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# A remote, wireless microseismic monitoring system

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## ABSTRACT

This paper discusses the design, installation, and performance of a remote microseismic monitoring system in a mountainous terrain. The system was designed to detect local seismic events that could be precursors of a landslide or indicators of seismic activity related to hydrocarbon production in the area. Six 3-component seismic stations were installed on Turtle Mtn., Alberta, Canada - site of North America's most fatal landslide in 1903. The area is also host to considerable natural gas production. We discuss the sensors used, recording apparatus, data transmission, marshalling, and storage. Event detection algorithms have been developed and hypocentre determination codes emplaced. We provide an overview of recent results.

## INTRODUCTION

Considerable attention has been directed toward seismic activity in oilfields as well as in earthquake and landslide-prone areas. In this paper, we discuss a system built for landslide applications which also can be used to monitor potential seismic events associated with gas production efforts. This case is from the Crowsnest Pass area of southern Alberta – renowned for the calamitous Frank Slide in 1903 and numerous rockfalls on Turtle Mountain since then (see Figure 1).

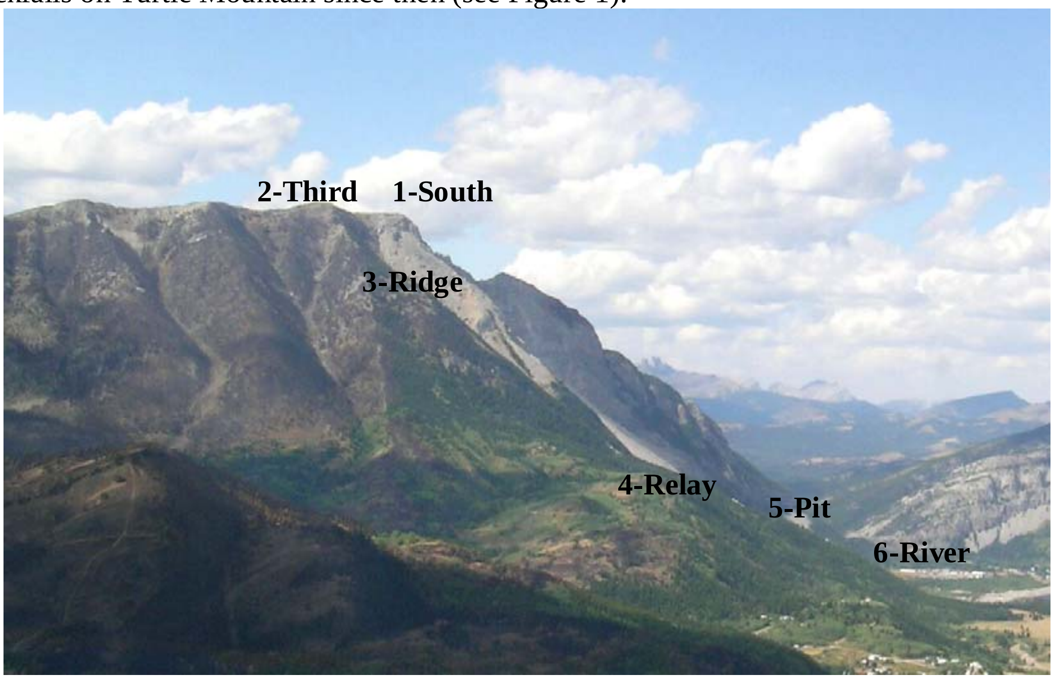


Fig. 1. View of Turtle Mountain, Alberta, Canada. The town of Hillcrest is visible in the lower right. The six seismic stations are indicated. They are concentrated in the two areas thought to be subject to the greatest deformation (South Peak summit and coal mine workings).

The mountain is comprised of an unstable anticlinal structure (Jones, 1993; AGS, 2003) with a number of large fractures in evidence on its summit.The mountain's tragic history, inherent instability, and nearby towns and infrastructure made it a candidate for detailed assessment (Read, 2002). The primary goal of the monitoring system described in this paper is to detect microseisimc events emanating from fracturing or deformation within the mountain.

## MONITORING SYSTEM

The monitoring system consists of six remote seismic sensors and transmitters. The stations are in two-way radio (2.4GHz) communication with a control centre (data processing, visualization and archival facility) at the provincially operated Frank Slide Interpretive Centre (FSIC). The sensors are distributed in a pattern such that sources originating from likely zones of seismicity within the mountain are to be detected. Regions targeted as likely candidates for generating microseismic events are near the South and Third Peak summits as well as on the mountain's eastern flank on the trend of the historic (post-1903) coal mining operations. Final decisions regarding locations were driven by these targeted regions, as well as the necessity for: visibility from the FSIC (for the radio link); good southern exposure (for maximum solar power generation); accessibility by foot in the summer and winter; and, the unlikelihood of being in any likely rock or snow slide paths. We conducted accuracy tests, using synthetic data and a model of the mountain's velocity structure, for the location of hypocentres using a variety of source locations and receiver distributions. We found that, given reasonable signal-to-noise ratios, six stations should provide adequate locations (errors within about a 50m radius).

We are using three triaxial (or three-component) geophones connected in series as the motion sensing units. The 28Hz geophones were set and cemented in outcrops (or the best facsimile thereof) some 10m from the recording equipment. We had conducted hammer and thumper seismic tests on the flanks of the mountain to estimate what frequencies we could expect. We observed that most transmitted energy was below 250Hz. The geophones were then encased in cement and connected via cable in a metal conduit to the data acquisition and pre-processing modules. Each station is also equipped with a GPS antenna for synchronizing the seismic data with recordings from the other stations. Batteries (12V, deep-cycle) and solar panels (100W) provide power to the radio, recording electronics, and the GPS (see Figure 2).

The Crowsnest Pass area features picturesque landscapes along with a fascinating, and occasionally turbulent, history. It is one of the windiest places in North America. Indeed, during Chinooks (warm winds) it is not uncommon for the weather station that sits just west of a ridge connecting Third and South Peaks to record speeds in excess of 150 km/h. This necessitated considerable effort designing the stations, in particular the solar panel mounting mechanism, so that they are not buffeted by strong gusts. We estimate that a gust of 180 km/h results in a force of nearly 400 lbs on each of the four guy wires supporting the mast.

## INSTALLING THE MOUNTAIN SYSTEM

Installation commenced in late November of 2003. Because of the hazardous alpine winter conditions, we contracted a professional mountain operations company (Vertical Systems Inc. of Canmore, Alberta) to assist us. This commenced with a mountain safety course which included instruction on clothing, industrial safety and regulations, logistics, emergency medicine, and a trip to Grotto Mountain, Alberta to practice safe alpine travel habits and route finding skills. As well, during the helicopter assisted installation trips, we contracted VSI to accompany us, during which they were responsible for the long-line slinging operations and route finding (particularly important given the early snowfalls and attendant avalanche hazard).

Fig. 2. Installing the seismic monitoring system on South Peak of Turtle Mt., Alberta.

Helicopters (from Bighorn Helicopters Ltd. from Cranbrook, B.C.) transported equipment and personnel with an A-Star 350D. Generally, it was possible to transport the heavy equipment (batteries, vaults, masts, solar panels, and conduit) via long-line slings to within a few metres of all the stations. As well, all the stations were within a ten or fifteen minute walk to helicopter landing sites, thereby minimizing the time spent travelling to the stations.

Installation commenced with drilling and emplacing rock bolts for guying the masts. Once the masts were erected, the battery vaults were secured and batteries deposited in them. Geophone conduit (with previously inserted geophone cable) was then deployed. The crown assemblies with GPS and radio antenna were attached to the top of the mast. Subsequently, the solar panels and electronics enclosures were also attached to the mast. A heli-portable drilling systems was also airlifted to the mountain and it drilled a shallow hole from the emplacement of two 3-component geophones.

## RESULTS

We have recorded a number of local seismic events on the system since its installation. One such event, located inside the mountain, is shown in Figure 3. The system has been serviced and updated a number of times, but is now producing reasonable data.

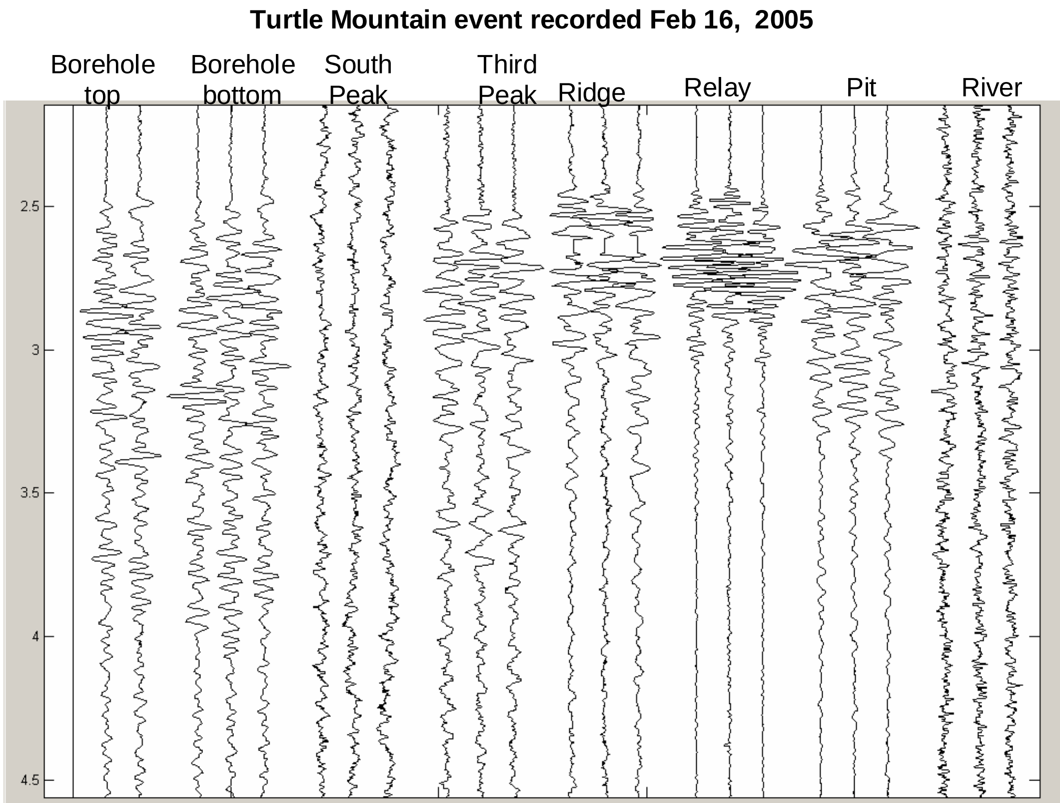


Fig. 3. An event, recorded on six seismic stations, located inside Turtle Mtn.

## SUMMARY

The surface seismic array on Turtle Mountain consists of remote, radio-enabled seismic sensors and transmitters. The stations are distributed in a pattern such that seismic sources originating from likely zones of seismicity within the mountain are to be detected. The station locations were chosen to be proximal to likely sources of microseismicity, but also constrained by topographic, safety, and vegetative factors. The rugged nature of the mountain and its adverse weather constrains the design of many of the station components. Each station includes a geophone, a recorder, a GPS antenna, a radio, and solar-charged batteries. The system is currently running with data transmission to the Frank Slide Interpretive Centre, archiving there, internet retrieval, and attendant analysis.

## REFERENCES

AGS, 2003, Implementation of a state-of-the-art monitoring system on Turtle Mountain: Rock Chips: Alberta Geological Survey newsletter, Fall/Winter 2003.

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