The Exshaw Quarry on Grotto Mountain, near Canmore, Alberta and possible rock-slide hazard in the area

Historical background, tour notes, discussion and recommendations

Voluntary, non-professional report offered at no charge to the Town of Canmore, Province of Alberta, Graymont Inc. and any other interested parties

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Summary

Limestone removal at the Exshaw Quarry on the southwestern slope of Grotto Mountain has been ongoing for many years. The quarry is now quite large. As an area resident with an Earth-science background, I am concerned that the loss of so much rock at the base of the mountain might possibly be destabilizing, such that a large rock slide could occur.

If that happens, in addition to loss of life in the area of the slide itself, there could be severe consequences for the town of Canmore, even though the town does not lie directly below the slope in question. The Bow River runs nearby, and central Canmore is not far upstream, built on the floodplain. A slide sufficiently large to block the river might back the water up into the town.

Responding to my concerns, quarry operator Graymont Western Canada Inc. was kind enough to hold a tour on 1 November 2016 for several Town of Canmore staff and me. The tour leaders highlighted the company's methods for ensuring safety in and about the quarry. They assured me that there was no slide hazard. I wish I could agree, but I'm still troubled. Here's why.

1. There is clear evidence of slide activity on Grotto Mountain in the geological past.

2. Slide hazard within and above the quarry may not have been evaluated during government approval of the quarry many years ago and may remain unstudied to this day.

3. The quarry amounts to a long, deep notch along the slope, low down. This has worrisome implications for the stability of the mountain.

4. Current monitoring of rock stability is limited to the quarry and is done by observation only, without any instrumentation anywhere on the mountain.

5. The provincial government seems not to have any formal regulatory oversight of geotechnical matters, apart from a worker's safety point of view.

This leads me to recommend that the Town of Canmore obtain as many relevant documents as possible from government and company sources, and that these documents be examined by a fully independent, qualified professional in this field. If it appears that a thorough, currently applicable evaluation of slide hazard and risk to the town has not been made, then a rigorous, peer-reviewable study should be carried out as soon as possible. Should the results show significant danger, then methods of slide prevention, impact reduction and emergency response need to be considered.

1. Introduction

The Rockies of Alberta and British Columbia are landslide country. I'm not an expert on landslides, but I do have a university degree in Earth science and a deep interest in Canadian Rockies geology, as evidenced by my books, lectures, museum exhibits and interpretive tours. Landslides have always been a special interest. (For more information about me, including my résumé, please go to my website, bengadd.com.)

I have learned to recognize the evidence for past slide activity in this region, and I am aware of the stratigraphic, structural and geomorphic combinations that favor slide occurrence here.

Ever since the Exshaw Quarry came to my attention in the 1980s—one couldn't help but notice the quarry increasing in size along the southwestern slope of Grotto Mountain—I have wondered about its effect on the stability of the mountain. These days my family and I live in the town of Canmore, which is located not far from the quarry. My concern has grown along with the quarry.

On August 14, 2014, by e-mail I alerted Andy Esarte, Manager Engineering Services, Town of Canmore, that I was concerned about possible rock-slide hazard on Grotto Mountain associated with the quarrying operation there. (I am not concerned about slide hazard from the adjoining Burnco Rock Products gravel pit, which seems to be removing only surficial deposits, not bedrock.)

Félix Camiré, Project Engineer in Andy's department, was kind enough to respond several times over the past 27 months, answering my questions and attempting to gather the information I requested.

In June of 2016 Félix let me know that he was trying to organize a tour of the quarry in cooperation with the company. I had not asked for this, but it certainly seemed to be a good idea. On November 1, 2016, the event was held, and it was excellent. Many thanks to Félix and Graymont.

This report details what I saw and learned on the tour, with additional information and discussion that may be useful to anyone interested in the matter. My recommendations are included at the end.

For the record, this report is strictly my own work. It has no professional status. I was not paid or otherwise rewarded to research and write it. I have no monetary interest in Graymont or the Exshaw Quarry, or in any rival company, nor do I wish to hinder Graymont in any way. My interest is strictly that of a knowledgeable and concerned citizen.

2. Location and historical background

Graymont's Exshaw Quarry is a limestone quarry located near the town of Canmore, Alberta on the southwestern slope of Grotto Mountain. (See figures 1 and 2, next page.) GPS coordinates for the centre of the quarry are latitude 51.0659 north, longitude 115.2779 west.

Grotto Mountain is located in the Fairholme Range, one of the front ranges of the Rocky Mountains. The mountain is 7 km long from northwest to southeast and 3.6 km wide from southwest to northeast. The summit elevation is 2706 m above sea level. The base lies at approximately 1300 m along the floodplain of the Bow River. The topographic relief is 1400 m (1.4 km of elevation gain) and the slopes are fairly steep, averaging 20–30°.

The quarry's area of disturbance is about 3 km long from northwest to southeast and up to 0.5 km wide from northeast to southwest. The most striking feature is the steeply sloping, planar quarry face—the "footwall," as Graymont refers to it—2.7 km long and about 200 m high (vertical distance). The size of the footwall slope varies along the length of the quarry, reaching a maximum of about 350 m from base to top.

The northwestern edge of the quarry lies 1.2 km southeast of the closest town habitation (horse stables and Alpine Club of Canada buildings) and 2.0 km from the edge of the town's built-up area, which is an industrial park.

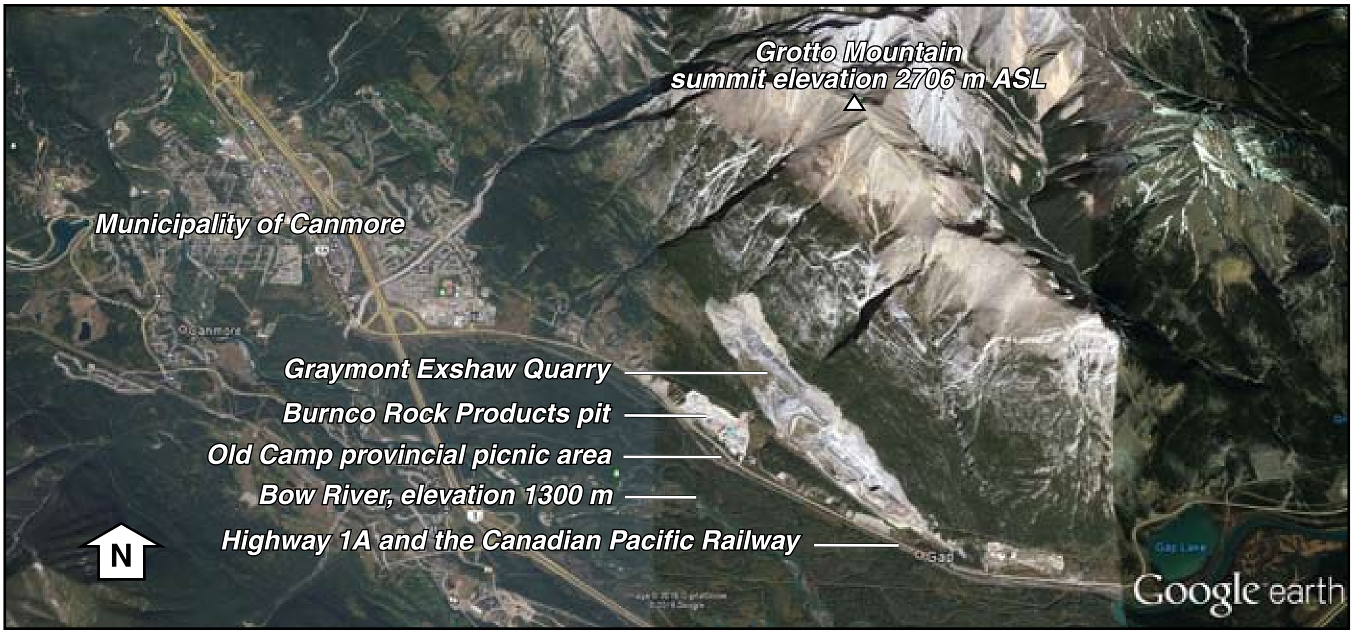

Figure 1, Grotto Mountain and the town of Canmore, as seen looking northward from an elevation of 24 km. Graymont's Exshaw Quarry is marked, as is the smaller Burnco gravel pit. Note that the Bow River flows close to the base of Grotto Mountain directly below the quarry. Google Earth image dated 2012.

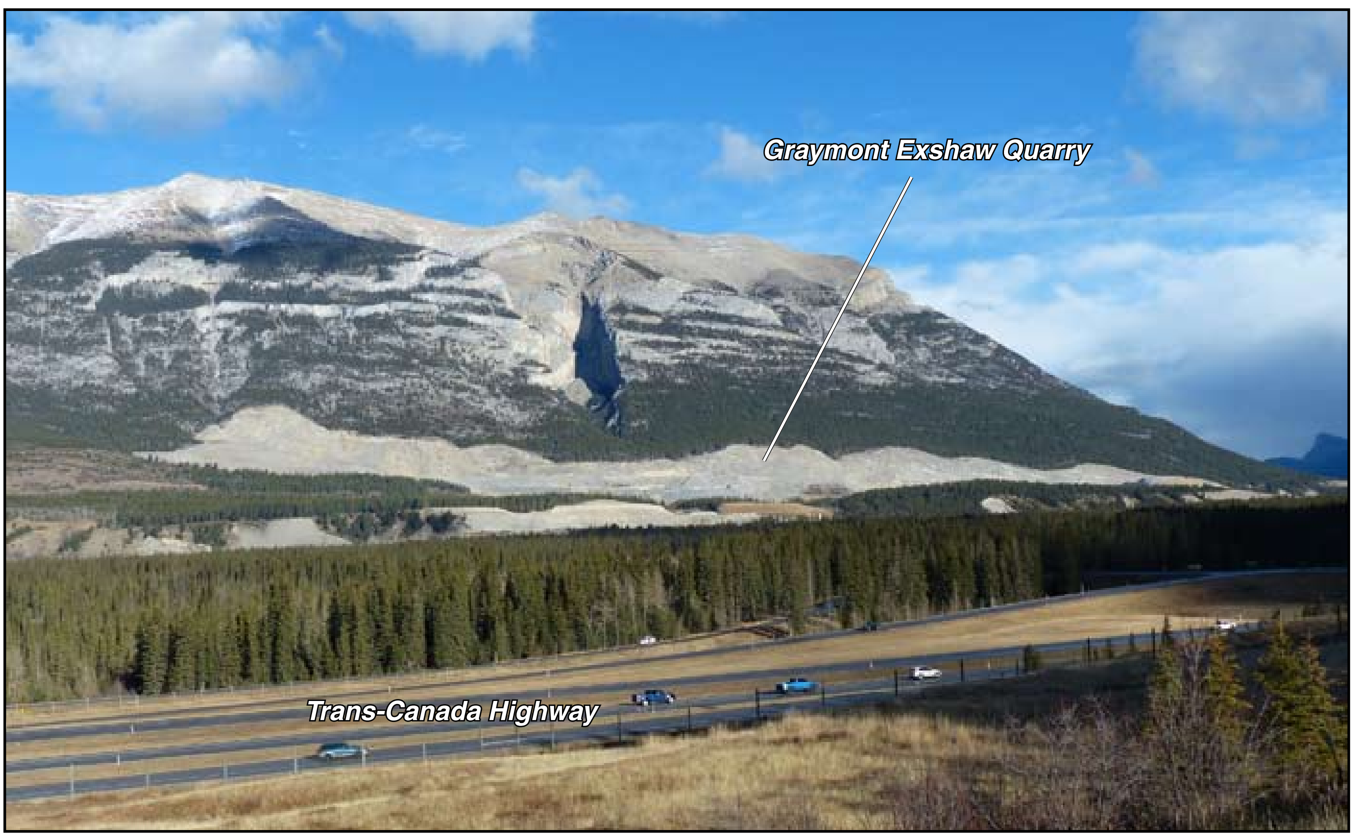

Figure 2, the southwestern slope of Grotto Mountain, view eastward from the Three Sisters area of Canmore. The Exshaw Quarry, which is about three kilometres long, is clearly evident near the base of the mountain. All photos in this report were taken by Ben Gadd in November of 2016.

Government of Alberta on-line records show that the Exshaw Quarry is on a provincial mineral lease that expires in 2026. The lease-holder is Graymont Western Canada Incorporated, a division of Graymont Inc., which is a multinational headquartered in Richmond, BC. According to Hoovers.com, Graymont Inc. has about 1500 employees and annual revenues of about $460 million. The company website is graymont.com, which indicates that Graymont mainly quarries limestone and processes it to produce lime products. It also sells plain limestone in various sizes, as well as sand and building stone.

Graymont has operations in the United States and New Zealand as well as Canada, with a "significant investment in Grupo Calidra, the largest lime producer in Mexico." Again quoting from Graymont's website, "Professionally managed and family owned, the Company has roots stretching back more than 65 years."

The term "Exshaw Quarry" is something of a misnomer, because the quarry is located closer to the town of Canmore, population 12,288 in a 2011 census, than it is to the small community of Exshaw, population 362 from the same census. Exshaw is located 8.5 km east of the quarry. However, the largest centre near Graymont's *plant,* where the quarried rock is processed, is indeed Exshaw (not counting the tiny company-founded settlement of Kananaskis, very close to the plant). The original quarry associated with this plant is a kilometre away from it to the northeast, right at the mountain front.

According to the Municipal District of Bighorn Heritage Inventory (Heritage Collaborative Inc., 2011), the mountain-front quarry (not the Exshaw Quarry) is old, dating to the early 1880s, when a Scot named McCandlish opened a small wood-fired lime kiln there.

Subsequent owners and developers have been Loder Brothers (1889), Harry Garnett (1938), Steel Brothers (1952), which opened the Exshaw Quarry in the 1960s, and Continental Lime (1988). Graymont bought the operation in 1989. The old quarry is currently not in operation and is being reclaimed. The plant feed now comes entirely from the Exshaw Quarry on Grotto Mountain. The quarried limestone is trucked east 12 km to the plant along Highway 1A, not the Trans-Canada Highway.

There is another large limestone quarry in the valley: the Lafarge North America (parent company LafargeHolcim) cement-producing operation at Exshaw. According to the company website, which is lafarge.com, their quarry dates to 1906. It was started by Western Canada Cement and Coal. Canada Cement bought it in 1909. This company was taken over by Lafarge in 1970. There seems to be no link to Graymont.

3. Quarry tour

The quarry tour was held on 1 November 2016 from 10:00 a.m. to 12:45 p.m. It was led by Carlos Morales, Senior Mining Engineer, Graymont, Calgary.

Geotechnical consultant Lee Nichols was along. Lee is the president of Terracon Geotechnique Ltd. of Fort McMurray and Calgary.

Carlos Morales and Lee Nichols did most of the speaking during the tour.

Grant Robinson, Quarry Lead Hand, was also present and answered questions.

Pierre Boucher, Plant Superintendent, attended. Other Graymont employees were also present, including Adam Johnston, who was kind enough to drive me around the quarry.

Andy Esarte, Manager Engineering Services for the Town of Canmore, and his assistant Félix Camiré, Project Engineer, were on the tour, along with other municipal employees.

Meeting at the quarry office at ten a.m., we were given a safety briefing and signed a form to indicate that we had heard and understood it. We also registered with the company as being on-site for the duration of the tour. I asked whether I was allowed to take photographs, and permission was granted.

Figure 3, geotechnical consultant Lee Nichols speaking to the members of the tour at the quarry overlook.

We drove in a convoy of company pickup trucks to the elevated edge of the extensive back-fill near the southeastern end of the quarry. This vantage point gave us a good overview of the workings extending northwestward.

After a productive discussion at this viewpoint, we drove down into the quarry and northwestward along it to a point near the northwestern end. The tour ended here with more discussion and questions. We returned to the quarry office around noon.

At the office, with everyone gathered, I was allowed to pose some additional questions that I considered to be especially important. These are covered in part 5 of this report, page 7.

4. Tour results

Here is what I learned from Carlos Morales and Lee Nichols during the tour, and what I observed, supplemented with geological information from published sources.

The "ore," as the quarry staff refer to the rock extracted, consists of limestone beds in the Mount Head Formation of the Rundle Group. The rock is Mississippian (early Carboniferous) in age, between 323 and 359 million years old.

The bedding of this rock dips to the southwest (the layers angle down to the left in Figure 4, next page) at an angle of between 42 degrees and 45 degrees. The footwall is on the right. It follows the dip and marks the top of the Salter Member of the Mount Head Formation.

According to the *Lexicon of Canadian Stratigraphy* (Glass 1990), in our area from bottom to top the Mount Head Formation consists of the Wileman, Baril, Salter, Loomis, Opal and Carnarvon members.

Carlos Morales said that the Salter Member continues to the right of the footwall into the mountain. It is primarily dolostone, with too much magnesium content for current company use. *Lexicon* also describes the Salter Member as silty and cherty (containing nodules of chert, which is a microcrystalline quartz mineral), other negatives. It is not quarried.

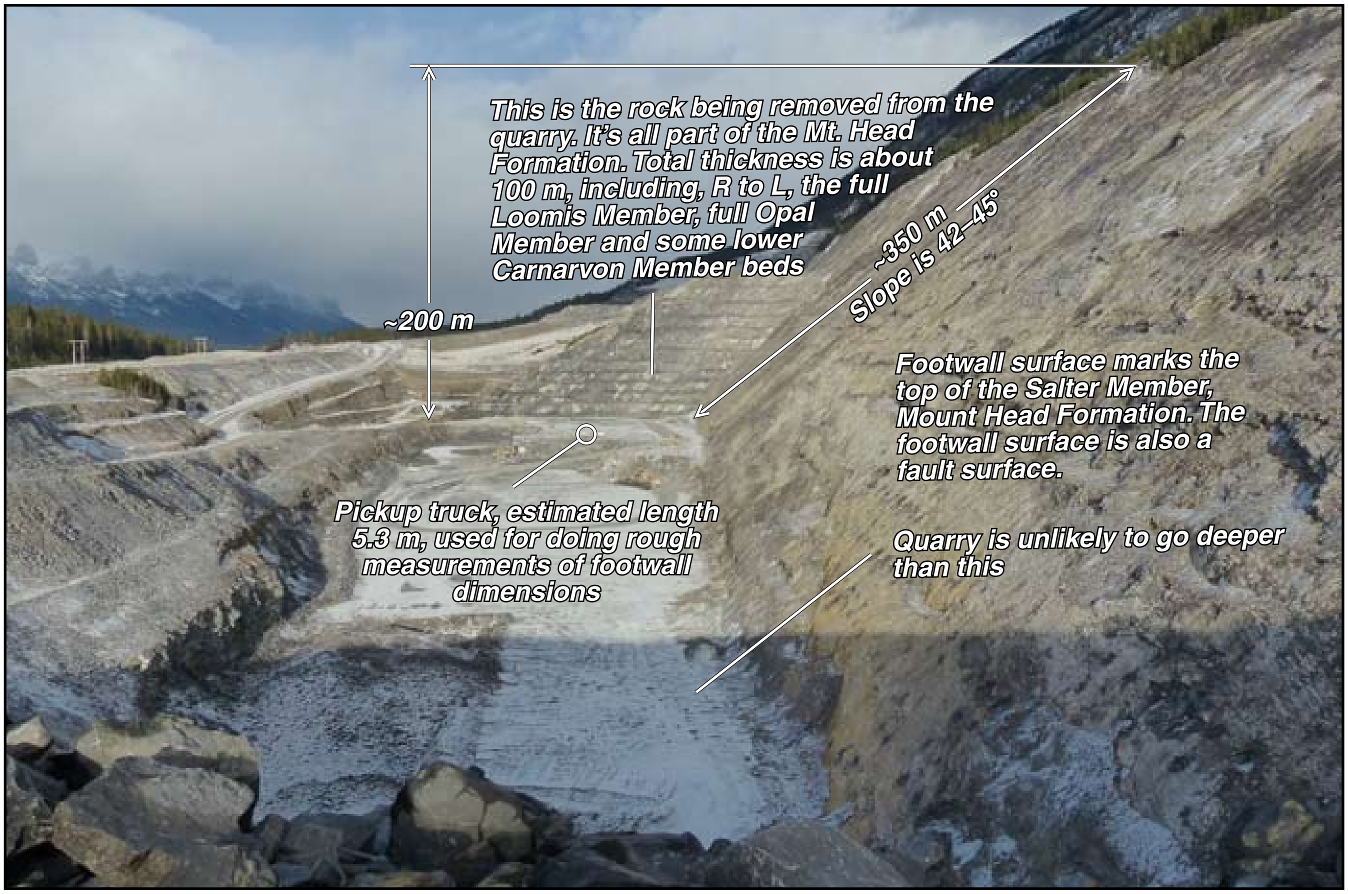

Figure 4, view northwestward into the Exshaw Quarry from the partially back-filled southeastern portion. Most of the quarry is visible. Heavy equipment in the central portion provides a sense of scale. I have also included some rough dimensions based on the approximate size of the pickup truck circled in the photo.

Figure 5, closer view of the footwall, showing the faulted surface. Pits in the wall are from blasting.

Left of the footwall and lower down we could see the Mount Head Formation exposed and being actively quarried. From right to left these beds included the full Loomis Member, full Opal Member and some of the Carnarvon Member.

Lexicon describes the Loomis Member as a thick-bedded lime grainstone, in other words a pure limestone. Carlos Morales confirmed that some Loomis beds are used for processing into the calcium products that Graymont makes at its Exshaw plant. According to Graymont's website, these include "high-calcium quicklime and hydrated lime." Portland cement, which is the main product at Lafarge's plant at Exshaw, seems not to be produced at the Graymont plant.

According to *Lexicon,* the Opal Member is also limestone, but the unit is cherty and not as pure as the Loomis Member. I could not confirm whether any Opal beds are used for the company's processed-limestone products, but perhaps Opal rock is suitable for the company's plain-limestone products.

Some lower Carnarvon Member beds are present at the left side of the quarry. *Lexicon* describes the lower Carnarvon as limestone with shale beds. Its value to the company is unknown.

The Loomis, Opal and Carnarvon members were too far away from our viewpoint for me to tell them apart. Judging from the size of a pickup truck seen near the quarry face, the total thickness of all these units looked to be about 100 m.

My apologies if these thicknesses and other dimensions are incorrect, but they are the best I could do in the absence of company figures.

The footwall of the entire quarry seemed to me to be a fault surface, smoothed and striated by rock movement. (See Figure 5.) Lee Nichols confirmed this impression. I asked Grant Robinson whether the presence of the fault aids quarrying, because the rock might break away from the footwall rather easily along the fault surface. Grant stated that this was true.

Quarrying is carried out from the top down. Successively lower horizontal working levels are established, each presenting a flat surface for drilling the shot-holes, into which, according to Grant Robinson, the ANFO explosive is placed. ("ANFO" is short for ammonium nitrate and fuel oil, in this case diesel.) The shot-holes are drilled in a grid at closely spaced intervals. The spacing and charge sizes are carefully designed to break the rock into pieces appropriately sized for screening and crushing. "Fly rock" thrown about by the blasting was said to be minimal and to fall within the quarry, not threatening traffic along Highway 1A, the Old Camp provincial day-use area or the Canadian Pacifc Railway, all of which are close by.

A fair amount of waste rock is created from the operation. It has been used to backfill the southeastern third of the quarry, leaving less of the footwall exposed there. More loose rock is piled outside the pit at the northwestern end of the quarry. I'm not sure whether it's waste or a stockpile.

I had heard that Graymont was looking for approval to expand the quarry toward the northwest. Carlos Morales could not confirm this, but he did say that an expansion of perhaps 250 m to the lease's northwestern boundary was feasible. He thought that obtaining approval to expand the lease farther in that direction was unlikely, because the existing lease boundary abuts a wildland-park boundary. Greater extension would also bring the quarry closer to Canmore.

Figure 4 shows the depth of the quarry. This is as deep as Graymont intends to go, because the water table lies not far below and going deeper would require pumping. However, it seems possible to remove quite a lot of additional rock if the quarry can be deepened to the same level all the way to the northwestern end. This would make the footwall correspondingly higher, and I don't know whether that would be feasible.

5. Questions I asked after the tour

When everyone had assembled back at the quarry office, I asked the following questions and invited any Graymont staff present to reply.

1. Before provincial approval of the quarry operation was given, how was the slide potential evaluated?

Development of the Exshaw Quarry began in the 1960s, according to Grant Robinson. Re potential slide hazard, Carlos Morales referred me to existing general geohazard studies of the Bow Valley, which he thought relevant. I could not locate these maps on-line. No one seemed to know for sure whether a slide study of Grotto Mountain in particular was done as part of the submission for approval before the quarry opened, or whether some such study was done later on, as the quarry grew.

The original approval for quarrying here might have occurred quite a long time ago. Grant said that there is some sort of lime-kiln structure in the area that may date back to the early 1900s. If this is the case, the original lease may have been much smaller and granted much earlier than the 1960s. Perhaps the 1960s approval was simply an expansion of this old lease, approved as a matter of course. This was before much environmental-impact work was being done in Alberta. (The Lougheed government of 1971 brought in the enabling legislation.)

2. Has the potential slide volume and run-out ever been estimated and/or modelled for slides of various sizes from Grotto Mountain?

Lee Nichols said that such modelling software exists, but he didn't know whether it had been applied to Grotto Mountain. Carlos Morales again referred me to regional geohazard studies.

3. During operation, how is slope stability monitored? Are strain-measuring and tilt-measuring instruments mounted in the rock? What records are kept? Are these records available for inspection?

Lee Nichols said that he knew of no instrumentation of this kind in place anywhere on the mountain. He said that stability was evaluated observationally, that is, by looking for signs of instability such as the appearance of tension cracks and increasing rockfall. The slopes extending up the mountain above the footwall are not checked for the appearance of cracks.

Lee also said that reports of such observations are on file with the company and presumably also with the provincial regulator. He thought that they might be public documents and accessible to anyone.

I finished by asking Carlos Morales and the other Graymont staff whether they would be willing to look for documents that might provide insight on questions 1 and 2. They said they would be willing to do that if they received a request in writing from the Town of Canmore.

6. Discussion

The tour was an excellent idea. Carlos Morales, Lee Nichols and Grant Robinson were all forthcoming in answering most questions. I learned a lot about the operation, both from a geological perspective—I had been wondering what rock units were being quarried, and how—and in regard to slide hazard on Grotto Mountain. At the end of the tour I made a point of thanking Graymont for providing it.

Carlos Morales and Lee Nichols did their best throughout the tour to reassure us that the operation was safe. Lee cited a somewhat less-steep slope that can be seen above the top of the footwall as a feature that enhanced slide safety. He called it a "terrace." (See Figure 6.) A vehicular access track runs across it for part of the way. This feature does not seem to be structural; that is, I could see no evidence of a fold or fault there. Nor does it form a straight line across the slope. Instead, it looks to me to be a differential-erosion feature. The Salter Member is softer and more easily erodible than the Loomis Member, so one would expect to see a gentler slope in the Salter than in the harder unit above, which is the Baril Member. Perhaps this minor feature of the mountain adds some measure of stability to

Figure 6, telephoto view of bedding atop the footwall. The layers show no structure other than the overall dip. (The apparent variation in the angle of bedding is illusory, a function of the angle of view.) The "terrace"—a change in slope—seen atop the bare-bedrock slabs is probably a differential-erosion feature.

the footwall in some way, but I don't understand how it could reduce slide hazard should the presence of the deepening quarry destabilize the long, steep slopes above.

Lee Nichols said that the average "safety factor," which in this case may mean the ratio of the forces resisting motion to the forces causing motion, has been computed to be about 1.2 for this kind of operation, and that the quarry exceeds that number significantly. But neither Lee nor Carlos Morales would tell us what the quarry's safety factor was, even though they said that they knew it.

Lee Nichols stated that provincial regulation of Alberta mines has contributed to safe operation of the quarry. However, Félix Camiré has told me that he has been in touch with the provincial government on this matter and has found that, while the province sets conditions of mineral leases, it does not appear that currently there is formal oversight of geotechnical matters in quarrying operations in Alberta other than factors concerning worker safety.

Certainly the company seems to be following safety procedures within the quarry to protect the workers from rockfall there. For example, a low berm along the base of the footwall serves to remind workers not to approach the footwall too closely.

The method of quarrying, which has been to remove rock from the top down, following the dip of the beds, would seem to be safer than cutting vertically across those beds. Cutting across the beds would leave their lower edges unsupported, which could seriously destabilize the slabs above.

But I remain unconvinced that the quarrying cannot induce a large slide from Grotto Mountain. Here are my reasons.

1. The company has concerned itself with slide hazard in and below the quarry but apparently not above it.

Neither Lee Nichols nor Carlos Morales said that they made observations up the mountain from the quarry, nor do they have stability-monitoring instrumentation there (or anywhere). Yet a slide from farther up is what worries me most.

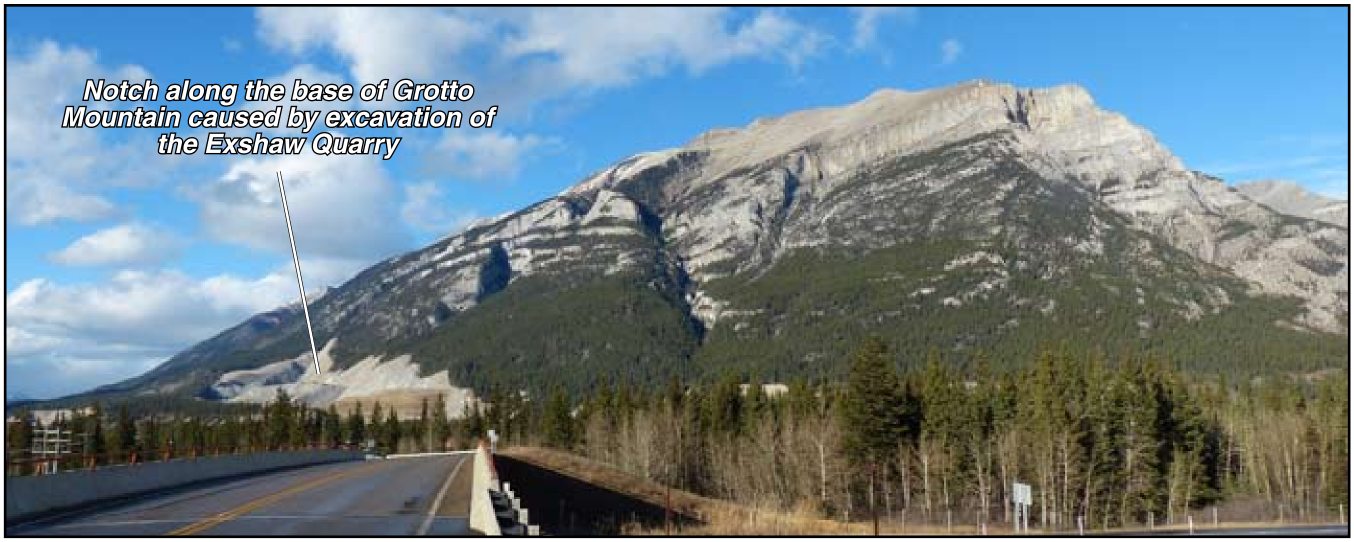

Figure 7, side view of the Exshaw Quarry from the Dead Man's Flats overpass along the Trans-Canada Highway east of Canmore, looking north, showing the overall slope of Grotto Mountain. As usual in our area, the slope is concave near the base. But quarrying has removed enough rock to produce a notch-type convexity in that slope. The rock dips ever more steeply toward the notch. Is this a potentially unstable situation?

2. Quarrying has cut a notch in the lower slope of the mountain.

As shown in Figure 7, it's already a sizable notch. The length is 2.7 km. It's up to 0.5 km wide. The footwall forming the uphill side of the notch is about 350 m high. The footwall might lengthen by about 250 m if the quarry expands to the northwestern edge of its lease. If quarrying continues as it has, the uphill side of the notch will continue to gain height northwestward as rock is removed. At exhaustion of the quarry the fully developed notch could extend across about half of Grotto Mountain's southwestern aspect.

Here is the significance of this, based on my understanding of the geological principles involved.

In sedimentary mountains the dip of the layers has a lot to do with slope stability and slide hazard, but the overall slope profile from base to top is also important. This is to some extent independent of the rock type or the dip of the beds. That's because gravity is always at work in any large mass of rock. One effect is to cause the mass to spread outward to the sides. Such spreading can occur in the form of frequent small-scale rockfall, a minor danger. However, it can also occur in the form of rock slides, and these are a more serious threat.

The threat is least when a mountain's slope profile is *concave upward near the base.* Most Rockies peaks and ridges exhibit this profile. The southwestern slope of Grotto Mountain was originally concave upward at the base, as can be seen in the historical photo, Figure 8. The quarry notch has altered that profile. In combination with the dip of the rock, quarrying has produced *a large convexity.* I am concerned that this may be a less-stable configuration.

It's worth noting that the southwestern slope of Grotto Mountain is slabby, with many bedrock exposures in places that are too steep to be tree-covered. However, nowhere on this slope is there a rock slab as steep and extensive as the quarry footwall. In fact, I cannot recall seeing a single, continuous slab of this height and length anywhere else in the Canadian Rockies.

The Exshaw Quarry's footwall is an unusual, artificial construct. This leads me to wonder how long it can last before it begins to break up. Since the footwall forms the face of that large notch in the mountain near the base of a very long slope underlain by steep and convexly angled beds—a possibly unstable situation—might the footwall break up all at once, as a very large collapse that could spread upward on the mountain and produce a major rock slide?

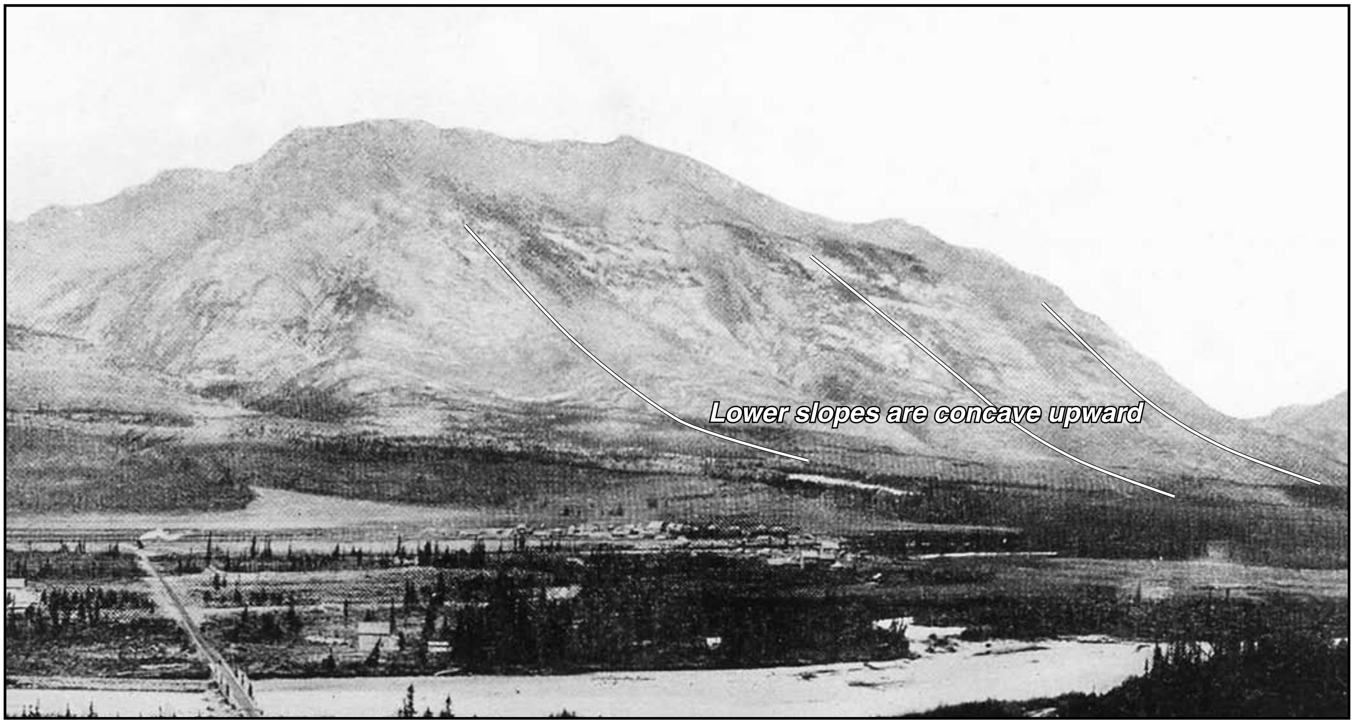

Figure 8. The southwestern slope of Grotto Mountain as seen from Canmore circa 1900, before any quarrying had occurred. The photo is from an old postcard and is fuzzy, but the concave shape of the lower slope can be discerned. (Image provided by Rob Alexander, canmorehistory.wordpress.com.)

3. The notch is likely to remain after quarrying has finished.

Lee Nichols and Carlos Morales both agreed that, when quarrying ends, the full restoration of the original slope of Grotto Mountain in the quarried area would be impractical. The amount of waste rock that will have been generated would be too small to backfill the quarry to the top of the footwall.

After exhausting the ore rock, the notch would remain, possibly presenting an ongoing slide hazard for a very long time. Partial backfilling might have a positive effect on such hazard, as could sloping the backfill upward along the footwall. The amount of backfill at time of closure of the quarry could be determined and its effect modelled.

4. I hope that Graymont or the provincial government can produce documents showing that the potentially dangerous full-slope situation has been modelled for stability, but I rather doubt that this work has ever been done.

It seems obvious to me that such modelling is essential to evaluating the overall slide hazard.

5. The fact that the footwall follows a smooth, relatively slippery fault surface worries me.

The fault looked to me to be a flexural-slip fault. Such faults are produced by folding during mountain-building, and they are common in front-range peaks. Grotto Mountain may have quite a few of them. This has implications for rock-slide hazard, as such faults can act as sliding surfaces. They are also weak zones. Thus they may be important for initiating and maintaining the down-slope movement of rock slides.

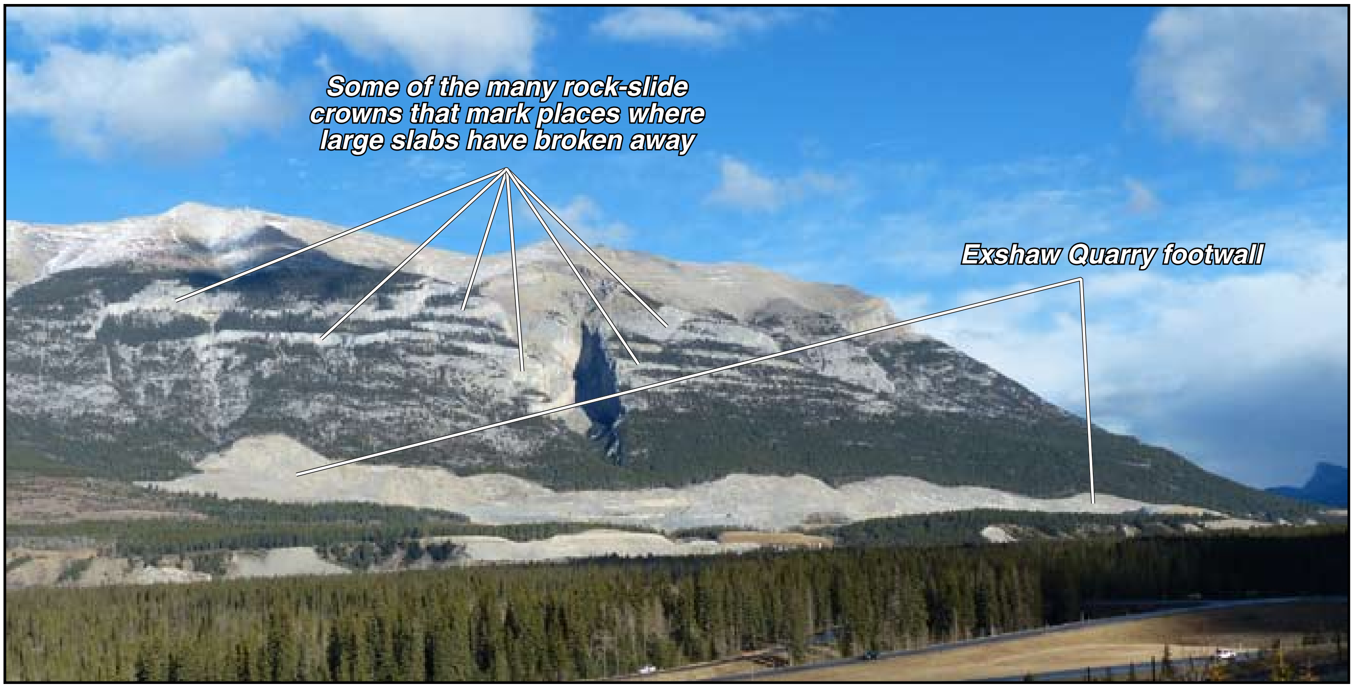

Figure 9. Grotto Mountain today, showing how much of the southwestern slope has been altered by the Exshaw Quarry. Many slide crowns—places from which rock slabs have broken away and slid into the valley—are visible above the quarry.

6. The southwestern slope of Grotto Mountain shows much evidence of the most common type of rock slide in the region, the dip-slope slide. An existing anticline and large thrust fault are also factors to consider.

Grotto Mountain displays an extraordinary number of slide crowns (Figure 9). These are the broken-off edges of once-continuous, steeply tilted rock slabs that have plunged downhill as "dip-slope" slides. Some of the slabs must have been very thick, judging from the tall crowns left at their upper ends. Clearly, this is a slope with a history of mass movements.

It seems likely that most of these slides occurred during periods of Pleistocene glaciation. Ice-age glaciers that flowed along the pre-existing river valleys of the Canadian Rockies have cut into the slopes on each side, widening the valleys a great deal and over-steepening the walls, such that sliding has occurred. I think that Grotto Mountain's many rock slides in the recent geological past can by attributed mainly to (a) the steep southwesterly dip of the bedding and (b) sideward cutting by the Bow Valley Glacier.

But if that's the case, where is all the slide debris? A map of the geomorphology of the Bow Valley shows none (Rutter 1972). Nor does the authoritative geological map of the area (Figure 10, Price 1970).

The answer is that the glacier would have carried the slide debris eastward and deposited it perhaps as far away as Calgary, the farthest point reached by ice flowing from the Bow Valley. Glacial deposits (till, moraines and erratics) found along the way contain huge amounts of such debris from many peaks.

Figure 10 shows that the rock in the slope in question is part of the southwestern limb of a large anticline (up-fold). The axis (centreline of the fold) is well up the mountain from the quarry. This big bend in the rock accounts for the convexity of the bedding, a naturally unstable configuration.

In addition, a sizable thrust fault (ticks on the overthrust, southwestern side) cuts through the mountain not far east of the fold axis. This is not the fault seen along the quarry footwall, but in cross-section (Figure 11) it looks to be equally steep. Its sliding surface, not exposed, is probably similarly polished and slippery.

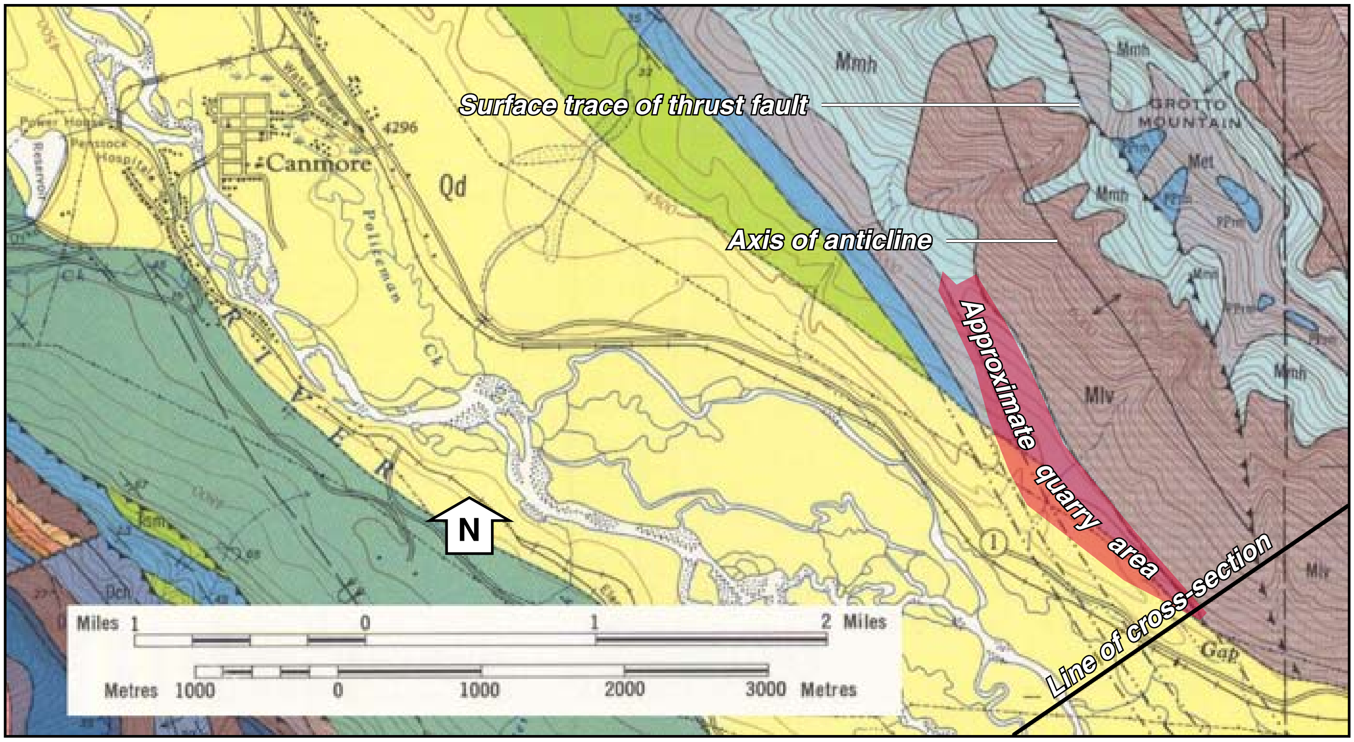

Figure 10, detail from the official geological map of the area, showing the anticline and thrust fault in the southwestern slope of Grotto Mountain (Price, 1970). Approximate location of the Exshaw Quarry is indicated by shading. The line of the cross-section (see below) is also shown.

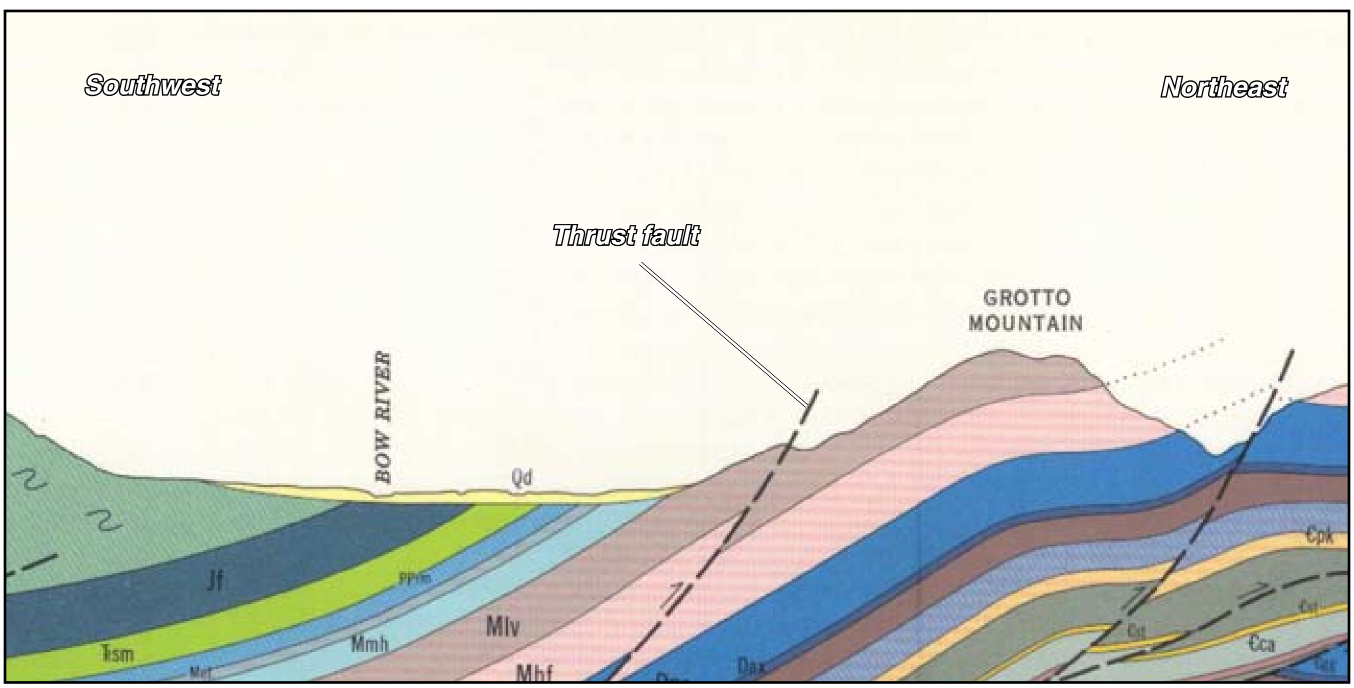

Figure 11, enlarged detail from a cross-section accompanying the geological map of the area (Price, 1970) showing the thrust fault in the southwestern slope of Grotto Mountain. The cross-section was located too far south to show the anticline, but it does show the steepness of the fault.

7. The Bow River runs close to the base of Grotto Mountain's southwestern slope (see Figure 1), and a large slide from that slope might cross its channel.

I'm concerned that a major rock slide starting at or above the quarry might conceivably occur, possibly with accompanying loss of life in the quarry, as well as in the Burnco gravel pit, along Highway 1A (the Old Camp picnic area is located directly below the quarry) and along the Canadian Pacific Railway line.

Making matters worse, such a slide might block the flow of the Bow River and cause it to back up behind the slide heap. Central Canmore has been built not far upstream on the floodplain. Depending on the slide's run-out length and the depth of the debris, as well as the topography of the valley floor, the town might be flooded. This is a worst-case scenario and it may seem far-fetched, but it can be modelled and evaluated.

7. Recommendations

In light of the foregoing, I would like to see Canmore's municipal government thoroughly examine the potential slide hazard Grotto Mountain represents and, should the results suggest it, respond appropriately. This might require up to four steps.

1. Gather as much existing information as possible about slide hazard on Grotto Mountain.

Relevant documents might have been submitted to provincial authorities as part of the approvals process before or during quarry development. These may be public documents and thus fairly easy to obtain. Graymont has offered to provide any public documents in its possession if asked in writing by the Town of Canmore.

As Carlos Morales has suggested, a regional slide-hazard map prepared by the Alberta Geological Survey may be available and relevant if it includes Grotto Mountain. There may have been one or more academic papers, theses or geological reports published about Grotto Mountain and its slide history.

Other documents of interest would be Graymont's observational records of slope stability in the quarry.

2. Evaluate this information.

To get credible, peer-reviewable results, the Town should employ a consultant who is well qualified and respected in the field of landslide analysis and forecasting. This consultant should be fully independent of Graymont or the provincial government, and payment for the work should be made only by the Town. Going through a university geological/engineering department might be a good idea, to ensure objectivity and minimize costs.

3. If the consultant thinks it warranted, a study of the current slide potential on Grotto Mountain and possible scenarios should be done using the latest data-collection and modelling techniques.

Such a study could answer important questions. Is a sizable slide or slides possible? If so, where on the mountain might such events occur? (The study might show that a large slide is possible that would have nothing to do with the quarry.) Is the presence of the quarry and the ongoing removal of rock significant? What would be the volume and run-out area of any potential slides? Given the configuration of the valley, could the flow of the river be blocked, potentially flooding downtown Canmore?

If a study along these lines goes ahead, I hope that Graymont will be cooperative. This would speak well for the company's commitment to public safety, corporate responsibility and community engagement.

4. Should the consultant conclude that significant slide hazard exists, action should be taken to reduce that risk, especially if there is risk to the town. If such reduction is not possible, means should be found to deal with the potential impact. A program of emergency response should be developed.

I certainly hope that no worrisome slide hazard will be discovered. However, in the event that the evidence suggests significant hazard, I think that the municipal government, with its responsibility to Canmore residents, and the provincial government, with its responsibility to all Albertans, will both need to be prepared.

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Good general reference on rock-slope engineering

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