# ENVIRONMENTAL GEOLOGY OF BELVIDERE MT., VERMONT

by

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## INTRODUCTION

In the ten years since the publication of Van Baalen et al. (1999), Belvidere Mt. has basked in the glow of renewed interest by the scientific community, government regulatory agencies, and the general public. Our 1999 paper dealt mainly with the hard rock geology of the ultramafic rocks on Belvidere Mt., that are best exposed in the asbestos quarries of the now closed Vermont Asbestos Group (VAG) mine shown in Figure 1. This mine, consisting of three major quarries, haul roads, mill buildings and huge tailings piles, occupies the lower southern and eastern slopes of the mountain, with an areal extent variously estimated at 1600 to 3000 acres. For many years, the abandoned mine has been regarded as unsightly at worst, but presenting no actual environmental risk. But as will be described below, the renewed interest has focused on slow erosion of the tailings piles, with attendant contamination of two stream drainages and related wetlands. In addition, questions have been raised whether airborne chrysotile asbestos from the mine site presents a public health risk. Our 1999 paper discussed this health risk and concluded that it is negligible.

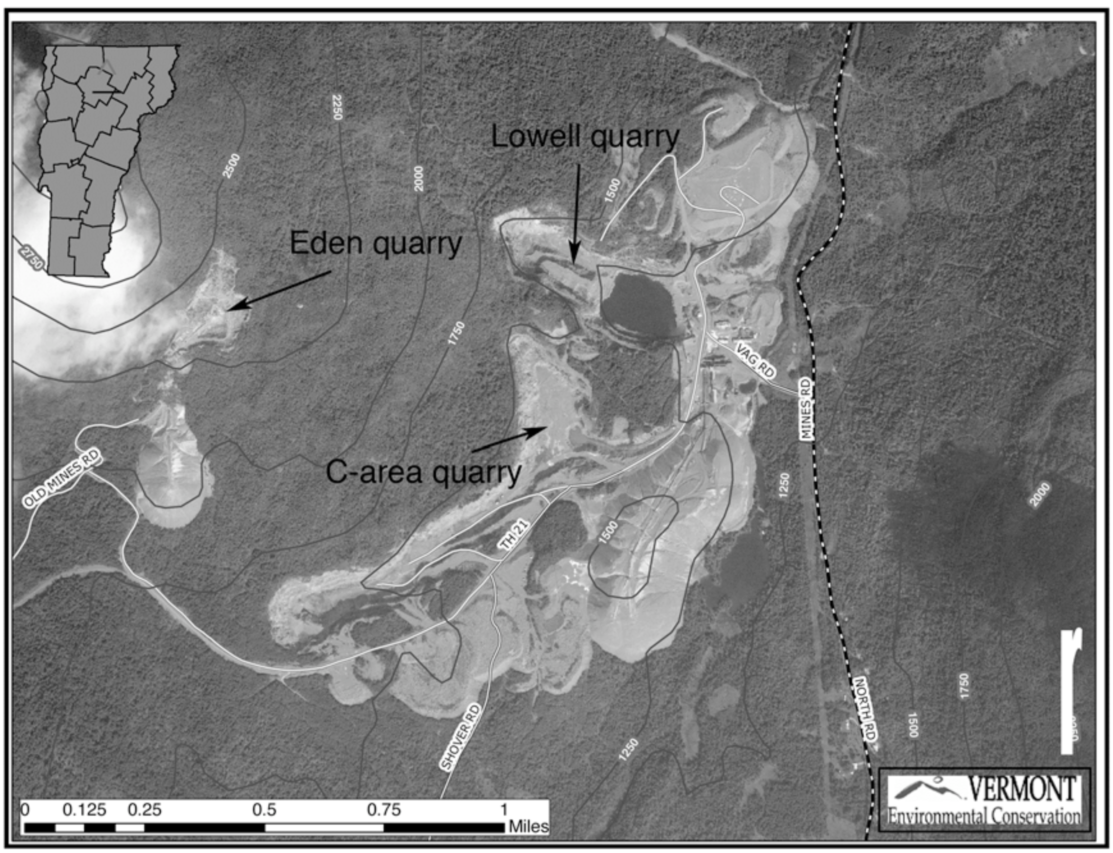


Figure 1. Locator map and orthographic aerial photo of the mines at Belvidere Mt. (DEC, 2009)

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**Geologic Background**

Belvidere Mt. lies in the northern portion of the Green Mountains of Vermont, between Mt. Mansfield and Jay Peak. The mountain lies partially in the Town of Eden (Lamoille County) to the south and the Town of Lowell (Orleans County) to the north. Belvidere also lies astride a drainage divide between the Lamoille River watershed on the south, and the Missisquoi River watershed on the north. Drainage from the east side of the mountain in the vicinity of the asbestos quarries follows either the Hutchins Brook, south to the Lamoille, or Burgess Branch, north to the Missisquoi. Belvidere Mt. is shown on the USGS Hazens Notch (1:24,000) metric topographic map. The bedrock geology of Belvidere Mt. was summarized in Van Baalen et al. (1999) and earlier works (e.g. Gale, 1986; Laird et al., 1984; Chidester et al., 1978).

Serpentinized ultramafic rocks at Belvidere Mt. form a part of the Appalachian serpentinite belt, stretching from Newfoundland to Georgia. The belt in Vermont is discontinuous but persistent: all of the east-west transects across Vermont completed by Hitchcock et al. (1861) encountered serpentinites. In Vermont, the serpentinites are emplaced within Cambro-Ordovician metasedimentary and metavolcanic formations, west of the Richardson Memorial Contact (RMC) but east of Logan's Line. These serpentinites probably represent ophiolitic fragments emplaced during the Taconic orogeny, by processes easy to conceptualize but difficult to explain in detail. Stanley & Ratcliffe (1985) suggest these fragments are imbricate fault slices of oceanic crust, thrust onto the Laurentian margin during subduction of a portion of the Iapetus ocean.

The Belvidere Mt. Complex, as used by Gale (1986), includes both the serpentinized ultramafic rocks, and a suite of amphibolites, greenstones, and mica schists previously known as the Belvidere Mt. Formation (Chidester et al., 1978). This Complex lies on the eastern limb of the Green Mountain Anticlinorium, a major structural feature of Vermont. Gale (1986) showed that the several "stratigraphic" units in this area are in fact fault-bounded slices of varying lithology, so that a stratigraphic sequence in the accepted sense of the term is not meaningful. Instead, she describes the succession of rock types as a "tectonic stratigraphy characterized by fault contacts between four structural packages which do coincide with previously mapped formations: Hazens Notch Fm.; Belvidere Mountain Complex; Ottauquechee Fm.; Stowe Fm." All of these formations have been regarded as of Cambrian age. However, age controls in the region are poor. One of the few reliable dates is from Laird (1993) who reported a $^{40/39}$Ar age of 505±2 Ma from the Belvidere Mt. amphibolite: this age is earliest Taconic if not pre-Taconic. For a fuller description of the mineralogy and petrology of the ultramafic rocks, consult Van Baalen et al. (1999).

Kerper et al. (2008) showed that anomalous graphite mineralization in the quarries was isotopically related to likely source regions in the graphitic Hazens Notch and Ottauquechee Formations that structurally underlie and overlie, respectively, the ultramafic rocks. Transport of carbon by, and its precipitation from, fluids associated with high angle faults resulted in the observed mineralization in the C-Area quarry. This locality was included in our 1999 field trip (Van Baalen et al., 1999).

**Formation of Chrysotile Asbestos at Belvidere Mt.**

Chrysotile asbestos at Belvidere Mt. formed by alteration and recrystallization under shearing stress of depleted mantle rocks that formerly consisted mainly of the minerals olivine (Ol) and orthopyroxene (Opx). The chrysotile is probably a fourth-generation product, as explained below. At Belvidere Mt. both serpentinized dunites and serpentinized harzburgites occur, but harzburgite dominates. These rocks are stable under mantle conditions but unstable at near-surface conditions in the presence of water and $CO_2$. Ol and Opx recrystallize as the one of the hydrous serpentine minerals, according to the following simplified reaction:

(1) $Mg_2SiO_4 + MgSiO_3 + 2H_2O = Mg_3Si_2O_5(OH)_4$

In the presence of $CO_2$ chrysotile is not stable, and the low temperature stable assemblage becomes talc with magnesite, according to the model reaction:

(2) $2Mg_3Si_2O_5(OH)_4 + 3CO_2 = Mg_3Si_4O_{10}(OH)_2 + 3MgCO_3 + 4H_2O$

Magnesite may further react with $H_2O$ to produce hydromagnesite and other low temperature hydrated carbonates:

(3) $5MgCO_3 + 5H_2O = Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O + CO_2$

Note that rocks containing talc and magnesite or hydromagnesite are extremely weak, resulting in the likelihood of collapse along veins and fractures. This process may be responsible for some of the recently observed rockfall in the Lowell quarry.

Finally, it was observed by Coleman (1977) that serpentine is significantly less Fe-rich than the precursor mantle olivine. The fayalite component of the olivine does not enter the serpentine minerals but recrystallizes as ubiquitous magnetite, leading to the model reaction (Van Baalen, 1995):

(4) $6(Mg_{1.5}Fe_{0.5}SiO_4) + 7H_2O = 3Mg_3Si_2O_5(OH)_4 + Fe_3O_4 + H_2$

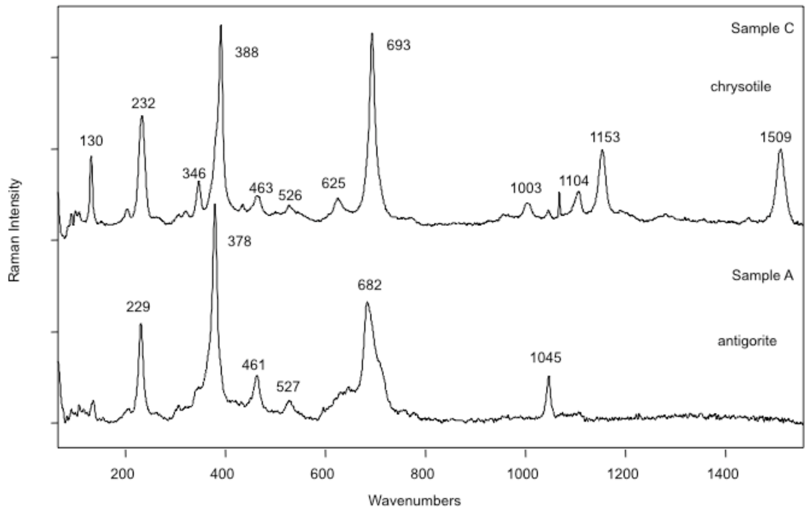
The very low oxygen fugacity implied by reaction (4) is consistent with observations of serpentinites worldwide. When serpentinites exhibit information on oxygen fugacity, it is invariably low.

In most cases the first serpentine mineral to form by hydration of Ol and Opx at low temperatures is not chrysotile, but lizardite (O'Hanley, 1996). The three common serpentine minerals, chrysotile, lizardite and antigorite, that have related crystal structures and similar compositions, are sometimes referred to as polymorphs. They are actually not polymorphs, because they do not have identical compositions. Lizardite requires a small amount of Al to stabilize its structure, while antigorite is Mg-deficient relative to chrysotile. So in reaction (1) representing first-generation serpentine, we should properly substitute lizardite as a product, and call it S1, i.e. the first-formed serpentine mineral. This serpentine may have first formed in the ocean floor setting prior to obduction. At Belvidere Mt. most or all of the S1 lizardite has in turn recrystallized to antigorite, the "high-temperature" form of serpentine, under amphibolite facies metamorphism (S2, the second-formed serpentine mineral). Locally, shear zones have developed in massive antigorite, that have been healed by recrystallized antigorite (S3), also at amphibolite facies. Chrysotile (S4) formed at low temperature, sub-greenschist facies under shearing stress, as slip fiber asbestos, but locally under tensional stress as cross fiber asbestos. It is this S4 chrysotile asbestos that is the ore mineral at Belvidere Mt. S4 mineralization crosscuts all earlier serpentine, and could be as young as Acadian, although there is no proof of this tempting speculation.

In order to better characterize these generations of serpentine minerals, two of us (MVB and CAF) visited Belvidere Mt. in July 2009 to obtain samples of the wallrock in the Lowell and Eden quarries. These samples were chosen as representative members of the varying lithologies there exhibited. Recently Raman spectroscopy has been shown to be a useful method to distinguish the serpentine minerals (Rinaudo et al., 2003). Micro-Raman spectroscopy has been successfully applied to serpentinites (Groppo et al., 2006), and was included among the suite of techniques that Levitan et al. (2009) used to characterized the mineralogy of mine wastes and rock samples at Belvidere Mt. (see below).

Chips from nine specimens of varying texture were examined by micro Raman spectroscopy at the Boston Museum of Fine Arts (courtesy of Richard Newman) to determine which serpentine mineral(s) characterize the textures readily recognized in hand specimens. The results of this quick survey are summarized in the following table, while the following figure shows representative Raman spectra from this study, illustrating the power of this technique in distinguishing serpentinte minerals.

| **Specimen** | **Texture** | **Serpentine mineral** |
|---|---|---|
| A | Lamellar | antigorite |
| B | Kernels:<br>1. thin, foliated slip surface<br>2.fine-grained massive (sucrose) interior | <br>antigorite<br>antigorite |
| C | Contorted foliated | chrysotile |
| D | Asbestos vein margin | antigorite + chrysotile |
| E,F | Massive “picrolite” veins | antigorite |
| G | Vein with radial texture | antigorite |
| H | Composite vein | chrysotile |
| I | Cross fiber asbestos vein | chrysotile |




The Belvidere Mountain serpentinite was studied in detail by Chidester et al. (1978). Their field work was mostly completed in 1951-1953 when the mine was active and the bedrock was exceptionally well exposed. They described and mapped "massive" and "schistose" serpentinites as end members, a distinction easily made both in the field and in hand specimens. They also described veins of (1) fibrous serpentine (asbestos), (2) massive serpentine (picrolite), and (3) other minerals. Their laboratory work, completed before the development of microbeam instruments, was limited to wet chemical analyses and optical determinations that were supplemented by DTA and X-ray powder diffraction (by George Faust). Their understanding of serpentine mineralogy at that time is summarized in Deer et al. (1962). In thin section they recognized bladed (antigorite) and fibrous (chrysotile) serpentine. Serpentine minerals are difficult-to-impossible to distinguish optically (O'Hanley 1996). In situ identification of the serpentines in thin section using a microbeam X-ray camera was an important innovation by Wicks & Whitaker (1977) that led to new interpretations of serpentinite textures and processes of serpentinization. The classic Belvidere Mountain serpentinite has not yet been thoroughly restudied using microbeam or Raman-FT technology and the new conceptual framework for serpentinites summarized by O'Hanley (1996).

Our identifications of the serpentine minerals contradict some of the work of Chidester et al. (1978) but are consistent with the four-fold serpentization process described above. By far the most abundant serpentine mineral at Belvidere Mountain is antigorite. It occurs in a variety of textures including the so-called kernels, which Chidester et al. included with schistose serpentine. Both parts of sample B are antigorite rather than chrysotile as implied by Chidester et al.'s classification of kernels with schistose serpentine. Chidester et al. (1978, p. 37) state that "all the serpentine in the asbestos veins and the picrolite veins is chrysotile." O'Hanley (1996) observed that any of the serpentine minerals can be found in picrolite veins. Thus picrolite is a textural term without a species implication. The three picrolite specimens examined in the present study gave poor or no Raman spectra, but were identified as antigorite by infrared spectroscopy. Vein sample G with its very unusual radial texture is also antigorite. Thus antigorite is even more abundant than heretofor believed.

Chidester et al. (1978, p. 37) also state that "the serpentine in the zones of marginal alteration bordering the serpentine veins is predominantly a mixture of lizardite and chrysotile, and, locally, minor antigorite." This is the only specific mention of lizardite at Belvidere Mountain by Chidester et al. Specimen D was examined to test this observation and proved to be antigorite with chrysotile. Lizardite has not yet to been found at Belvidere Mountain because it was destroyed in a prograde metamorphic event and replaced by antigorite.

## MINING HISTORY

Asbestos was reported in the Belvidere Mt. area as early as 1824 (Thompson, 1824). Asbestos fibers were also noted in the area around 1860 (Hitchcock et al., 1861). Prospecting continued in the 1870s (Marsters, 1904). However, no significant mining activity took place until near the end of the 19$^{th}$ century, when asbestos was rediscovered by Canadian loggers in the employ of Judge M.E. Tucker of Hyde Park. A colorful account of this rediscovery is provided by Dann (1988). Historical accounts vary, but this "rediscovery" of asbestos by loggers around the turn of the century led to the opening of the Lowell quarry by the Tucker Asbestos Co. in 1899 and of the Eden quarry by the short-lived New England Company in 1901. The Tucker Asbestos Co. in turn sold out in 1908 to the Lowell Lumber and Asbestos Co., William Gallagher, president. It should be noted that asbestos was also discovered in nearby areas not on Belvidere Mt., but that large scale commercial production has been limited to Belvidere. Figure 2 shows asbestos-bearing rocks of Vermont as part of a belt continuing well into Canada, where mining has since occurred on a vastly greater scale. By 1910 asbestos production was in full swing, at the rate of about 200 tons/day, and the mine site was known by the name Chrysotile, Vermont (Figure 3). However, the economics of the operation were marginal and production later ceased.

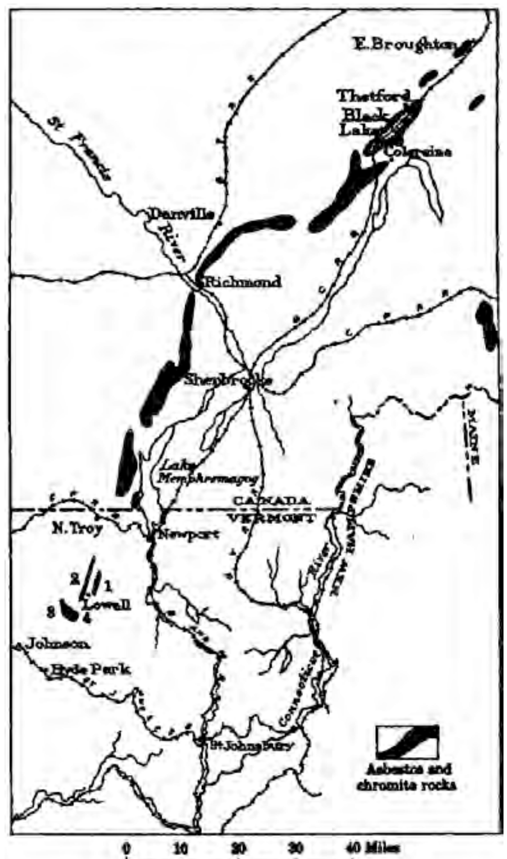



Figure 2. Map showing regional asbestos deposits (Hayes & Lindgren, 1910)

Figure 3. Photo of the mill at the Lowell Lumber and Asbestos Company, Chrysotile, Vermont (Richardson, 1910)

In 1920 the Asbestos Corporation of America was established, and acquired all the various properties at Belvidere Mt., and reopened the mine (Perkins, 1921). This company was in turn acquired by the Ruberoid Corp. in 1936. Ruberoid built an aerial tramway to the mill at the Eden quarry, parts of which are still visible (Kierstead, 2008). In the 1950s the so-called C-area quarry on the south side of Belvidere Mt. was opened, and a new mill constructed below the Lowell quarry. The buildings visible to the visitor today date from this period. During the NEIGC field trip described in Van Baalen et al., (1999), trip participants were treated to a tour of this mill by retired mine superintendent Elverne Jones. Appendix A to this document contains a bit of oral history in the form of a 2007 interview of Mr. Jones, then aged 91. Ruberoid was acquired by General Analine & Film Corp. (GAF) in 1967 and the mine continued operating under that name until 1974. At that time EPA required GAF to install extensive dust handling and other safety equipment at the mine, and GAF elected, based on economic considerations, to close its doors. However, the employees of GAF decided in 1975 to purchase the mine and incorporate as the Vermont Asbestos Group (VAG). VAG became one of the largest employee-owned companies in the U.S. (material from unpublished VAG handout). In 1993 VAG ceased operations and the quarries on Belvidere Mt. fell silent after a century of activity. Meanwhile, G-I holdings became a successor corporation to GAF, with important implications described presently. Coincidentally, or maybe not, 1993 also saw the closing of the only other asbestos mine in the U.S., the KCAC mine at New Idria, California.

A more detailed history of the mines and of mining technology employed there is contained in Kierstead (2008).

## THE TAILINGS PILES

### Legacy of a Century of Mining

The asbestos-bearing rock at Belvidere Mt. contains at most 5% chrysotile asbestos. In other words, 95% or more of the ore derived from the quarries has little economic value and has been stored in increasingly huge tailings piles for 100 years. There are several piles, including one standing in front of the Eden quarry, estimated at 12 million tons (EPA, 2009a), and the Lowell pile, estimated at 30 to 60 million tons (EPA, 2009a). Additional piles lie to the northeast and are not included in these estimates. The mineralogy of the tailings piles is discussed below. The immediate environmental problem here is that portions of the tailings piles are slowly eroding, allowing material to wash down into the drainages of the Hutchins Brook and the Corez Pond and Burgess Branch, a tributary of the Missisquoi River. In the case of the Hutchins Brook drainage, material has invaded the wetlands of the adjacent property owner, and begun to fill in the pond in front of his fishing camp. This unacceptable situation led to the involvement of the

Vermont Agency of Natural Resources (ANR), starting in 2004. Remediation began in 2007 and is discussed below.

**Mineralogy of the Tailings Piles**

The mineralogy of the asbestos deposit was described in Van Baalen et al. (1999) and Chidester et al. (1978). However, since the publication of those papers, environmental concerns over non-occupational exposure to asbestos at this locality have heightened, and since the mine tailings might pose a risk to the local community, a more detailed examination of the mine tailings seemed warranted. (See Gunter et al., 2007a and references therein which discuss these issues.) We can assume that the mineralogy of the tailings piles is closely related to that of the wallrock in the quarries, discussed above.

Also it has become accepted that exposure to chrysotile asbestos is far less harmful than amphibole asbestos. In fact, asbestos-related diseases among chrysotile workers are often ascribed to the possibility of amphibole asbestos occurring in the chrysotile ore (Gunter et al., 2007b). Because of this, newer methods have been developed to better characterize the mineralogy of chrysotile ores and tailings (Williams-Jones et al., 2001; Gunter et al., 2007b). Williams-Jones et al. (2001) found amphiboles occurring in veins, but not the chrysotile ores in the Jeffrey Mine in Asbestos, Quebec. These veins may in turn represent intrusion by mafic dikes prior to serpentinization, a feature generally absent at Belvidere Mt. (with the significant exception of the large rodingite dike in the Lowell quarry). Gunter et al. (2007b) found only trace amounts of non-asbestiform amphibole in one of ten samples they collected from the Carey Canadian Mine, which is approximately 50 km northeast of Asbestos. Both of these studies help lay the groundwork for the current studies on this deposit, especially Gunter et al. (2007b) in which a powder X-ray diffraction (XRD) method was developed with a detection limit for amphibole of about 0.1%, or better.

In June 2007, one of us (MEG) collected five tailings samples and two ore samples with the sole purpose to determine if amphiboles were present by using XRD. He found trace amounts of amphiboles in all five tailings samples, and no amphiboles in the two ore samples. In a much larger study researchers with the USGS visited the deposit in July 2007 and collected 16 tailings samples and 2 processed ore samples. MEG provided them with his two ore samples. These samples were then characterized by a combination of: XRD (to determine the minerals present), polarized light microscopy (PLM) (to determine the morphology of the particles), scanning electron microscopy (SEM) (to determine the morphology of the particles and aid in identification), electron probe microanalysis (EPMA) (for precise compositional determinations), and Raman spectroscopy (to distinguish the different serpentine minerals). What follows is a brief overview of this work. For details see Levitan et al. (2009).

The following minerals were identified by XRD: serpentine group minerals (i.e., chrysotile and antigorite), magnetite, chlorite, quartz, pyroxene, brucite, mica, and carbonate minerals. Also based on XRD, 12 of the 16 tailings samples contained amphiboles, while no amphiboles were detected by XRD in the four ore samples. EMPA yielded 4 different species of amphiboles: edenite, magnesiohornblende, magnesiokatophorite, and pargasite. Observations of the amphibole's morphology showed them all to be non-asbestiform. Last, and possibility most importantly, Levitan et al. (2009) pointed out that the surface of most of the tailings piles is cemented by secondary magnesium carbonate minerals. Needless to say, this secondary mineralization will help reduce the risk of off-site wind dispersion of chrysotile asbestos – the only asbestos found in the tailings.

**Nickel and Chromium**

Another issue related to erosion of the tailings piles is watershed contamination by the heavy metals Ni and Cr. The ANR Water Quality Division report (ANR, 2008), evaluated the health of vertebrate and invertebrate faunal communities in the areas immediately below the tailings piles. They also analyzed stream sediments and the chemistry of surface waters. In this study (p. 16) is the statement that "Metals ... particularly nickel and chromium, are present in high concentrations within the chrysotile fiber structure." A more likely source of these metals is small eroded and transported particles of the minerals chromite ($FeCr_2O_4$) and heazlewoodite ($Ni_3S_2$) that are reported at Belvidere Mt. and are ubiquitous in serpentinites worldwide. One striking thing about the biological results is that degradation of the stream environment is extremely localized in the areas downstream of Belvidere Mt., and that the health of the streams more than three miles from the mountain is deemed excellent. The multi-faceted drainage controls described in the next section are intended to reduce or eliminate downstream contaminarion from the tailings piles. This in turn may invalidate the conclusions of ANR (2008) and require a new assessment. Further discussion of the Ni and Cr story is beyond the scope of the present paper and will be addressed separately.

## MITIGATION EFFORTS

As mentioned above, a 2004 complaint was filed by an adjacent landowner in the Hutchins Brook watershed to the Vermont Department of Environmental Conservation (DEC). In 2005 and 2006, studies were undertaken by DEC and the Agency of Natural Resources (ANR), that substantiated this complaint (ANR, 2008). In 2007, ANR requested the involvement of EPA. These agencies embarked on a multi-faceted drainage control project in 2007 and 2008. The purpose of this project was to redirect stream flow away from the tailings piles by use of grading and culverts, and to construct berms and settling ponds that would contain material eroded from tailings piles onsite, thus preventing the downstream contamination of the two watersheds. In addition, a program of ongoing air quality sampling with a network of monitors was established (Figure 4). This work was completed in 2008, and is detailed in EPA (2009a).

Meanwhile, the Vermont Dept. of Health (DOH) became concerned about the possible risks to residents of adjacent communities from windblown asbestos fibers from the tailings piles. The DOH study (DOH, 2008) created an uproar in the local community and in the scientific community beyond. See below for a complete discussion of this report.

EPA also engaged in what is known as activity based sampling to assess the risks of asbestos inhalation to ATV riders who frequent the site. Sampling was undertaken in October, 2008, with the results published in July, 2009 (EPA, 2009b). Instrumented ATV riders in protective clothing followed specific routes at the mine, and their attached air filters were analyzed for asbestos fibers. Other workers aggressively disturbed the soil with steel rakes. Still others sampled the interiors of some of the mine buildings on the site. This study confirmed that there is indeed chrysotile asbestos at the asbestos mine, and that disturbing the soil raised the concentration of airborne fibers. Highest concentrations for the ATV riders came from the Eden tailings pile. Overall, highest fiber concentrations came from the interiors of some of the onsite buildings. Ambient air samples from a control station adjacent to the mine showed asbestos fibers. The highest fiber concentration observed was 0.000165 structures per cubic centimeter (s/cc), which is at or below background levels in the U.S.. Significantly, the study presented no evidence that walking on the site, which might be done by visiting scientists, presented a hazard. Also, EPA does not require its own workers who routinely monitor the air quality sampling stations to wear personal protective gear.

While these physical activities at the mine site were underway, EPA attorneys were negotiating with G-I Holdings, Inc., a former owner of the mine (see above). The goal of these negotiations was to obtain a consent decree and settlement agreement to provide funding for some of the remedial work. This decree was logged by the U.S. Bankruptcy Court for New Jersey on July 2, 2009. In the settlement, G-I agreed to fund 8.6% of future remediation costs. A Trust has been created to administer the various site-related activities going forward.


Figure 4. EPA Air quality monitoring station at Belvidere Mt.

**The Boy Scout Camp**

As this article was about to go to press, the authors became aware of an additional study of asbestos at the Mt. Norris Scout Reservation, operated by the Green Mountain Council, Boy Scouts of America. Mt. Norris is about 5 km. East of the VAG mine, and a summer camp operates there. The Boy Scouts were advised that a potential risk to these campers from asbestos exposure existed, resulting in an EPA sampling study in March, 2009. Preliminary results suggested measurable asbestos in dust in some of the cabins, and also in air samples in some of the cabins. Some of these measurements fell above conservative EPA guidelines. As a result, the camp was closed for the 2009 season. The results of the March study were released in August, 2009 (EPA, 2009c).

## STUDIES OF ASBESTOS HEALTH RISKS

In the formerly unregulated workplace, i.e. before OSHA regulations were passed in 1970, asbestos fibers have given rise in workers to fibrosis of the lungs (pulmonary fibrosis or asbestosis) and pleura, i.e. the membranes that encase the lungs (pleural fibrosis) (Mossman and Churg, 1998; Kamp, 2009). Fibrosis is defined as excessive deposition of extracellular material in the lung. Fibrosis is a non-malignant, but debilitating disease that can result in shortness of breath and when progressive, death. However, clinical and epidemiologic studies have shown that this is an occupational disease not observed in humans since lower environmental concentrations of asbestos were mandated by regulation. These results are consistent with experimental animal studies indicating that asbestos-related diseases occur in a concentration or dose-related fashion. In addition, occupational exposures to asbestos fibers are associated with the development of lung cancers, tumors almost exclusively observed in smokers, and malignant mesotheliomas (MM), rare tumors occurring from lining (mesothelial) cells of the lung and peritoneal (gut) cavities. MMs generally take decades to develop, and the average latency period, i.e. time from initial exposure to asbestos to tumor diagnosis, may be 30 to 40 years. Both epidemiologic and lung burden studies, in which asbestos fiber types are identified and quantitated in lungs digested from patients, show that MMs, as opposed to fibrosis and lung cancers, occur at lower concentrations of amphibole (crocidolite, amosite) or mixed (chrysotile and amphibole fiber) exposures to asbestos (reviewed in Mossman et al., 1990; Robinson and Lake, 2005). Several clinical studies suggest that crocidolite and amosite asbestos may be more harmful than chrysotile asbestos, particularly in the causation of MM because amphibole fibers in general tend to remain in the lung and not dissolve over time as does chrysotile asbestos (National Cancer Institute, 2009). Moreover, unlike additive or synergistic effects of asbestos exposures in the development of lung cancers, smoking combined with occupational exposures to asbestos, does not increase the risk of MM (Mossman et al., 1990; Robinson and Lake, 2005; National Cancer Institute, 2009). Asbestos ingested by animals does not cause tumors. Moreover, asbestos does not cause an increased risk of gastrointestinal or colorectal cancer in the vast majority of studies. Thus the evidence for any type of asbestos being a carcinogen at past, high unregulated airborne concentrations in the workplace is "inconclusive" for these and other tumor types (National Cancer Institute, 2009). The EPA acknowledged decades ago that asbestos fibers in drinking water are not carcinogenic.

In 2008, the Vermont DOH published a cross-sectional study of asbestos-related morbidity and mortality in Vermonters residing near Belvidere Mountain based on data from individual death certificates and hospital discharges from 1996-2005 using "three different databases". This study concluded that Vermonters who were diagnosed or died of asbestosis or who were diagnosed with lung cancer (note that data on individual smoking status were not collected nor assessed) were "statistically more likely to live closer to the mine." The publication and dissemination of this study, which was based on 3 asbestosis-related deaths, 2 of which upon follow-up by citizens of the area were associated with high previous occupational exposures to asbestos elsewhere, engendered public fear in the community. Subsequently, a case series follow-up by the Vermont DOH was published in April 2009 which clarified that all reported deaths were due to occupational exposures, stating that they "found no evidence that people who live near the mine are more likely to die of non-occupationally contracted asbestos-diseases than people who live elsewhere in the state".

## DISCUSSION

The preventive measures consisting of extensive drainage controls and construction of settling ponds completed in 2008 (EPA, 2009a) were necessary and appropriate, in order to stop downstream transport of materials from the tailings piles. It is important that these drainage controls be maintained and that the monitoring of their effectiveness continue.

As this article goes to press, the EPA is considering adding Belvidere Mt. to the National Priorities List under the Superfund Program. The 2008 DOH report conclusions are the scientific basis of this proposal. Unfortunately, the now-discredited and retracted DOH study has been used as justification for additional remedial activities said to be protective of the public health although scientific evidence for deaths of residents near the mine or historically exposed to Belvidere Mt. tailings is lacking. The EPA activity based sampling study at Belvidere Mt. (EPA, 2009b) was not a scientific study in the normal sense of the word, because it was not undertaken in order to advance human knowledge, but rather as part of a legal strategy related to the G-I holdings consent decree (ANR, 2009). However, this study did provide evidence that ATV riding at the mine site significantly raised airborne asbestos levels. For this reason, as well as the more important risk of destabilizing the tailings piles and increasing erosion rates, we agree that reasonable limitations on ATV riding at the mine are also necessary and appropriate. The 2009 study of asbestos contamination at the Boy Scout camp (EPA, 2009c) found that some of the measurements were above EPA guidelines. As a result the camp was closed, and the boys who might have attended in 2009 did not do so. A proper scientific study of that situation might well conclude that the positive benefits on health and social development of boys attending the camp far outweigh the tiny risk imposed by hypothetical asbestos exposure. While a full discussion of the Ni-Cr story is beyond the scope of the present paper, it does seem likely that the source of Ni and Cr is the tailings piles. The drainage controls installed at the mine in 2007-2008 have reduced downstream contamination from the tailings piles. This may in turn invalidate some or all of the conclusions of the ANR (2008) water quality study that was based on field work in 2005-2006, and necessitate a re-examination. In order to convey all the above information to the local community, EPA and ANR have conducted a series of public meetings in the local area. These meetings have been contentious and an atmosphere of mistrust has continued.

What all of this means to the scientific community is unclear. As noted above, the scientific history of Belvidere Mt. goes back to at least 1824, and ongoing research mentioned previously promises new insights. EPA and DOH studies have not shown statistically significant risk to either residents of surrounding communities or from non-destructive visits to the site (as opposed to ATV rides on the tailings piles). It is difficult to accept the argument that such non-destructive visits are hazardous when EPA employees themselves have been observed at the mine, site doing routine maintenance, in civilian clothes, without respirators or other visible personal protective gear. One of us (MVB) responded to the U.S. Dept. of Justice concerning the 2009 G-I Holdings consent decree public comment period. In this letter, he argued that a reasonable procedure should be established for continued scientific access to the Belvidere Mt. quarries, and that this access would not inhibit or be in conflict with future remediation activities. He further argued that outside peer review of future agency studies would enhance the public interest and improve the science surrounding the remediation. It is likely that the decision on whether to move forward with Superfund listing for Belvidere Mt. will involve the most senior officials in the state government. We believe that these officials would benefit by outside input from scientists not connected with the several state and federal agencies.

## ACKNOWLEDGMENTS

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## APPENDIX

This appendix contains the transcription of an interview of Mr. Elverne Jones by two Harvard students, Danielle Kerper and Allison Gale, on November 18, 2007. Mr. Jones worked at the mines on Belvidere Mt. for over 60 years and served in a variety of roles, including mine superintendent, during that time. He is now in his 90s and lives in Eden Mills, Vermont. He suffered a stroke in 2006, approximately one year before this interview. In the text, Mr. Jones is identified as JONES, Danielle Kerper as DK, and Allison Gale as AG.

JONES: I'll tell you my mind is not very good to remember since I had that stroke. Hour from now, half hour maybe when I'm talking I can think of things that I couldn't tell you. Then I'm thinking what do you want to hear? What I have done?

DK: I basically would like to know what it was like, when the quarry was actually functioning and you were overseeing.

JONES: Well, first there's two quarries. They used to be the Gallagher mines. That was in Lowell, just over the line. And one's on the line, and Eden was there. But Gallagher, I didn't work there during that time. I've got some papers here that, fellow that knew a little about it, and he gave them to me here two, three days ago, you can have them if you want them. The Gallagher mine.

DK: All right. Yes, thank you.

JONES: Then they come over on the Eden side here, and started a mine over here. The dates, I didn't pay attention to them. Because I worked up there between 60 and 70 years at the mines, and I'll tell you this asbestos kills you. Didn't have no luck for me anyway. And then this stroke. I was working up until till I had the stroke a year ago. I'd done every job when I first went up there. I worked on the farm over here that summer. And you get on the hay, and you probably don't know much about farming, and then there's nothing to do really in the fall of the year. So I thought I'd go up to the mines. So I went up there and they gave me a job, running the jack hammer. Do you know you go up to their mines and, oh boy! The next morning I couldn't get my shirt on. What I finally did, I went back to work, and I worked about a month or two, and then they shut down in the wintertime, because there's so much snow, you couldn't do anything. This time of year back then, you couldn't see a car go by. They run with the summertime and not in the wintertime, and wintertime second year I went to Montpelier -- that was the legislature where they make laws, rules. I went there. I worked that winter. I came back and went on the farm, and then it came that fall. Well, I said I'd go back up to the mines. No, I guess somebody came to see me. So that winter I was up there alone with a dog. People that was there, they had left. And I thought they were going to stay, but they didn't. And from then on the mines wanted me to come back up and I said, no, I don't want to do it. They kept after me, two or three of them. Finally I went back up and stayed there, and I was there ever since. I've had different jobs, jack hammers to plant manager. Worked through everything up there. I started jack hammer, and then I was on the bulldozers and every job up there except bagging. Bagging is dusty. I never had done that. You bag the asbestos. Yeah, the mine was operating. After a few years the mine operated in the wintertime you know, after I was up. And times was tough. There was ten men that could do the job, and I walked up there. It was two miles up on the mountain. And some of us walked up there to get to work. And then they got an old plow, a nice little tractor. And they tried to plow the roads. Done pretty good. And finally they got it straightened out, all the roads, and we worked the year around. Then they started the mine over here, the new mine, and they put it over the mountain on buckets, cable and buckets. We'd go up there, took it, little buckets and get it up there.

DK: Was that the Lowell quarry?

JONES: Yeah, from the Lowell quarry. So then they was building in the mill in the yard and everything, and finally they stopped the buckets. They started quarrying over here.

DK: In the C area?

JONES: Yeah. C area. And they, what year that was, I can't remember. That was about it as far as I was concerned. Done everything. The job there was tester-grader. You make the fiber. They tell you what they want. If you can get it out of it, you had no say but you'd go up there and say hey, I want 5r, and they're going to turn that rock over to get it. And that you use. And that wasn't my type of job. I wanted to be outdoors and so I went to Carl White. He was the superintendent. So I said why are you keeping me on here? I said, I don't want to be. Carl says, you'll like it after a while, you're in our employment. And I said, I don't like this job though, I want to do something else. No, I said, I'll do something else. I said, why did you get me? He said, I got you on here because I know you can do it. And I have to say that I did, was tester-grader for a long time because you run the whole mill. You got the shaker table, you got everything up there, and you got to put so much on this one and so much on that one, and fiber come out down there, test you on just what you want. So after I went on, that was it, it isn't going to do me good. Then I really liked it, it was really challenging, and they kept me on that for a long time, because I could do it, and then they got by making grades and different grades, and they'd all put them on my shift. And so I said something, Carl, why in Jesus do I have to make all these special grades? He said you do it because you know you're doing right. [LAUGHTER] And that's the way it was. Then I went to foreman I guess, No, I went into the mine office, in the mill office with Carl actually, you know. Clerk. You know, pay this and that. And I was there a few years, and funny thing happened. This company was in New York, and they came up, some of them. Nobody knew that they was coming. I was there. Carl was gone. He was off, I don't know somewhere, and the plant manager, he was gone. And these guys came up and said, who else is here? I says, nobody. They says, you mean you're the plant manager? No, I said, I'm not a plant manager, but I'm doing the job. Work here for a while. They was amazed at that. They didn't think, they didn't see how anybody could do that. But I did it, and so I did that a while. And that's, well after tester-grader I was general foreman in the mill and quarry and everywhere. It was a challenging job; there was always something. But when they say asbestos kills you, it probably does, the right people. Anything would kill the right people you know. But I've been, well I say I've been up there 'til last year because I worked there. I worked in that day after day. Come home at nights and you couldn't see where the hell I was. Covered with dust and everything. I never got it.

DK: Did you ever wear respirators?

JONES: I'm not telling anybody they should do it. It's just the way that it happens with different people, and there was not that many that ever died of asbestosis. There's a few of them there, but you have a few in anything. No, I wouldn't recommend anybody to breathe it, but they did. And then they got to where they had to -- the State required that you had respirators on most of the time when you was in certain areas. So we put a man on to clean them at nights, you know, and get them ready for the next day. And that didn't last very long. [PAUSE] Anything you think of, you ask me and I'll tell you.

DK: How many people worked there?

JONES: Our people, probably when they was working full time probably there was well over a hundred because there were three shifts, you see.

DK: How much of the rock was actually asbestos?

JONES: Oh, that varies. Small amounts.

DK: Five percent?

JONES: I would say five, ten percent. It was rock, asbestos rock. It's in veins. You ever seen it?

DK: Yeah, I've been in the quarry, twice.

AG: Is it still operating?

JONES: No.

DK: Closed it in 1994?

JONES: '94, yeah, but they've fiddled it around last year. A little less. I know it's running a while but --

AG: Because of all these concerns of asbestos?

JONES: Yes, yes. That's what it was, asbestos. Because they're all… the mines are closed. They're all closed up in Canada and everywhere. I've traveled in Canada, and I've traveled in California for the company. They have different things, and they have the mine in California. I used to have to go out there once in a while.

DK: Whereabouts in California?

JONES: I forgot now where I went. But there's a big mine out there in California. [ed. the KCAC mine in New Idria, California]

DK: OK. So you would mine the asbestos and then you'd bag it, and then where was it sent?

JONES: A lot of the years a lot of it was trucked you know, but most of it was railroad. They had a warehouse in Morrisville, that's another job that I've done, I was a warehouse foreman. And then we moved it from there up to North Shore once when they were having a strike out there. So I was between two, three places all the once [LAUGHTER].

DK: So do you know what this asbestos was used for -- building material, or in brake pads? Do you know what kind of products?

JONES: Brake pads was one of the things, the biggest thing. It was used in everything, but as I say everything, not everything but now that they fireproof you know …

DK: Insulation.

JONES: Yeah, insulation. But it takes different grades. There are several grades that you make. You start with the best. It's probably what they called Hooker 1, and it was a long fiber.

DK: Is it different diameters of the fiber, or different quality?

JONES: Yes, longer fiber, it was like this, a bit longer. The longer is higher grade, and then there was a 4t, which was a very popular one after that. And then there was 5r, and 5r5. And 6d, 7d, 7m. There was that many different grades. And you made these all the once. So it's almost impossible to be a tester when you're right in there. And then you go upstairs and change something on the different strain or something to get more of it, you know. You couldn't get all of it because if you've got to Hooker 1, you sure as hell ain't going to get 4t out of it. Because it's too long. We had fellows up there that didn't know really any of that, even the foremen. So tester-grader, they know more about the mill than anyone.

AG: What about the bulk rock? Was there any chrome in the rock? Or was it just --

JONES: It's uncommon.

AG: I'm wondering within that asbestos, was it serpentinite, or what was the mass rock?

JONES: Oh, it was just a blue hard rock. Very hard rock. It's in the veins. You crush it and you got your veins. You get this fiber out, and then it goes into mills where it beats out, and you get it out to the tables where I can see it, separate it.

DK: Was water used ever to keep the dust down?

JONES: No, no, no. Never water. Never used to keep the dust down. I don't know there was a place where I could use it. DK: Was it separated with magnets, or with the shakers?

JONES: Shakers, mostly crushing and shaking. Crushing was a main thing you had. You really crush it, and then the fibers would show up. They're really there, and then you've got to put it through things that beat it, you know, and that would loosen them up. That's all.

DK: I'm studying a graphite deposit, in the C area. Do you know the place I'm talking about?

[ed. Jones thought this question was about garnet, not graphite.]

JONES: No, but there's a tremendous amount of garnet in different colored stones. I've been day after day, after a blast. You know, go out and literally be covered with maybe green this time, maybe red stone like a diamond. And some of the guys, there's a fellow working in that quarry for me there, Clem Mason. He picked it up. He never let anybody else. Of course he was a driver. It would be bulldozed right out. Tons and tons and tons of the stuff that's got rolled over. You go in the mill and then the dryers and some days stand and watch that belt. It is quite amazing to see the tons of garnet and different stuff. It ain't only garnet, it's all kinds of stones there.

DK: There are a lot of minerals. That's a very popular mineral collecting site.

JONES: The biggest garnet in the world was found up here. It was in some museum somewhere, I don't know where it was.

DK: Not at Harvard though.

JONES: No, I don't think so.

AG: And you would just create dump piles, they would just dump the rock into piles?

JONES: Dump the rock that you're going to use?

AG: Well, I mean the rock that was waste rock.

JONES: Oh, waste rock. That was all dumped up there. Right out the side of the mountain. Now then there's mountains of waste rock everywhere. You're going up to the mines?

DK: We're just going to go to the entrance. We're not going to go inside.

JONES: You can't go in anyway because the State is in there.

DK: EPA.

JONES: Yeah. Too bad it is, because if it had been a few months ago I could have taken you in there. Showed you everything.

DK: I've been in there, but unfortunately when the government's involved it makes it harder.

JONES: Something else?

DK: Memories. Any particular really big important thing that happened, or you found something really special?

JONES: No. We was asked just about diamonds. Anything you can come up, boy, you would bulldoze them off. So you picked them up, put them in your pocket. I never was on hand to ever do it. In all the years that I was there and traveled around through there, I've seen this. I never saved any of it. I never was interested. I've been in the mill when you'd see it on the belts.

AG: Never interested in garnets?

JONES: No.

AG: You could have made a lot of money. Gem stones.

JONES: Yeah, I could have. Well, this Clem Mason I was telling you about. He was quarry superintendent, and he had one of the biggest collections. He sold that to someone. They sold it after he died. It went to some college or something. And there was another gentleman worked for me, Dick Earl. He saved a lot of it. And when he died, I don't know what they done with it. Somebody got them. No, I had the best opportunity than anybody ever lived there, because I was around there, because I was superintendent there a long time. I see how good it was and how much stuff there was, and I see if I'd have picked up a handful or two every time… [LAUGHTER]. Well I wasn't interested in it. DK: I notice you have a little painting up on your wall right there.

JONES: Yeah. Well, that one there is from somebody's mineral collections -- gave that to me. They used to come here, mineral collectors. I let them in you know, and they paid a small fee, not very much, to go in and collect things. You probably know it's one of the best collecting places in the world.

DK: It's a very well known site.

AG: Now the government's preventing access.

JONES: Well, the government, this is a funny thing. The government's up there. What they're doing is putting this back. And I'll be damned if the government ain't doing it. I can't understand this government. There's no way that I can understand these things. Thousands and thousands and thousand dollars being spent up there now. They've got a shovel. They got everything up there cleaning it up.

DK: Are they taking down the tailings pile from the upper quarry? Is that the one that's causing all the issues?

JONES: No, no, no. They weren't there. The ones right here.

DK: The one right on the road?

JONES: Well, no, there's some up the other way too that… well he started this fellow that's got some lot right near there. I don't remember him at all, but you got invited to – well, anything you don't want you dug a ditch and just put it over onto his. And that's been how it's done up here. Now they're up there fixing it up. Then they wonder why our taxes are higher. Who the hell's paying? Who's paying for it? You and I are paying for it. We're paying for that up there.

DK: It's the EPA.

JONES: And that's the drop in the bucket in this country.

DK: Are there any big accidents, or did anything go wrong? Was there any explosion that wasn't planned, or any bad accident?

JONES: No. I never knew of one. Have a lot of memories of hurts, you know. Getting caught in machinery. Didn't have no guards. Nothing. First was over at the Gallagher mines, when they first come

over here. It was a few of the guys who got killed, and after that… wasn't nothing. They improved it some. They had these high, high ledges, and they'd blast it, but a lot of the years they covered us so there wasn't so much to come down onto the shovel when you was shoveling with the power shovel. That's another job I've done. I've run the power shovel. I've done about everything.
DK: So the main hazard was falling rock?
JONES: Yeah. You see, you'd be going right through the rock up here, something I can show you. Was hoping we could go up there and I could take you in there. Then you'll see barren rock, nothing in it. Of course you've drilled all this. Core drill. You know what a core drill is? Core drill is all same as they did in Maine. Everywhere is core drilling. They know what it was so they got to get that other ore burden off there first. You ever drove up there?
DK: Yes. I've been in the mine. I've been in the C area quarry. I'm looking at a graphite deposit in the C area quarry.
JONES: I didn't even know it was there! (Laughter) Graphite, yeah.
AG: No source of asbestos in there.
JONES: Nothing.
DK: There's no asbestos in the graphite, but I'm trying to figure out where the graphite came from. So it's a very interesting geological puzzle.
JONES: Yeah, yeah. Well, any help to you?
DK: Yes, definitely. I'm going to be looking at health issues associated with asbestos mining as another part of my project.
JONES: Well, they did a lot of things up here after they divided those three shifts in these bigger places, You have to wear protection, you know, and they say they had a man on there that cleaned them at night, They done a lot. But they gradually didn't wear them. They wasn't forced to wear them, and well, they says it was their own fault.
DK: Do you know of many cases of --
JONES: Asbestosis? I'm going to say eight to ten I actually know of. There could have been some more, you know, but they left and you never knew it. But it seemed, I don't know, it always seemed to me there was somebody that been allowed to smoke in there, something like that. But this asbestosis. So was it asbestosis or was it smoking, or what was it? I smoked, I chewed it, I'd done everything after a while.
AG: You're 91.
JONES: 92 almost. My health was perfect up till I had this stroke here. I like to work, so I worked. I needed to. I liked my job up there and could do it, and that's why I stayed. Hell, what's the use of coming home and sitting down if you…, I didn't need the money. I got to retire. Don't need much in retirement.
[PAUSE]
DK: Well, I think that's good. Thank you very much.

**ROAD LOG**

Note: On account of ongoing legal disputes over the status of the quarries, participants will be asked to sign a release of liability, and the Vermont Geological Survey sponsorship of NEIGC 2009 will not extend to this field trip. Those wishing to visit the mine site in the future are urgently warned to seek permission from the land owner, H.A. Manosh of Morrisville, Vt., before entering onto the property.

This field trip begins at Lyndon State College in Lyndonville, Vermont. The mileages on the road log begin at the I-91 (Exit 24) onramp north of Lyndonville. From the LSC campus, find your way to I-91 Exit 24 north of Lyndonville. Suggested route is to depart campus eastward on College Rd. At the Lyndon Institute, turn left onto Center St. Turn left onto SR 122 (west) and follow that to the I-91 onramp.

**Mileage**

0.0 onramp to I-91 north bound.

21.6 Exit 26 (Orleans, Irasburg), US 5 & SR 58. Go west towards Irasburg.

21.7 left turn, following SR 58.

25.0 center of Irasburg, town common. Right turn, following SR 58.

26.2 left turn, following SR 58.

30.1 pull over on right at sign for Rotboy Rd. Scenic vista.

**STOP 1. GEOLOGICAL OVERVIEW.** (15 minutes). From this spot on a clear day, we see a panoramic view of the northernmost portion of the Green Mountains of Vermont. From our viewpoint we are looking over the valley of the Missisquoi River. On the extreme left lies Belvidere Mt. with its fire tower. Next in order lie Tillotson Peak and Haystack Mountain with its little bump representing a haystack. Directly ahead lie the steep walls of Hazens Notch. To the right of the notch, the long summit of Buchanan Mountain is visible, then a series of summits culminating in the horn-like Jay Peak, with a portion of its ski area visible. To the right of Jay Peak the summits decline in height noticeably as the range continues into Canada. If we had X-ray vision and could see through the mountains, we would observe the waters of Lake Champlain 40 miles to the west.

These mountains lie along the axis of the Green Mountain Anticlinorium, that plunges to the north under the plains of the Eastern Townships of Quebec. The basement rocks of this structure are Grenville age (ca. 1 Ga) gneisses, that are mantled by Neoproterozoic to Ordovician metasediments and metavolcanics (Kim, 2009). Basement rocks crop farther south along strike, but do not crop out north of Camels Hump (J.B. Thompson, Jr., personal communication). Early deformation and metamorphism in this region are of Ordovician (Taconic) age, but Devonian (Acadian) overprints have affected most rocks in the area (Gale et al., 2001). Age controls in the area are limited.

Our destination, Belvidere Mt., has particularly complex geology. Ultramafic rocks representing a Taconic ophiolite slice have been emplaced here, and are both underlain and overlain by Cambrian metasediments. The serpentinized ultramafics have been quarried for over 100 years for chrysotile asbestos.

Return to vehicles and continue west on SR 58.

34.5 intersection of SR 58 and SR 100. Continue straight ahead on SR 58 through tiny village of Lowell.

36.0 turn left onto Mines Rd. About two miles further along, observe tailings piles for the mine on the right.

40.7 turn right onto short mine access road, stop at gate.

**STOP 2. VERMONT ASBESTOS GROUP MINE**

Note: as of this writing the physical access situation at the mine is in flux, so it is not possible to give a detailed road log within the mine property. In addition, some of the stops are weather dependent. Again, readers of this article in the future are urgently warned to seek permission from the land owner, H.A. Manosh of Morrisville, Vt., before entering onto the property.


**STOP 2a. VIEW OF MINE BUILDINGS AND THE LOWELL QUARRY BEYOND.**

**STOP 2b GALLAGHER PIT AND LOWELL QUARRY**

**STOP 2c EROSION GULLIES ON TAILINGS PILES**

**STOP 2d EDEN QUARRY AND TAILINGS PILE**

**STOP 2e DRAINAGE CONTROLS IN HUTCHINS BROOK DRAINAGE**

**STOP 2f COREZ POND DRAINAGE CONTROLS, BURGESS BRANCH**

We will examine phase one remedial action at a demonstrably effective berm.

**Return to vehicles, exit mine gate**. Mileage inside mine not included in road log. Therefore, as we exit the mine property and turn south on North Rd., reset odometers to 0.0.

0.0 turn right onto North Rd.

1.4 overlook of mine property (good photo op but bad place to park vehicles)

3.6 stop sign. Join SR 100 southbound in tiny village of Eden Mills.

3.7 Ingalls Store on right. Stop here for cold drinks. Continue on SR 100.

4.8 turn right onto Shover Rd., immediately prior to intersection of SR 118. Eden General Store opposite.

7.8 end of Shover Rd. Park in turnaround area. Walk back along Shover Rd. 0.1 mile to driveway. Follow driveway to fishing camp. Note this is private property; owner's permission required to enter. Contact Robert Manchester, Esq. (802-658-7444) to request permission.

**STOP 3. HUTCHINS BROOK WETLANDS** (1 hour)

Erosion of the Eden tailings pile that we visited at Stop 2d has allowed serpentine gravel to accumulate in the Hutchins Brook drainage. This gravel has resulted in a prograding delta that is devouring otherwise pristine wetlands. The log cabin here might look out onto a scenic pond, but instead looks out onto several acres of serpentine gravel. The centimeter size of the gravel suggests that most of the material is transported during the period of spring runoff, as the brook here is quite small. The owner of this property filed a complaint in 2004 with the State of Vermont, asking that this problem be addressed.

**End of trip**. Return to vehicles and retrace the route back to the store at Eden Mills. From here, follow SR 100 north to Lowell, turn right onto SR 58 towards Irasburg and Lyndonville.

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