

## EPIDEMIOLOGIC STUDIES OF MINING POPULATIONS EXPOSED TO NONASBESTIFORM AMPHIBOLES

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### INTRODUCTION

Current standards for the control of asbestos exposures have resulted from proven and serious health effects caused by commercial asbestos, principally chrysotile, amosite and crocidolite. There is more limited information from asbestiform tremolite, actinolite, and anthophyllite. The latter amphibole minerals are also commonly found in nonasbestiform habits. It has become a matter of considerable scientific, social, and economic importance to define precisely which elongated and asbestos-like particles are hazardous to health. Of particular interest is to determine whether or not there is any need to regulate exposures to acicular particles, such as cleavage fragments of nonasbestiform tremolite, actinolite, and anthophyllite as well as the nonasbestiform varieties of other amphiboles. Particles of these minerals found in the environment may meet the currently accepted 3:1 length-to-width (aspect) ratio used to define fibers, but not be asbestiform. The mining populations to be discussed in this report supply information on the health effects of such exposures.

Although not addressed in detail, important related questions pertinent to the biologic effects of elongated particles are: (1) What should be the minimal particle length subject to control, i.e. should fibers shorter than 5 micrometers be included? (2) Since there is considerable doubt as to whether particles with aspect-ratios below 1:10 or 20:1 are hazardous, is it proper to use an aspect-ratio of 3:1? These important questions are discussed in detail in mineralogic references cited in the bibliography.<sup>5,6,17,24,33,38,39,41,42,43,44,45,46</sup>

### MINING POPULATIONS THAT WERE STUDIED

Four areas were identified where there have been health studies of mining populations known to have been exposed to nonasbestiform amphiboles. In each there had been concern about the potential for asbestos-like effects. These were (1) taconite mines in the eastern Mesabi Range in Minnesota; (2) the Homestake gold mine in western South Dakota; (3) the Sydvaranger iron mine in northern Norway; (4) iron mines in southwestern Labrador.

### MINNESOTA TACONITE OPERATIONS

Minnesota taconite mines came under active study after the discovery in 1972 of asbestos-like particles in the water supply of Duluth.<sup>23,27</sup> These were attributed to the discharge

into Lake Superior of tailings from the Reserve mining operation located at the eastern end of the Mesabi Range. The mining of taconite as a major source of iron had begun in this area in the early 1950's with pilot operations starting about 1947. The consensus of mineralogic and environmental studies<sup>2,3,15,32,35,36,39,40,45</sup> is that (a) ore bodies in the eastern portion of the range contain amphiboles, principally cummingtonite, grunerite, actinolite and hornblende; (b) there are many cleavage fragments that meet the regulatory definition of fibers by having 3:1 aspect-ratios; and (c) asbestiform particles are rare, although a small amount of asbestiform ferroactinolite was found in one area.<sup>9,10</sup> Dust exposures in some locations were sufficient to cause concern as to possible silicosis. Langer in 1981<sup>22</sup> summarized the major issue in the Minnesota taconite mines as being "the biological activity of acicular (needle-like) cleavage fragments of grunerite..."

Clinical studies of Reserve miners and millers by Clark et al.<sup>8</sup> and Higgins et al.<sup>18</sup> showed no evidence of asbestos-like effects, but there was radiographic evidence of possible early silicosis. An analysis of mortality in 5,751 Reserve workers who had been employed for one or more years in the period 1952–1976 showed 15 lung cancer deaths with 17.5 expected for an SMR of 84.<sup>19</sup> During the observation period 15 or more years after hire, the SMR was 102, based on 8 deaths from lung cancer.

Cooper et al.<sup>11</sup> analyzed mortality in 3,444 taconite miners and millers employed by the Erie Mining Company or by U.S. Steel for 3 months or more between 1947 and 1958. There were 801 deaths, with 41 due to respiratory tract cancer, 61% of the number expected using U.S. death rates or 85% of expected using Minnesota rates. There were small but not statistically significant excesses in deaths from kidney and lymphatic cancers. There was one death from pleural mesothelioma, which was not attributable to mine exposures, since it occurred only 11 years after hire and there had been probable pre-employment asbestos exposures.

One can conclude that there is no evidence of asbestos-related disease associated with employment in the Reserve, Erie and U.S. Steel iron mines in Minnesota, where there have been opportunities for exposure to nonasbestiform amphiboles in the taconite ore deposits.

### HOMESTAKE GOLD MINE

In 1974 it was recognized that the ore body of the Homestake

gold mine in western South Dakota contained cummingtonite-grunerite similar to that which was of concern in Minnesota. Since Homestake mining operations had begun in 1876 and past dust exposures had been relatively high, it was realized that epidemiologic studies could yield valuable information.

There have been a number of mineralogic and environmental studies.<sup>1,4,12,29,30,39</sup> There is general agreement that cummingtonite-grunerite, tremolite-actinolite and hornblende are present, that acicular fragments are common, and that there are few if any asbestiform particles. Current exposures to acicular fragments corresponding to 3 f/ml were reported, with estimates of time-weighted average exposures to such particles ranging from 0.25 to 1.72 per ml.<sup>47</sup>

There have been three published epidemiologic studies of Homestake miners. The first, by Gillam et al. in 1976<sup>14</sup> reported 10 deaths from respiratory tract cancer with 2.7 expected as well as 8 deaths from non-malignant respiratory disease with 3.2 expected. The authors attributed the latter to asbestos. This study was seriously flawed, and later analyses of mortality in larger cohorts have not confirmed the authors' conclusions. McDonald et al.<sup>28</sup> in 1,321 Homestake workers employed for 21 years or more found no excess lung cancer deaths (17 with 16.5 expected) but there were 37 deaths from pneumoconiosis and 39 deaths from tuberculosis (SMR = 1,038, or over 10 times the number expected). A single mesothelioma death was observed, in a surface worker who during a relevant time period (22 to 26 years before death) had worked in machine maintenance with probable exposures to asbestos. In a more recent study sponsored by NIOSH, Brown et al.<sup>4</sup> similarly found no excess lung cancer deaths in a population of 3,328 underground Homestake miners (43 with 42.9 expected). There were 53 deaths from nonmalignant respiratory disease observed with 19 expected, due to a large number of deaths from silicosis and silicotuberculosis.

In describing the exposures of workers in their study, Brown et al.<sup>4</sup> stated that cummingtonite-grunerite, silica, arsenopyrite, and radon were possible hazards. Their results were consistent with the conclusion that silica was of major importance. With respect to amphibole exposures, they stated that the mean time-weighted-average exposures of all miners to C-G particles longer than 5 micrometers was 0.44 such particles per cubic centimeter, based on a 1977 survey. Early exposures had probably been greater.

One can conclude that despite dust exposures sufficient to cause severe and often fatal silicosis, with concurrent exposures to nonasbestiform amphiboles, there was no evidence of excess deaths attributable to asbestos, i.e., lung cancer, mesothelioma, or asbestosis.

### SYDVARANGER IRON MINE

Iron mining began near Kirkenes in the northernmost county of Norway in 1907. The ore body resembles that in Minnesota, containing cummingtonite-grunerite, actinolite, and hornblende. These amphiboles occur in elongated fragments, many of which are over 5  $\mu\text{m}$  in length with aspect-ratios as high as 11:1.<sup>16</sup> Amphibole bodies have been found in the lungs of deceased miners by Gylseth et al.<sup>16</sup> There are no reports to indicate that any of the elongated particles are

asbestiform, nor is there any evidence to date to indicate asbestos-related disease. Gylseth et al.<sup>16</sup> stated that an analysis of deaths during the period 1949 through 1963 showed no excess lung cancers. Saugstad in 1980<sup>34</sup> studied deaths from lung cancer in Finnmark County where the mine is located. While the county had a higher lung cancer incidence than Norway as a whole, this did not appear to be related to working in or living near the iron mine. Data from the Norwegian Cancer Registry have not shown any excess mesothelioma deaths in the area.

### LABRADOR IRON MINES

During the early 1970's it was discovered that iron ore deposits in the Wabush Range in southwestern Labrador contained amphibole minerals, including cummingtonite-grunerite. The two iron mines in the area, one operated by the Iron Ore Company of Canada (IOCC) and the other by the Erie Mining Company, had begun operations in 1962 and 1965 respectively. They had been alerted to dust hazards because radiographic changes consistent with pneumoconiosis had been found during surveillance programs required because of potential quartz exposures. Because of concern that there might be asbestos-related disease, a major study was started in 1979. Financed by industry, it was coordinated and supervised by the provincial government and a distinguished scientific committee selected by industry, government, and labor. The actual investigation, the Labrador West Study, was carried out by the Labrador Institute of Northern Studies, based in the University of Newfoundland.

The results of the Labrador West Study were made available in 1982.<sup>21</sup> They confirmed the presence of cummingtonite-grunerite and other amphiboles, but the concentrations of fibrous particles (i.e. those with aspect-ratios 3:1 or more) were relatively low and 98.5% were shorter than 5 micrometers. Very few were considered to be asbestiform. Lee and Fisher<sup>25</sup> and Lee et al.<sup>26</sup> reported more detailed mineralogic findings in the Labrador mine which were in essential agreement.

Medical studies<sup>7,13,21</sup> have confirmed the presence of a mixed-dust pneumoconiosis, presumably due to combined exposures to iron oxides and silica. Although the original detailed report<sup>21</sup> contained a section which suggested that there was evidence of pleural thickening in some of the chest films, this was not mentioned in the published report of the radiographic findings.<sup>7</sup> Review of films reported as positive for pneumoconiosis by Cooper and Sargent (personal observation) showed no changes suggestive of asbestos effects.

The Labrador populations have not been the subject of a cohort mortality analysis. They are reaching a time period, 23 to 26 years after the start of operations, where meaningful results might be obtained.

### SUMMARY AND CONCLUSIONS

In four mining areas where exposures to elongated but nonasbestiform amphibole particles have been confirmed, there has been no evidence of asbestos-like effects. The negative evidence is strongest in the Homestake gold mine,

because of the proven high dust exposures in the past as shown by the high silicosis incidence, and the opportunity for observation after long latency. The evidence is convincing in the Minnesota taconite miners. Although the exposures were lower, the populations are large and there has been ample time for latent disease to appear. The information from the Sydvaranger iron mine and the Labrador mines is also reassuring, but it would be of value to have historical-prospective cohort studies of mortality to augment the existing negative evidence.

Cumulatively, these studies do not indicate that there is any reason to control nonasbestiform amphiboles in a manner comparable to that required for commercial asbestos.

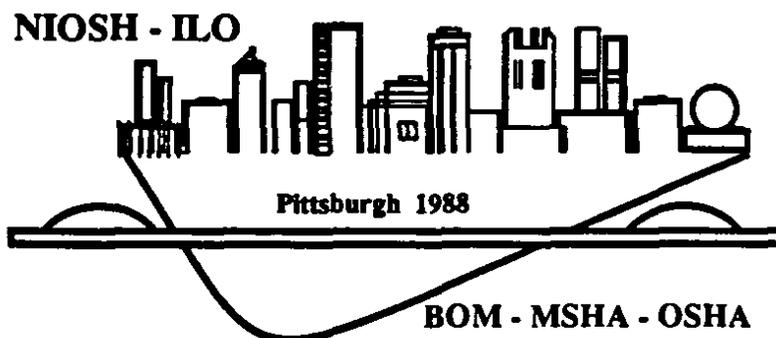
## REFERENCES

- Bank, W., Schutz, L.A., Hudson, H., Trabant, G.D.: *Fiber Survey—Homestake Mine, Homestake Mining Company, Lead, Lawrence County, South Dakota*. Mining Enforcement and Safety Administration Health and Safety Technical Support, United States Department of Interior, Sept. 23–Oct. 3, (1974).
- Bonnichsen, B.: *Geology of the Biwabik Iron Formation, Dunka River Area, Minnesota. Economic Geology* 70:319-340 (1975).
- Bonnichsen, B.: *Metamorphic Pyroxenes and Amphiboles in the Biwabik Iron Formation, Dunka River Area, Minnesota. Mineralogical Society of America Special Paper* 2:217-239 (1969).
- Brown, D.P., Kaplan, S.D., Zumwalde, R.D., Kaplowitz, M., Archer, V.E.: *A Retrospective Cohort, Mortality Study of Underground Gold Mine Workers in Silica, Silicosis and Cancer: Controversy in Occupational Medicine* pp. Goldsmith, D.F., Wing, D.M., Shy, C.M., Eds. Praeger, Philadelphia (1985).
- Campbell, W.J., Blakely, R.L., Brown, L.I., Cather, E.E., Sjöberg, J.J.: *Selected Silicate Minerals and their Asbestiform Varieties: Mineralogical Definitions and Identification. Information Circular 8751*, U.S. Dept of the Interior, Bureau of Mines (1977).
- Campbell, W.J., Steel, E.B., Virta, R.L., Eisner, M.H.: *Characterization of Cleavage Fragments and Asbestiform Amphibole Particulates. Dust and Disease (Occupational and Environmental Exposures to Selected Fibrous and Particulate Dusts)* pp. 275-285. Lemen, R., Dement, J.L., Eds. Pathotox Publishers, Inc. Park Forest South, Illinois (1979).
- Chittai, S., Martin, J.R., Moore, E., Segovia, J., Muir, D.C.F.: *Distribution of the ILO U/C Categories (1980) for Pneumoconiosis in Two Iron Mines in Labrador West and their Correlation to Measurement of Health and Exposure. Proc. Vth International Pneumoconiosis Conf.*, pp. 1098-1106., Bochum. Fed. Repub. Germany (1983).
- Clark, T.C., Harrington, V.A., Asta, J., Morgan, W.K.C., Sargent, E.N.: *Respiratory Effects of Exposure to Dust in Taconite Mining and Processing. Am. Rev. Resp. Dis.* 121:959-966 (1980).
- Coffin, D.L., Palekar, L.D., Cook, P.M.: *Correlations of in vitro and in vivo Methods by Means of Mass Dose and Fiber Distribution for Amosite and Fibrous Ferroactinolite. Env. Health Persp.* 51:49-53 (1983).
- Coffin, D.L., Palekar, L.D., Cook, P.M.: *Tumorigenesis by a Ferroactinolite Mineral. Toxicology Letters* 13:143-149 (1982).
- Cooper, W.C., Wong, O., Graebner, R.: *Mortality of Workers in two Minnesota Taconite Mining and Milling Operations. J. Occ. Med.* 30:506-511 (1988).
- Dement, J.M., Zumwalde, R.G., Wallingford, K.M.: *Discussion Paper: Asbestos Fiber Exposures in a Hard Rock Gold Mine. Ann. N.Y. Acad. Sci.* 27:345-352 (1976).
- Edstrom, H.W., Rice, D.M.D.: *"Labrador Lung": an Unusual Mixed Dust Pneumoconiosis. Canadian Med. Assn. J.* 126:27-30 (1982).
- Gillam, J.D., Dement, J.M., Lemen, R.A., Wagoner, J.K., Archer, V.E., Blejer, H.R.: *Mortality Patterns among Hard Rock Gold Miners Exposed to an Asbestiform Mineral. Ann. N.Y. Acad. Sci.* 271:336-344 (1976).
- Gundersen, J.N., Schwartz, G.M.: *The Geology of the Metamorphosed Biwabik Iron-Formation, Eastern Mesabi District, Minnesota. Bulletin No. 43, University of Minnesota, Minnesota Geological Survey. The University of Minnesota Press, Minneapolis* (1962).
- Gylseth, B., Norseth, T., Skaug, V.: *Amphibole Fibers in a Taconite Mine and in the Lungs of the Miners. Am. J. Ind. Med.* 2:175-184 (1981).
- Harlow, G.E., Kimball, M.R., Dowty, E., Langer A.M.: *Observations of Amosite/Grunerite Dusts. Proc. Second International Congress on Applied Mineralogy in the Minerals Industry, Los Angeles Feb 22-25 1984* pp 1147-1157 Applied Mineralogy (1984).
- Higgins, I.T.T., Glassman, J.H., Ph, M.S.: *The Effect of Taconite Dust Exposure on the Health of Employees of Reserve Mining Company. Mortality, Respiratory Symptoms and Chest Radiography. Report from Dept. of Epidemiology, The University of Michigan School of Public Health* (1981).
- Higgins, I.T.T., Glassman, J.H., Oh, M.S., Cornell, R.G.: *Mortality of Reserve Mining Company Employees in Relation to Taconite Dust Exposures. Am. J. Epidemiology* 118:710-719 (1983).
- Knight, G.K., Moore, E., Smith, C.W.: *Size Distribution of Airborne Dust in Labrador Iron Mines. Am. Ind. Hyg. Assn. J.* 46:150-154 (1987).
- Labrador Institute of Northern Studies: *Labrador West Study. Reports to Minister of Labour and Manpower—Government of Newfoundland and Labrador, July 30* (1982).
- Langer, A.M.: *Host Rocks and Gangue Minerals in Relation to Pneumoconiosis and Cancer. (Editorial) Am. J. Ind. Med.* 2:89-90 (1981).
- Langer, A.M., Maggione, C.M., Nicholson, W.J., Rohl, A.N., Rubin, I.B., Selikoff, I.J.: *The Contamination of Lake Superior Water with Amphibole Gangue Minerals. Ann. N.Y. Acad. Sci.* 330:549-372 (1979).
- Lee, R.J., Fisher, R.M.: *Identification of Fibrous and Nonfibrous Amphiboles in the Electron Microscope. Ann. N.Y. Acad. Sci.* 330:645-660 (1979).
- Lee, R.J., Fisher, R.M.: *Characterization of Amphiboles in Wabush Iron Formation (Southwestern Labrador). Report No. 80-01. Historical Background, Rationale of the Experimental Approach and Outline of the Proposed Program to Characterize Amphibole Minerals. U.S. Steel Corp. Research Laboratory, Monroeville, PA, January* (1981).
- Lee, R.J., Huggins, F.E., Szirmai, A., Fisher, R.M.: *Characterization of Amphiboles in Wabush Iron Formation (Southwestern Labrador). Report No. 80-02 Preliminary Examination of Anthophyllite Ore, "Spiral Mat", "Worse Case" Location Filters and Lung Tissue. U.S. Steel Corp. Research, Laboratory, Monroeville, PA February* (1981).
- Masson, T.J., McKay, F.W., Miller, R.W.: *Asbestos-like Fibers in Duluth Water Supply. Relation to Cancer Mortality J.A.M.A.* 228:1019-1020 (1974).
- McDonald, J.C., Gibbs, B.W., Liddell, F.D.K., McDonald, A.D.: *Mortality after Long Exposure to Cummingtonite-Grunerite. Am. Rev. Resp. Dis.* 118:271-277 (1978).
- Noble, J.A.: *Ore Mineralization in the Homestake Gold Mine, Lead, South Dakota. Bull. Geological Soc. America* 61:221-252 (1950).
- Noble, J.A., Harder, J.O.: *Stratigraphy and Metamorphism in a Part of the Northern Black Hills and the Homestake Mine, Lead, South Dakota. Bull. Geological Soc. America* 59:941-975 (1948).
- Occupational Safety and Health Administration: *Occupational Exposure to Asbestos, Tremolite, Anthophyllite, and Actinolite Final Rules 29 CFR Parts 1910 and 1926. Federal Register* 51: 22612-22790, June 6 (1986).
- Ring, S.J.: *Analysis Results of Tailings Samples from Taconite Processing Plants. Report, Minnesota Dept Health, May 12* (1981).
- Ross, M., Kuntze, R.A., Clifton, R.A.: *A Definition for Asbestos. Spec. Tech Publication 834, Am. Soc. for Testing and Materials* pp 139-147 (1984).
- Saugstad, L.F.: *Cancer and Atmospheric Pollution. Nordic Council Arctic Med. Res Reports* 35:53-61 (1983).
- Sheehy, J.W.: *Reconstruction of Occupational Exposures to Silica-Containing Dusts in the Taconite Industry. Thesis, Submitted to University of Minnesota for Degree of Doctor of Philosophy, February* (1986).
- Sheehy, J.W., McJilton, C.E.: *Development of a Model to Aid in Reconstruction of Historical Silica Dust Exposures in the Taconite Industry. Am. Ind. Hyg. Assn. J.* 48:914-918 (1987).

37. Swent, L.W., Herrin, G.R., Waterland, J.K., Bell, R.F.: Mortality Pattern among Hard Rock Gold Miners. *Unpublished Critique* (1976).
38. Thompson, C.S.: Consequences of Using Improper Definitions for Regulated Minerals. Spec. Tech. Pub. 834. Am. Soc. for Testing and Materials pp. 175-183 (1984).
39. Virta, R.L., Shedd, K.B., Wylie, A.G., Snyder, J.G.: Size and Shape Characteristics of Amphibole Asbestos (Amosite) and Amphibole Cleavage Fragments (Actinolite, Cummingtonite) Collected on Occupational Air Monitoring Filters. Chapter 47, pp. 633-643 in *Aerosols in the Mining and Industrial Work Environments*, Volume 2, Characterization. Maple, V.A. and Liu, B.Y.H. Eds. Ann Arbor Science, Ann Arbor (1983).
40. West, R.: Mining Environment Target Investigation: Taconite. *National Institute for Occupational Safety and Health*, May, 1982. National Technical Information Service PB 83-193037 (1982).
41. Wylie, A.G.: A Rationale for Increasing the Aspect Ratio Criterion for Fiber Counting. *Draft Report submitted to the National Stone Association*, March 30, (1987).
42. Wylie, A.G., Virta, R.L., Russek, E.: Characterizing and Discriminating Amphibole Cleavage Fragments and Amosite Fibers: Implications for the NIOSH Method. *Am. Ind. Hyg. Assn. J.* 46:197-201 (1985).
43. Wylie, A.G., Virta, R.L., Segrette, J.M.: Characteristics of Mineral Populations by Index Particles: Implications for the Stanton Hypothesis. *Env. Research* 43:427-439 (1987).
44. Zoltai, T.: Asbestiform and Acicular Mineral Fragments. *Ann. N.Y. Acad. Sci.* 330:621-643 (1979).
45. Zoltai, T., Stout, J.M.: Comments on Asbestiform and Fibrous Mineral Fragments, Relative to Reserve Mining Company Taconite Deposits. *Report to Minnesota Pollution Control Agency* March 24 (1976).
46. Zoltai, T., Wylie, A.G.: Definitions of Asbestos-Related Mineralogical Terminology. *Ann. N.Y. Acad. Sci.* 330:707-709 (1979).
47. Zumwalde, R.D., Ludwig, H.R., Dement, J.M.: Industrial Hygiene Report, Homestake Mining Company, Lead, South Dakota (Date of Survey July 12-23, 1977) *Final Report, Jan 30, 1981. NIOSH, Cincinnati* (1981).

*Proceedings of the VIIth International Pneumoconioses Conference*  
*Transactions de la VIIe Conférence Internationale sur les Pneumoconioses*  
*Transacciones de la VIIa Conferencia Internacional sobre las Neumoconiosis*

Part **I**  
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Parte



Pittsburgh, Pennsylvania, USA—August 23–26, 1988  
Pittsburgh, Pennsylvanie, Etats-Unis—23–26 août 1988  
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**September 1990**

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**DHHS (NIOSH) Publication No. 90-108 Part I**