

## **A MINE EXPLOSION SOURCE PHENOMENOLOGY EXPERIMENT**

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### **ABSTRACT**

The seismic and acoustic discrimination of large surface and underground mine blasts, including mine collapses and rock bursts, continues to be a difficult scientific problem (Report of a Working Group from Government, Industry and National Laboratories, 1999). Under a Comprehensive Nuclear-Test-Ban Treaty monitoring regime the discrimination of signals from such large mine blasts may be ambiguous. The difficulty is due, in part, to the lack of complete understanding of the source models for the seismic and acoustic signals, the fact that mines operate in both soft and hard rock environments, use different blasting techniques and signals from such activities will most likely be recorded regionally, which are difficult to interpret. Alternatively, if controlled mine blast experiments could be performed, in close collaboration with the mining industry, significant knowledge could be gleaned to reduce the chance of false alarms from such mining activities and, hopefully, provide the mining industry with useful information to conduct more cost-effective blasting operations. In addition, these experiments could also be used to provide important empirical calibration information for the International Monitoring System (IMS). It is important to conduct such experiments in the full spectrum of mining locales and geographical regions, including both hard and soft rock environments. One of the goals of this effort is to engage the mining industry in a variety of collaborative experimental field efforts in which both the seismic monitoring community and mining industry benefit from the resulting exchange of ideas and information.

In concert with the above, a controlled mining experiment was suggested by Walter *et al.*, 1999, in which a surface delayed-fired production explosion and a buried single explosion (zero delay) are collocated and detonated simultaneously. This experiment would provide valuable insight into answering important scientific issues related to source phenomenology, depth of burial effects, and regional effects on seismic wave propagation and useful IMS calibration information.

As part of its effort, Weston Geophysical has arranged, in principle, the collaboration of a major mining company, to conduct the experiment described by Walter *et al.*, at one of its hard rock mines in South America. As part of the collaboration, the mining company has agreed to pay all expenses related to detonating the controlled blasts. The mine under consideration routinely conducts both surface (open pit) and below ground (block caving) operations. The company has made available extensive information regarding its mining operations, detailed geological information and will provide major logistical support to participants at its mine during the experiment. In addition, it will allow participants access into the mine for the purposes of recording both seismic, acoustic and video near - source data. Also, the mine is located in a geographic area that is extremely interesting from a scientific perspective in terms of tectonics and earthquake activity. Consequently, numerous scientific experiments will be taking place at regional distances from the mine, supported by other funding agencies, which can be leveraged by all parties to enhance the results from individual efforts.

### **OBJECTIVES**

The objective is to identify and develop cooperative targets of opportunity with the mining industry that will result in field experiments to seismically calibrate the International Monitoring System (IMS), reduce the ambiguity of identifying seismic signals from mines and, at the same time, be of use to the mining industry to improve its blasting techniques. These cooperative experiments will involve monitoring mine blasts of routine production explosions, e.g., delay or ripple fired, and in certain instances conducting and monitoring mine explosions designed to answer specific technical questions. It is also stressed that an inherent goal of this effort is to develop a symbiotic

relationship with the mining industry to provide mining engineers information that will be useful in their design and execution of production blasts and for the seismic monitoring research community to improve discrimination capability.

The Preparatory Commission (PrepCom) of the Comprehensive Nuclear-Test Ban Treaty Organization, under the auspices of Working Group B (CTBTO/WGB), has identified the need for highly focused research to provide regionalized travel times to improve seismic event location methods to be used in the International Data Centre (PrepCom, 1999). Regional seismic calibration will be useful to help reduce event location uncertainty and improve the location accuracy. WGB has recommended the enhancement of existing ground truth databases through the collection of pertinent information such as may be provided by chemical mining explosions and well-recorded earthquakes. It also suggested that mining explosions that may be recorded on more than one IMS station should be given priority and cooperation with the mining industry is encouraged in order to obtain detailed information on the mining explosion characteristics such as its explosive size, spatial and temporal distribution. There are numerous other reasons to study mining explosions in the context of treaty monitoring. For example, the identification of large chemical mining explosions may be problematical under certain conditions as no validated seismic discriminants exist for mine blasts. Also, a field experiment has been proposed (Walter *et al.*, 2000) to aid in determining the differences in source phenomenology between a surface production mine explosion and a buried fully contained nuclear test. Such an experiment would also address long-standing nuclear test evasion concerns regarding the possible “masking” of an underground nuclear explosion within the confines of a working mine.

The objective of this research is twofold: (1) implement the recommendations of the CTBTO’s WGB to develop improved empirical travel times needed to calibrate the IMS and (2) to decrease the ambiguity of seismic signals from mining operations. Progress towards both of these goals may be achieved by executing the field experiment proposed by Walter *et al.* Such an experiment should ideally be carried out within an active mine that routinely conducts both surface and underground operations at the same location. A large copper mine meeting these criteria has been identified within 100 kilometers of Santiago, Chile. The seismic signals from explosions at this mine could be recorded at numerous IMS stations, including primary and auxiliary stations and both infrasound and hydroacoustic stations within the southern part of the continent.

The mining company has agreed, in principle, to conduct collocated surface and underground explosions, pay for the explosives, preparation of the shots and the associated logistics. It will further cooperate by allowing the installation of near source instrumentation within the mine, providing information on the mine’s geology and rock properties and detailed information related to the characteristics of its production blasts.

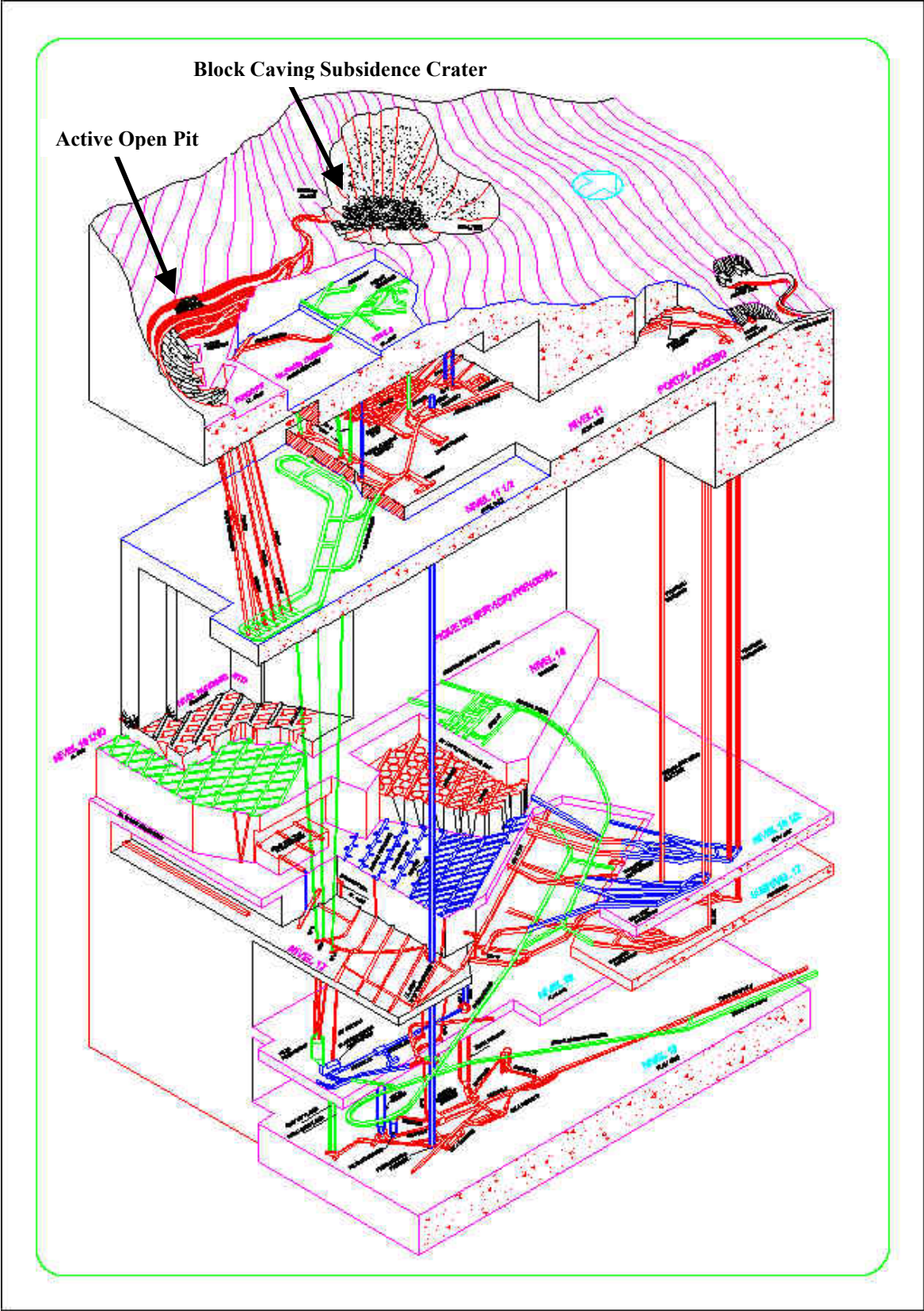
As noted earlier, operations at this copper mine consist of both open pit and underground extraction. The underground extraction is performed using block caving, as well as mechanical extraction, depending on the degree of rock fracture. The mine’s operations are conducted at an elevation of 3500–4000 meters. Adverse weather conditions during part of the year dictate that all extraction processes and operations take place below the surface. Because the mine conducts very extensive operations below the surface, it provides ample opportunity to conduct an experiment of the type described by Walter *et al.*, i.e., a collocated surface delay fired production explosion at a location just above a single fired fully contained explosion. There are a myriad of abandoned tunnels and drifts at various depths that provide an opportunity for conducting such collocated explosion pairs. Existing operations allow for the explosions to be located directly above one another, i.e., the open pit is currently directly above the block caving extraction process, see Figure 1. The experiment is currently being planned to take place in early 2002. As production continues, the geometry of the experiment could be altered but, hopefully, not significantly. The draft test plan, which is still evolving, calls for seismic instrumentation to be installed within the mine’s boundaries, generally within five kilometers of the explosions. Approximately 5–7 sites would be occupied in the mine. These data will provide detailed information to formulate a seismic source model for the explosions. Another critical aspect of the test plan would be to acquire regional seismograms to improve knowledge of how the geology affects the radiated seismic energy. A number of international research efforts are currently underway or being planned to record data in the Andes. By cooperating with these other groups, e.g., the Universidad de Chile and University of Arizona, resources would be leveraged. For example, the University of Arizona (S. Beck and T. Wallace, private communication, 2000) will be conducting an extensive field deployment and has agreed, in principle, to cooperate by allowing use of its communication links and other resources, including instrument deployment at regional distances, as logistics permit. Plans are currently being made to finalize the test plan for this experiment in order to conduct the experiment in early 2002.

## **REFERENCES**

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**Figure 1.** This figure shows the open pit operation which is collocated above the block caving operations. The close proximity of the open pit and the subsidence crater from block caving operations can be seen.