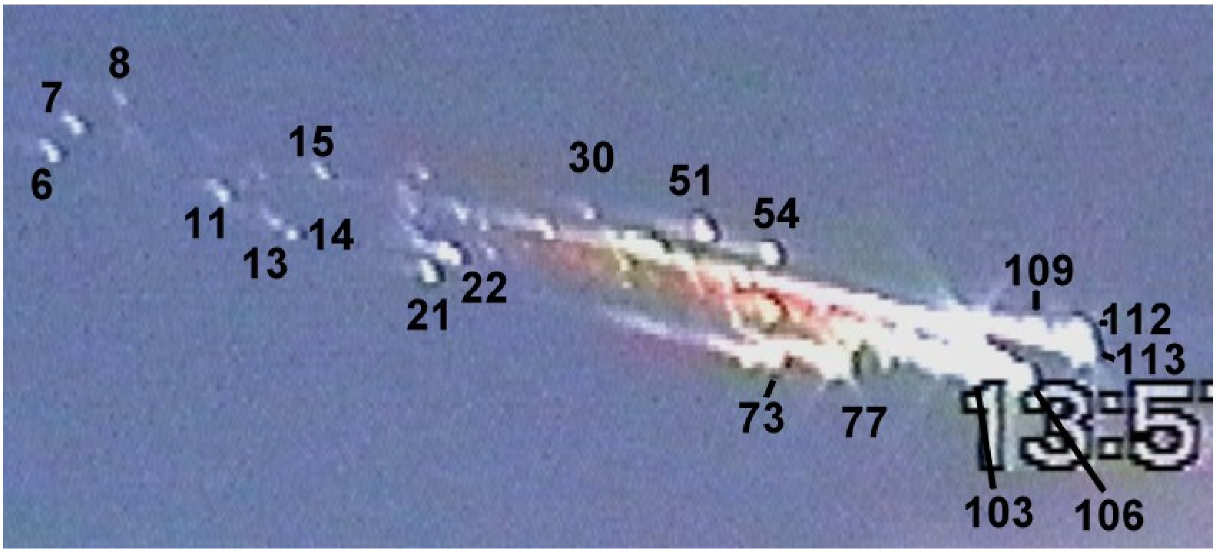
Seismic records of recent large fireballs
P.Kalenda, J.Borovička, P.Spurný, J.Pazdírková

Registration of atmospheric sources is not a typical task for seismic networks. Nevertheless, such by-product can be very useful for astronomers studying interactions of large meteoroids with the Earth's atmosphere. There were two cases in the Czech Republic since 2000, when local, regional or national seismic networks recorded sound waves that resulted from penetration of meteoric bodies through the atmosphere.

The first was **the Morávka** fireball on May 6, 2000 at 11:51 UTC. The meteoroid was about one meter in diameter and its initial entry velocity was 22 km/s, which resulted in sonic boom generation along the atmospheric trajectory from 65 km to 20 km above surface, where the body was decelerated below the speed of sound. The body suffered many explosive fragmentations during the flight. The signatures of the explosions could be identified in seismic records and the positions of fragmentation points could be localized.

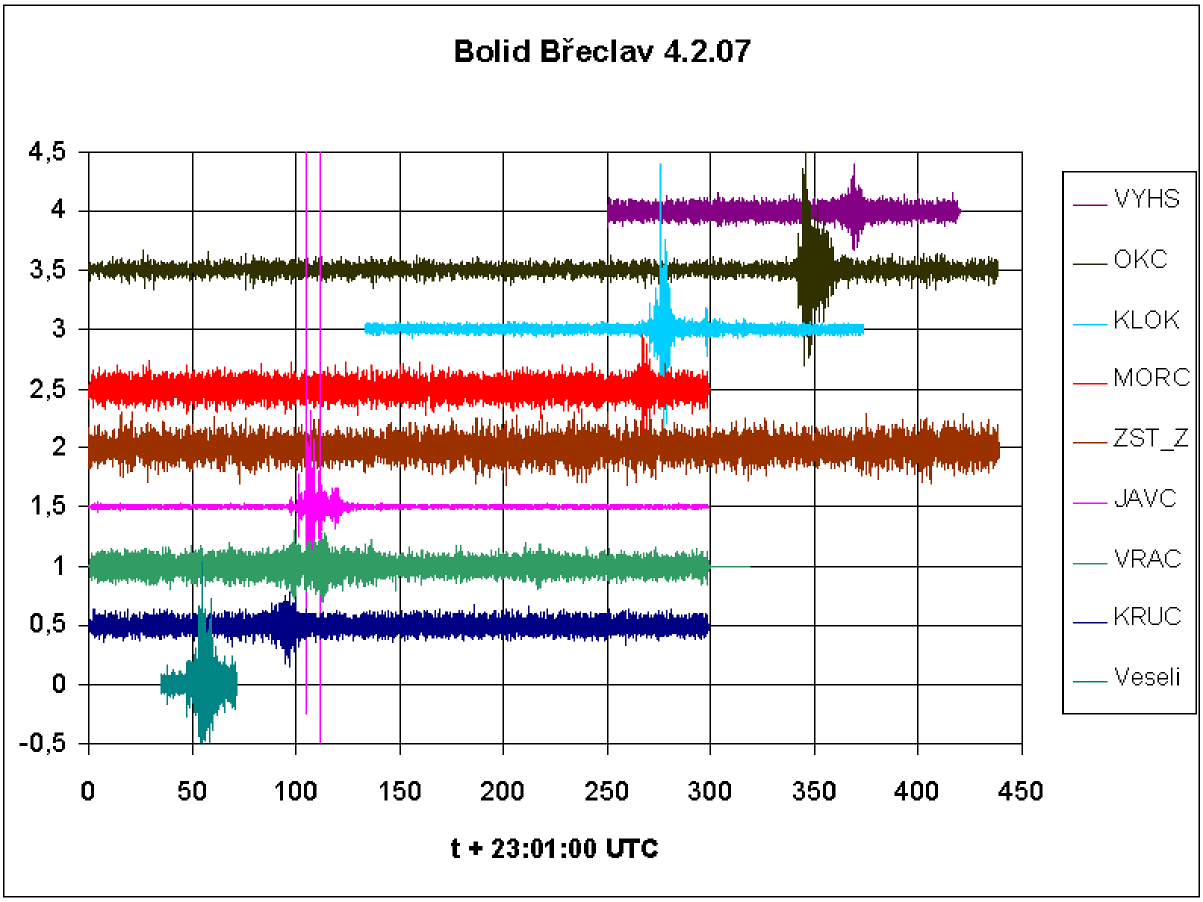
Fig. 1 – Detail of the Morávka fireball on video frame taken by J.Mišák in Kunovice



Sonic waves were recorded by a local seismic network both on the surface and in depths 700 – 1000 meters below the surface, at coal mine seismic stations. The localization of the sources of sonic booms and spherical waves generated by explosions during fireball destruction along with the video records (one frame showing extensive fragmentation is on Figure 1) enabled to determine the fireball atmospheric trajectory and its orbit in our Solar system.

The second big fireball, which was recorded by seismic stations of the national seismic network was the **Břeclav fireball** on February 4, 2007 at 22:59:15-18 UTC (see Fig.2). In contrast to the Morávka fireball, whose trajectory was rather flat (slope of 20^{o} to the surface), the Břeclav fireball penetrated through the atmosphere much steeper (72^{o}) and its destruction was sudden and complete at the height of about 37 km above Earth's surface. Its atmospheric trajectory as well as the heliocentric orbit was very precisely determined from 6 photographic records taken by all-sky cameras at 4 stations of the Czech fireball network. Seismic stations along with one sound record taken by one fireball camera close to the fireball trajectory only helped to localize the main destruction point and not the whole trajectory. The localization error of the seismic method determined by the comparison with the photographic method was few hundreds meters.

Fig. 2 - Seismic records of Břeclav fireball on seismic stations and microphone in Veselí



By comparison of the classical photographic method (fireball network) and seismic network we can say that seismic network can help with trajectory localization of big fireballs only in the specific cases of flat trajectory. On the other hand, in the case of bad weather or daylight fireballs, when photographic data from the fireball network are not available, the seismic method can be the only one, which can localize the fireball trajectory or points of its destruction. The seismic networks in the Central Europe are dense enough that at least 4 stations can record fireballs producing by interplanetary bodies larger than one meter in diameter.

Fig. 3 – Map with projection of the fireball trajectory, as it was determined from photographic records and fireball record.
Localization of the main destruction point by seismic network before (small square) and after correction to high altitude wind (small yellow arrow).

Reference:
Brown P.G., Kalenda P., ReVelle D.O., Borovicka J.: The Moravka meteorite fall: 2. Interpretation of infrasonic and seismic data *Meteorit. Planet. Sci.* **38**, 989–1003 (2003).