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Geyser's Eruptive Activity in Broadband Seismic Records

Yulia Kugaenko and Vadim Saltykov

Geophysical Survey of Russian Academy of Sciences, Kamchatka Department, Petropavlovsk-Kamchatsky, Russian Federation (ku@emsd.ru, +7-415-2258898)

A geyser is a spring characterized by intermittent discharge of water ejected turbulently and accompanied by a vapor phase (steam). The formation of geysers is due to particular hydrogeological conditions, which exist in only a few places on Earth, so they are a fairly rare phenomenon. The reasons of geyser periodicity and specifics of the activity for every particular geyser are not completely clear yet. So almost for all known geysers it is necessary to develop the personal model.

In given study we first use seismic method for detection of possible hidden feature of geyser's eruptive activity in Kamchatkan Valley of the Geysers. Broadband seismic records of geyser generated signals were obtained in hydrothermal field. The Valley of the Geysers belongs to Kronotskiy State Natural Biosphere Reserve and the UNESCO World Natural Heritage Site "Volcanoes of Kamchatka".

Neither seismological nor geophysical investigations were carried out here earlier. In September, 2009 seismic observation was organized in geyser's field by 24-bit digital output broadband seismometers (GURALP CMG-6TD flat velocity response 0.033-50 Hz).

Four geysers were surveyed: the fountain type Big and Giant geysers; the cone type Pearl geyser and the short-period Gap geyser. Seismometers were set as possible close to the geyser's surface vent (usually at the distance near 3-5 m).

Main parameters of the eruptions for the investigated geysers:
- The Giant geyser is the most powerful among the regular active geysers in Kamchatkan Valley of the Geysers. The height of the fountain reaches 30 meters, the mass of water erupted is about 40-60 tons. The main cycle of activity varies significantly: in 1945 the intervals between eruptions was near 3 hours, nowadays it is 5-6 hours. As a geyser of fountain type, the Giant geyser erupts from the 2*3 m^2 pool of water.
- The Big geyser was flooded by the lake after the natural catastrophe (giant mud-stone avalanche, formed by landslide, bed into Geiyzernaya River on June 3, 2007 and new dammed lake was formed in the Valley of the Geysers; a part of geysers has been destroyed and flooded). Some days the Big geyser was on the depth near 10 m. It got free from water in beginning of September, 2007 and reactivated. In September, 2009 eruptions were very active with the interval between them 55-60 min without quiet mode or pause in boiling.
- The Pearl geyser eruptions are near 5 min., main cycle is 300-360 min. The height of fountain is 8-10 m. It is one of most picturesque geysers in the Valley.
- The Gap geyser is the cone type geyser with stable rate and relatively shot cycle (33-34 min.). Eruptions are near 5 min. and not strong. The main feature of the Gap geyser is absence of boiling-effusion mode before eruption.

For the large Big and Pearl geysers low-frequency seismic response on geyser's eruption was detected. Seismometer shows surface deformation caused by water-steam burst from the vent (or geyser eruption) with the period about 10-12 min. Slow vertical and radial displacements were recorded as travel of instrument's mass position. It was shown, that eruptions of the Big geyser are not constant. We can observe it in seismic records at different frequency bands. Some eruptions are weaker then other in low-frequency band (lesser then 0.01 Hz), but approximately similar for the range 20-50 Hz. It means possible deep variations of thermal supply.

The weak short-period Gap geyser has high stability of eruptive activity in seismic records at frequency band 1-50 Hz. The correlation between envelops for different geyser's cycles exceeds 0.9. It demonstrates the invariability of thermal and water supply of this geyser. The seismic record of the eruption cycle starts with the activity increasing in intensity and amplitude, and than signal amplitude gradually decays until the final moment before an eruption. The amplitude decay was explained by (Kieffer, 1984) by an increased acoustic impedance mismatch between the two-phase steam mixture and the conduit wall, due to an increased amount of steam in final stages of boiling.

The most important result is detection of hidden underground geyser in the area of the Giant geyser. Its deep activity is recorded by seismometer (by seismic and mass position channels) as very stable quasi-periodic oscillations with period 16-18 min. Earlier the existents of the underground geyser was assumed due to observation of intense bursts with such periodicity during boiling-effusion mode berofe every eruption of the Giant geyser. So the supposed underground geyser was accounted as the main heat provider and the principal cause of the Giant geyser eruptions. We named this deep quasi-periodic source of seismic signal (underground geyser) "Heart of Giant".

As a result of that, our reconnaissance seismic survey is informative and shows some new facts about geysers, which were not detected earlier by other most traditional methods of geyser study. The main task for future seismic research in the Valley of the Geysers is the location and more particular analysis of the underground "Heart of Giant" geyser.