28), Amchitka (open circle), Adak (18), Nikolski (16), and Unalaska (24).

- Comprehensive Test Ban Treaty (CTBT) adopted by the United Nations in 1996

Signed and ratified	France, Russia, United Kingdom
Signed but not ratified	China, Israel, United States
Not signed	India, Iran, North Korea, Pakistan

International Monitoring Service (IMS) developed to monitor nuclear tests.



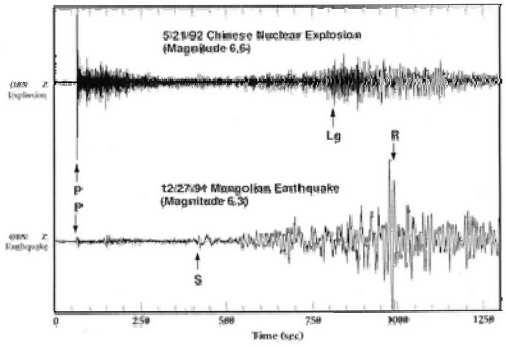
Worldwide, the International Monitoring System will consist of 321 monitoring facilities to help detect possible violations to the comprehensive nuclear test ban treaty. Approximately one-third of the planned monitoring stations are currently operational.

Sources: Coalition to Reduce Nuclear Dangers; US Department of Defense

C2.5.2 Discrimination at teleseismic distances

Most Cold War monitoring operated at teleseismic distances (> 2000 km). Several observations can be used to distinguish earthquakes from nuclear explosions.

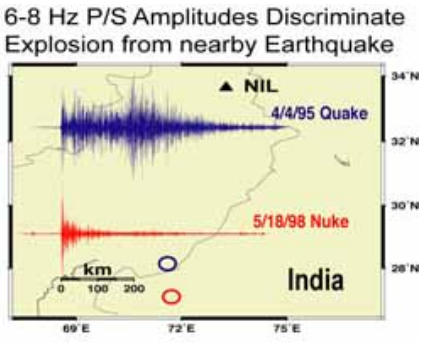
Explosions give stronger P-waves than S-waves



Example from a 1992 nuclear test at the Lop Nur test site in China, as recorded in Russia. Ground motion compared to an earthquake that occurred nearby. Both seismic signals have traveled a similar distance and should show similar amounts of attenuation.

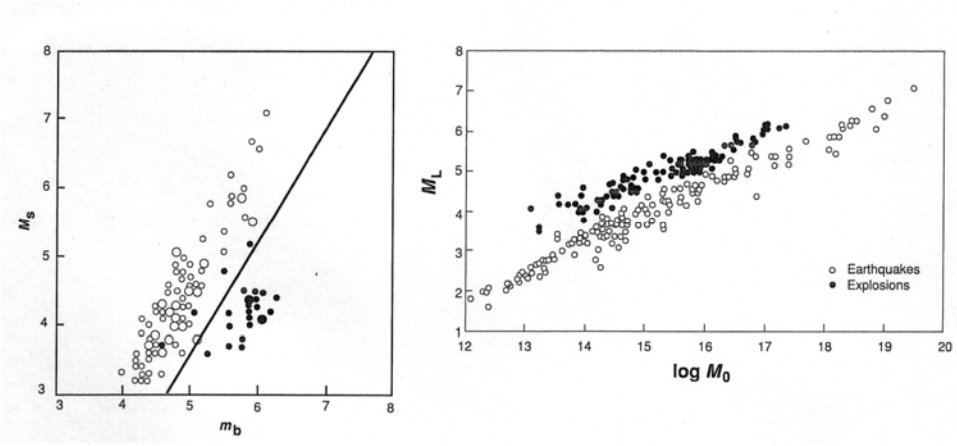
Note that the P-waves from the explosion are larger in amplitude than both the S-waves or Rayleigh waves.

http://www.iris.iris.edu/HQ/Bluebook/chapter3.html



- Seismogram recorded in Pakistan from a 1998 nuclear explosion in India.
- Compared to a regional earthquake, the nuclear explosion has a large amplitude P-waves.

Ratio of surface wave amplitudes and body wave amplitudes

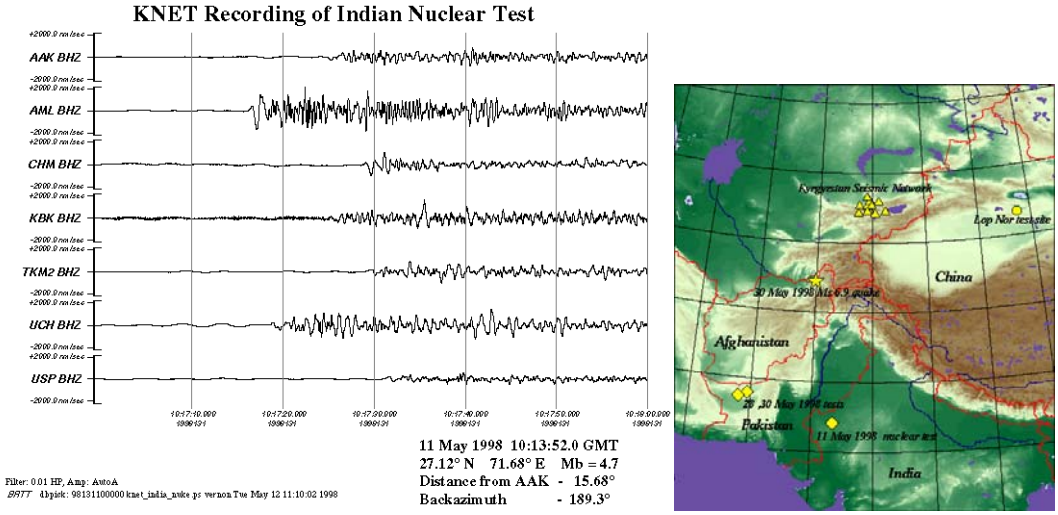


Left :Fowler 4.11a. Earthquakes and explosions in Eurasia. Solid line shows bounds between earthquakes and explosions. $m_b = 2.87+0.6M_S$

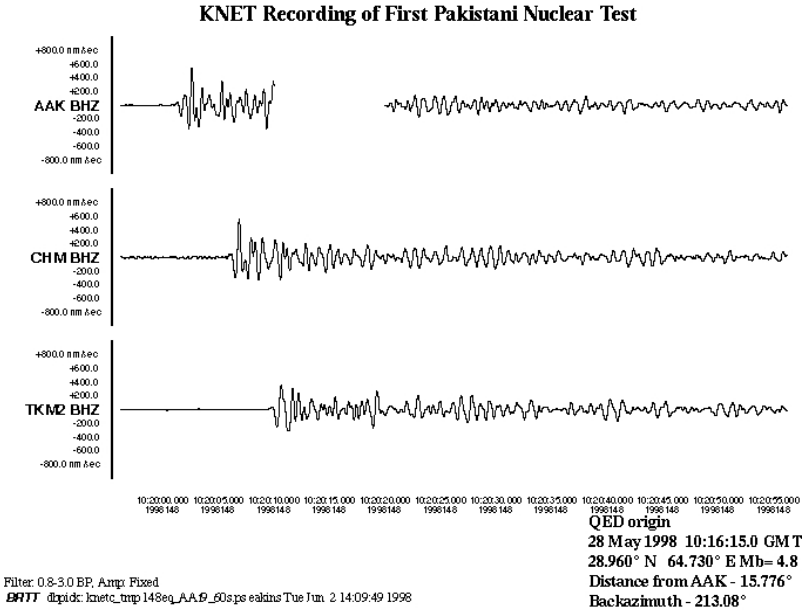
Right : Ratio of local magnitude to moment for explosions at the NTS and earthquakes in California, Nevada and Mexico : Fowler Figure 4.11b

C2.5.3 Regional detection of nuclear explosions

C2.5.3.1 Kyrgyz Broadband Seismic Network (KNET)



May 11 1998 Seismogram from : http://eqinfo.ucsd.edu/special_events/nuclear_tests/india/index.php



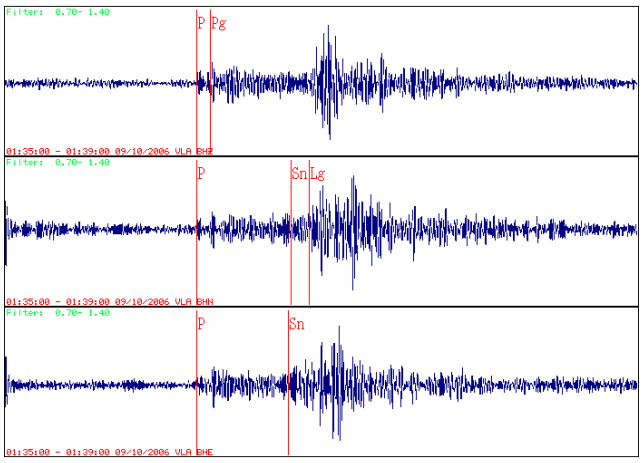
May 28 1998 Seismogram from : http://eqinfo.ucsd.edu/special_events/nuclear_tests/pakistan/index.php

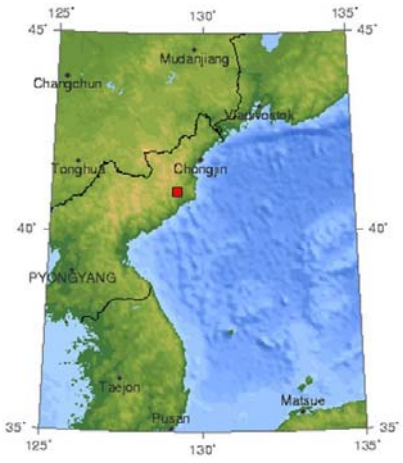
Chinese events

http://eqinfo.ucsd.edu/special_events/nuclear_tests/china/1999-01-27.php

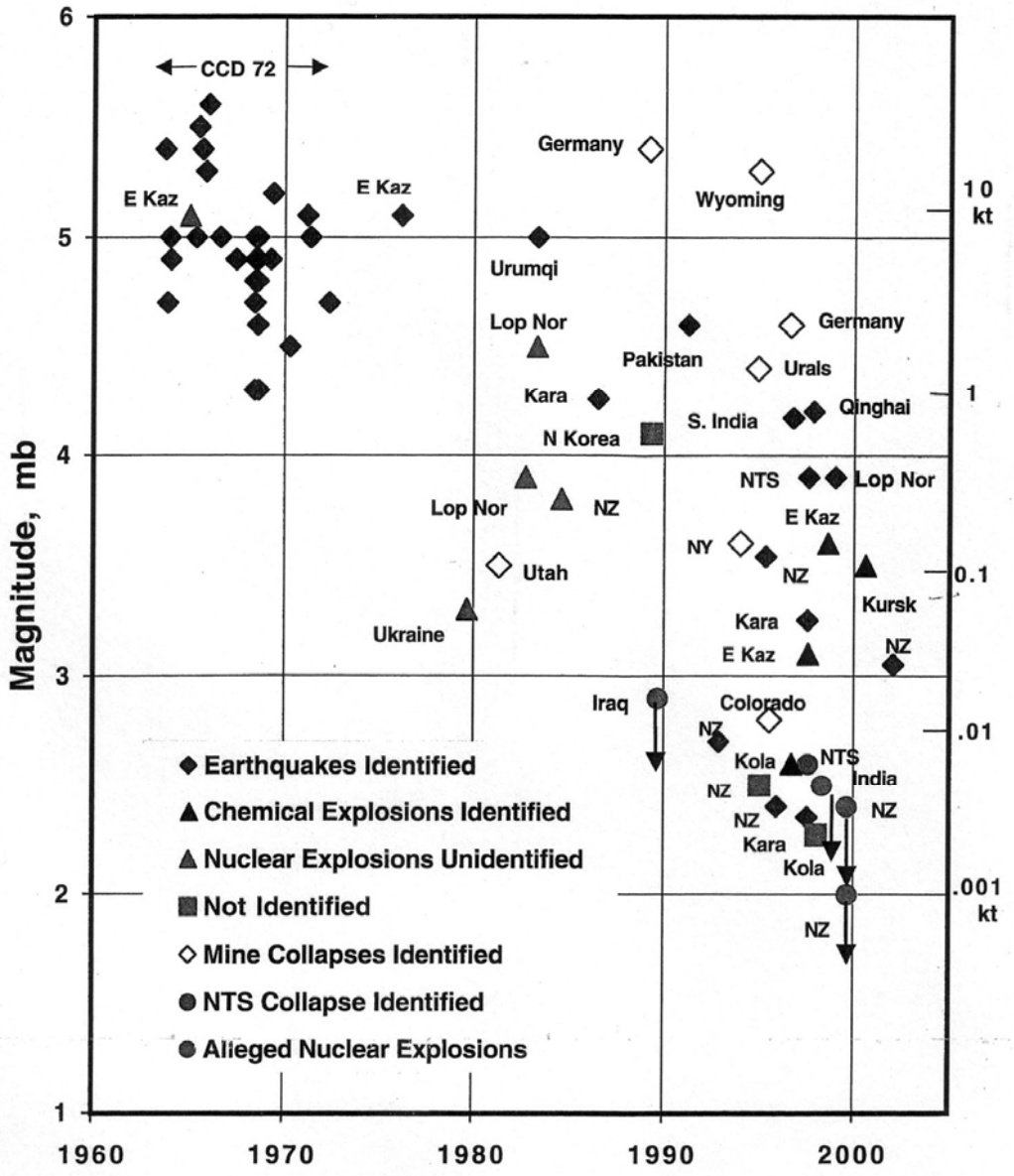
http://eqinfo.ucsd.edu/special_events/nuclear_tests/china/index.php

C2.5.3.2 North Korean explosion in 2006





C2.5.3.3 Unresolved seismic events



- Unresolved seismic events from Sykes (2002)
- Detection threshold has decreased from 1960-2000

References

Carder, D.S., et al., Seismic wave arrivals from Longshot, 0° to 27°, Bulletin of the Seismological Society of America, 57, 573-590, 1967.

Kim, W.Y., P.G. Richards, V. Adushkin, V. Ovtchinnikov, Borovoye Digital Seismogram Archive for Underground Nuclear tests during 1966-1996, http://www.iris.edu/data/reports/borDSA.pdf

Richards, P.G. and W.Y. Kim, Testing the nuclear test ban treaty, Nature, 389, 389, 781-782, 1997

Sykes, L.R., Four decades of progress in seismic identification help verify the CTBT, Eos, 83, 44, 29 October 2002.

Links

CTBT	http://www.ctbto.org/ http://www.ctbtcommission.org/
Nuclear Testing	http://www.answers.com/topic/nuclear-testing
Vela Incident 1979	http://www.answers.com/topic/vela-incident
Vela Uniform Project	http://en.wikipedia.org/wiki/Vela_Uniform
Amchitka Island	http://www.cresp.org/Amchitka/Amchitka_Final_Report/index_FinalReport.html
	http://www.phys.ualberta.ca/highlights/amchitka-edmonton-journal-june20-2004.htm