The Kirovskiy Explosion of September 29, 1996: Example of a CTB Event Notification for a Routine Mining Blast

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Abstract—On September 29, 1996, a routine mining blast of about 390 metric tons was detonated underground at the Kirovskiy mine in the central Kola Peninsula. The United States was notified two weeks in advance that the blast was to take place and was given the date, approximate time, location and total charge. The explosion was detected and located by the prototype International Data Center (pIDC) and published in the Reviewed Event Bulletin (REB). Detailed information about the blast, including the type and depth of mining operation, the underground charge configuration, and the blasting delay pattern, is reviewed and combined with a seismological analysis of the event. The seismic analysis points to a possible associated tectonic component to the blast, consisting of a small rock burst or induced tremor, spall, or some combination of these mechanisms, that may have enhanced the shear waves, produced large $R_g$ waves at low frequency, and small $Pn/Sn$ and $Pn/Lg$ amplitude ratios at high frequency. While these discriminants might identify the event as an earthquake, the spectral/cepstral analysis of the event clearly shows the ripple-fire delays. This event provides important confidence-building measures for both location calibration, in the form of travel-time corrections for location of mine events in this region, and for improved understanding of seismic discriminants expected for large mine blasts that may have an associated induced tectonic component (e.g., spall, mine tremor or rock burst).

Key words: Mining, explosion, ripple-fire, discrimination, confidence building.

Introduction

On September 29, 1996, a routine mining blast of about 390 metric tons was detonated underground at the “Rudnik” shaft of the Kirovskiy mining combine, located in the central Kola Peninsula. This blast was unusual, in that the United States was notified\textsuperscript{3} two weeks in advance that the blast was to take place and was given the date, time, location and approximate total charge. The blast occurred underground at nuclear-test containment (200–300 m) depths in a region of intense mining activity, where both surface and underground mining operations occur and

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\textsuperscript{3} The United States was notified on September 18, 1997, by facsimile from the Russian Ministry of Defense, Special Monitoring Service, to the U.S. Deputy Assistant Secretary of Defense for Nuclear Treaty Monitoring.
the potential exists for underground cavity creation. The mining techniques employed in the region are relatively common, and therefore, they represent a potential source of network-locatable underground events.

The explosion was detected and located by the prototype International Data Center (pIDC), published in the Reviewed Event Bulletin (REB), and had a magnitude ($M_L = 3.4$) in the range of a small-scale or cavity-decoupled nuclear test. Having occurred only days after the adoption of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) by the United Nations, this event is the first example of the pre-notification of an explosion under the voluntary confidence building measures of the CTBT.

Analysis of this event provides a detailed picture of a type of underground mining explosion that will be detected by the CTBT International Monitoring System (IMS). We have collected detailed information on the September 29, 1996 blast (hereafter, the “Kirovskiy blast”), including the type and depth of mining operation, the underground charge configuration, and the blasting delay pattern. We have also completed a detailed seismological analysis, evaluating spectral discriminants and performing cepstral analysis to detect ripple-fire. Our main objective in this study has been to determine if the seismic data analysis can confirm the information provided in the pre-blast notification for purposes of confidence building under CTBT.

**Mining Operations**

The Kirovskiy mine is located in the Khibiny Mountains of the central Kola Peninsula (Fig. 1). In this heavily mined area, where rich apatite (calcium phosphate) and related ores are excavated as the principal raw material for Russia’s superphosphate industry. Khibiny operations accounted for 70% of all phosphate mined in the former Soviet Union (Levine, 1989). The Kirovskiy mine is one of the largest underground mining enterprises in Russia, in terms of production capacity, and the ores are excavated from the greatest depths of underground development in the Khibiny massif.

The location uncertainty ellipse reported in the REB is plotted on Figure 1. The REB location is offset about 40 km northwest of the actual mine location, and the ellipse does not contain the Kirovskiy mine but actually encompasses a different mining region. This points up the need for location calibration, and this event, in fact, will serve as a useful reference event for location calibration in the region.

The underground ore body is elongate, 12 km in length, with a thickness ranging from 50 to 300 m. The rock massif is distinguished by its high strength (approaching that of granites), structural irregularities of various scales (from the Saam fault, with a thickness of 2–5 m, to a network of small fractures, with spacings from 0.1 to 1 m),