SERPENTINE- AND CARBONATE-HOSTED ASBESTOS DEPOSITS
(MODELS 8d, 18e; Page, 1986; Wrucke and Shride, 1986)

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SUMMARY OF RELEVANT GEOLOGIC, GEOENVIRONMENTAL, AND GEOPHYSICAL INFORMATION

Deposit geology

The term asbestos as used in this discussion is a collective term applied by mineralogists to certain fibrous minerals and not to other mineral species that are called asbestos in common parlance. The particular asbestos mineral that is the focus of this discussion is chrysotile.

Serpentine-hosted asbestos: Chrysotile (white asbestos) forms veins in serpentinized ultramafic rocks. Protoliths include ophiolite and stratiform complexes. The veins commonly fill fractures developed in shear zones, notably near changes in rock competency, as near contacts between serpentinite bodies and igneous masses emplaced into serpentinite. Minor asbestos veins are present in unaltered ultramafic rocks adjacent to serpentinite.

Carbonate-hosted asbestos: Veins of cross-fiber chrysotile asbestos are in tabular masses of serpentinite that replaced metalimestone during contact metamorphism related to intrusion of diabase sills, sheets, and dikes. The metalimestone developed from a cherty dolostone protolith early in the metamorphic event. Asbestos veins filled fractures incrementally during dilation caused by the diabase intrusion.

Examples

Serpentine-hosted: Canada- Thetford Mines, Black Lake, and Asbestos-Shipton areas, Quebec; Cassair, British Colombia; White Bay area, Newfoundland (Riordon, 1957; Virta and Mann, 1994). United States- Belvidere Mountain, Vt. (an extension of the Quebec deposits) (Chidester and others, 1978); Calaveras and San Benito Counties, Calif. (Rice, 1966; Virta and Mann, 1994; Coleman, in press). Africa and Europe- Bazhenovo district, central Ural Mountains, Russia (Virta and Mann, 1994); Balangero, Italy (Virta and Mann, 1994); Barberton area, South Africa (Sinclair, 1959; Anhaeusser, 1986); Troodos Complex, Cyprus (Virta and Mann, 1994); Shabani, Zimbabwe (Anhaeusser, 1986; Virta and Mann, 1994).

Carbonate-hosted: Gila County, Ariz. (Shride, 1969; 1973); Barberton-Caroline district and near Kanye, South Africa (Sinclair, 1959; Anhaeusser, 1986); Laiynan district, Hobei Province, China (Sinclair, 1959).

Spatially and (or) genetically related deposit types

Related deposits include metadolomite-hosted talc and talc associated with serpentinized ultramafic rocks (Brown, 1973; Chidester and others, 1978); no deposit models have been developed for these deposit types.

Potential environmental considerations

(1) Most natural exposures of asbestos-bearing rock, particularly serpentinite derived from ultramafic rocks, are readily eroded by natural agents and the activities of man because most serpentinite is composed of weak, highly fractured rock; however, some serpentinite bodies are highly resistant to erosion.

(2) Sedimentary deposits and debris slides derived from asbestos-bearing rocks provide asbestos for redistribution by water and wind.

(3) Vehicles driven across serpentinite and mine waste can dislodge asbestos, adding it to dust or making it readily available to surface drainage; roads also produce channels that aid run-off. The surface area of roads in the southern half of the chrysotile-bearing New Idria serpentinite in San Benito County, Calif., exceeds the area disturbed by the three largest asbestos mines in this area (Woodward-Clyde Associates, 1989).

(4) Waste generated from asbestos mining and milling operations exposes asbestos to erosion by natural agents. The U.S. Environmental Protection Agency (EPA) considers mine waste that contains more than 1 volume percent asbestos hazardous (Derkies, 1985, p. 4-34). The California Air Resources Board considers asbestos contents of mine waste greater than 5 volume percent as a potential toxic hazard (Resolution 91-27, April 1990).

(5) Asbestos fibers can be incorporated by surface drainage in areas of asbestos-bearing rocks and mines. In central California, water in the California Aqueduct System contains asbestos (Kanarek and others, 1980; Coleman, in press). However, the EPA has concluded that ingestion of asbestos fibers poses no significant cancer risk (U.S. Environmental Protection Agency, 1991).

(6) Chrysotile deposits may contain small amounts of fibrous tremolite, which is classifiable by EPA as asbestos and a risk to human health (U.S. Occupational Safety and Health Administration, 1975).

7) Health risks to humans from exposure to small quantities of chrysotile asbestos in the environment are controversial. The controversy results from the EPA assumption that any amount of asbestos is potentially hazardous.

Exploration geophysics

Remote sensing techniques can detect belts of ultramafic rocks, intrusive masses, residual iron oxide minerals, and serpentinite by infra red reflectance, thermal properties, and botanical anomalies (stress and density) in areas of serpentinite-hosted chrysotile, and can identify diabase outcrops in areas of carbonate-hosted chrysotile. Magnetic techniques can be used to identify serpentinite derived from ultramafic rocks because of their high magnetite content. However, the method may not be useful in identification of serpentinite developed from carbonate rocks. This serpentinite may contain magnetite, but the protoliths are carbonate rocks that generally have a low initial iron content, and associated serpentinite bodies are small.

References

Geology: Shride (1969, 1973), Chidester and others, (1978), Ross (1981), Anhaeusser (1986), Virta and Mann (1994).
Environmental geology: Derkies (1985), Coleman (1995).

GEOLOGIC FACTORS THAT INFLUENCE POTENTIAL ENVIRONMENTAL EFFECTS

Deposit size

Deposit size varies from large in serpentine-hosted deposits to small in carbonate-hosted deposits. Serpentine-hosted deposits commonly contain hundreds of million tonnes of ore. In the 1950s the asbestos deposit at the Jeffrey Mine in Quebec had ore reserves as large as 450 million tonnes (Shride, 1973). By the mid 1970s, this mine, which at that time was the largest known asbestos deposit in the world, had the capacity to produce 544,000 tonnes of asbestos fiber a year (Energy, Mines, and Resources Canada, 1976). The mine was an open pit 600 m across in 1983 (Mann, 1983). The Bazhenovo district of Russia may contain larger deposits. This district had the capacity to produce at least 1.36 million tonnes of asbestos annually in the early 1980s (Mann, 1983). Reserves of chrysotile fiber at the asbestos deposit near Copperopolis, Calaveras County, Calif., are reported to be about 1.2 million tonnes (Rice, 1966). The deposit is now closed and is used as an asbestos waste dump. Production of chrysotile from the New Idria serpentinite in San Benito County, Calif. (the largest asbestos deposit in the United States) is now confined to one property, that of the King City Asbestos Corporation (KCAC, Inc.). In 1975 production from this property was 68,000 tonnes (Mumpton and Thompson, 1975). In the past, The New Idria serpentinite was the locale of many mining ventures, including chrysotile asbestos mining. All but one of these asbestos mines have ceased operations, and part of the properties are now EPA superfund sites. In 1989, the latest year for which data are available from the U.S. Bureau of Mines, the production of chrysotile from the KCAC Inc. mine and one in Orleans County, Vt. totalled 17,427 tonnes (Virta, 1989). In contrast, Arizona deposits contain a few tens to a few thousand tonnes of chrysotile asbestos (Shride, 1969). Data on chrysotile mining in Arizona (Shride, 1969 and the Yearbooks of the U.S. Bureau of Mines) for the period 1914 to 1982 (when mining ceased) indicate production of about 90,000 tonnes of asbestos fiber.

Total United States asbestos production in 1989 was 17,427 tonnes compared to world production of 4,237,659 tonnes (Virta, 1991). About 98 percent of the asbestos produced in 1990 worldwide was chrysotile (Virta and Mann, 1994).

Host rocks

Serpentine-hosted deposits: These deposits are in massive serpentinite, commonly highly sheared and widely exposed, that has largely replaced the host ultramafic protolith. Associated ultramafic rocks locally host asbestos veins.
Carbonate-hosted deposits: Serpentinite in these deposits has replaced metalimestone or dolostone. In Arizona, the serpentinite bodies commonly are 1 to 3 m thick, are present at a few stratigraphic intervals in the host metalimestone section, and are structureless, except for asbestos veins.

Surrounding geologic terrane

Serpentine-hosted deposits: Most of these deposits have developed in ophiolite complexes, which are composed of oceanic crustal fragments consisting of a basal peridotite (that becomes serpentinized) overlain in sequence by cumulate gabbro, sheeted dikes, and pillow basalt, commonly capped by deep oceanic pelagic strata. Accreted ophiolite commonly is dismembered into structurally complicated fragments. In Quebec and New England, these rocks are associated with metamorphosed sedimentary and igneous rocks, including schist, greenstone, quartzite, and

amphibolite, of early Paleozoic age. The New Idria serpentinite, Calif., which hosts the KCAC asbestos deposit and others, is completely separated from mafic oceanic crust and is surrounded by sedimentary rocks of the Cretaceous Franciscan and Panoche Formations. These rocks are folded with unconformably overlying Tertiary marine sedimentary rocks.
Carbonate-hosted deposits: Deposits of this type in Arizona are in Middle Proterozoic rocks that include siltstone, arkosic arenite, cherty dolostone, argillite, quartz arenite, local basalt, and intrusions of diabase sheets, sills, and dikes.

Wall-rock alteration

Serpentinization of host rocks and subsequent serpentinite alteration are common kinds of wall-rock alteration associated with asbestos. In serpentine-hosted deposits, serpentinite results from hydration of igneous protoliths, commonly harzburgite and dunite, which are unstable in the presence of water at crustal temperatures (Coleman, 1971; Coleman and Jove, 1993). For example, the mineralogical nature of the New Idria serpentinite probably is related to the relative amounts of orthopyroxene and olivine in the primary peridotite. Reactions with water can be written:

1) $3Mg_2Si_2O_6$ (pyroxene) + $4H_2O$ = $2Mg_3Si_2O_5(OH)_4$ (serpentine) + $2SiO_2$ (quartz)
2) $2Mg_2SiO_4$ (olivine) + $3H_2O$ = $Mg_3Si_2O_5(OH)_4$ (serpentine) + $Mg(OH)_2$ (brucite)

Reaction 1 produces weathering-resistant silica-bearing serpentinite that forms pinnacles, common in the New Idria serpentinite, whereas reaction 2 produces predominantly highly weathered and rounded boulders and fine soil-like material (Malcolm Ross, written commun., 1995). Serpentinization releases calcium that becomes available for secondary minerals. Iron in the primary silicate minerals, when not incorporated into serpentinite, may form magnetite. With increasing metamorphic temperature, lizardite of the original serpentinite is replaced by antigorite, which at higher temperatures is converted, by dehydration, to talc, olivine, and water (Coleman and Jove, 1993). Common alteration products in metamorphosed serpentinites of Quebec and Vermont are talc in steatite and schistose masses, talc-carbonate rocks, and quartz-carbonate bodies (Chidester and others, 1978).

Late stage serpentinization of carbonate-hosted deposits follows dedolomitization and development of calcium-magnesium silicate minerals during contact metamorphism. Subsequent serpentine alteration proceeds as outlined for serpentinite-hosted deposits.

Nature of ore

Serpentine-hosted deposits: These deposits commonly consist of stockworks (networks of veins) of cross-fiber veins that are aggregates of two or more thin parallel layers of fibers oriented about normal to vein walls. Most deposits contain some slip-fiber veins composed of fibers in the plane of the fracture. In a few deposits, this is the principal fiber type. In the New Idria serpentinite, ore is in sheared and pulverized serpentinite and consists of flake-like agglomerates and sheet-like masses of finely matted chrysotile (Mumpton and Thompson, 1975). Much of this ore may be secondary (see section below entitled "Secondary mineralogy"). Asbestos contents vary widely in the serpentine-hosted deposit type. Typical deposits contain 5 to 15 volume percent asbestos fiber; in the New Idria serpentinite, ore contains in excess of 50 volume percent chrysotile (Mumpton and Thompson, 1975).
Carbonate-hosted deposits: Ore zones consist of sets of cross-fiber veins subparallel to bedding in the serpentinized host. Commonly, veins are composed of multiple parallel layers in which the fibers are oriented about at right angles to vein walls and aggregate 1 to 20 cm in width; multiple layers indicate incremental development. Veins pinch and swell, anastomose, and vary in dip. Productive zones may be 10 cm to a few decimeters thick and constitute as much as 40 volume percent of a serpentinite body (Shride, 1969; Otton and others, 1981). However, asbestos veins commonly are contained in much greater thicknesses of massive, barren serpentinite. Chrysotile veins locally are in fine-grained calc-silicate rocks developed from cherty dolomite.

Deposit trace element geochemistry

Manganese, chromium (trivalent), copper, nickel, and platinum are rare elements found in chrysotile (Ross, 1981; Wicks and O'Hanley, 1988). Hexavalent chromium, known to be toxic, is not present in these asbestos deposits. Trace element composition has not been considered an environmentally significant aspect of chrysotile deposits.

Ore and gangue mineralogy and zonation

In serpentine- and carbonate-hosted deposits, the only ore mineral is chrysotile. Serpentinite-hosted deposits contain magnetite in the serpentine gangue and locally talc, as well as quartz-calcite veins (Riordon, 1957). In Canadian deposits, magnetite commonly is concentrated in wall rock adjacent to asbestos veins, along vein walls, in partings between layers of multiple veins, and can be disseminated parallel to chrysotile fibers (Riordon, 1957). Chrysotile, brucite, and magnetite are common in serpentine of the New Idria body (Coleman, in press). Carbonate-hosted deposits may include sparse calcite veins, otherwise the gangue is serpentine.

Mineral characteristics

Chrysotile is one of six mineral species called asbestos because of their fibrous habit (Skinner and others, 1988). Of these, chrysotile is the only fibrous serpentine mineral. The other five asbestos minerals belong to the amphibole group; these are grunerite asbestos (commonly referred to as amosite), riebeckite asbestos (commonly referred to as crocidolite), anthophyllite asbestos, tremolite asbestos, and actinolite asbestos. Chrysotile ($Mg_3Si_2O_5(OH)_4$) consists of layers of linked SiO_4 tetrahedra and misfit layers of linked $MgO_2(OH)_4$ tetrahedra that together roll into sheets, making hollow tubes having diameters of about 25 nm (Ross, 1981). Most chrysotile contains less than 2 weight percent iron as FeO, though as much as 8 percent has been reported (Wicks and O'Hanley, 1988). Small amounts of aluminum, manganese, magnesium, calcium, potassium, and sodium also may be present (Ross and others, 1984). Vein fibers range in length from less than 5 µm to 10 cm or more. They can vary in flexibility, hardness, tensile strength, and other physical properties and chemical properties of importance in determining their commercial use (Shride, 1973).

Secondary mineralogy

Although serpentine minerals are considered to be stable in the upper crust (Coleman and Jove, 1993), studies in California show that they are unstable in the range of pH and Mg^{2+} and $Si(OH)_4$ concentrations encountered in most soil (Mumpton and Thompson, 1966; Wildman and others, 1971). Iron-rich montmorillonite is a common product of serpentine in this soil type (Wildman and others, 1971). Brucite ($Mg(OH)_2$), one of the hydrothermal minerals that develops during serpentinization and makes up 7 to 8 volume percent of the New Idria serpentinite, is destroyed in the weathering zone, producing coalingite (an iron- and magnesium-bearing carbonate), compositionally similar pyroaurtite (Mumpton and Thompson, 1966), hydromagnesite, and secondary chrysotile (Mumpton and Thompson, 1975). Some chrysotile is developed during tectonic milling and may be the most important process in the formation of chrysotile at the New Idria deposit (R.G. Coleman, written commun., 1995). Deeply weathered serpentinite can produce the nickel-bearing minerals nepouite and pecoraite (Mumpton and Thompson, 1975), but most serpentine contains only very small amounts of nickel.

Tremolite, an amphibole, can be fibrous and is associated with chrysotile deposits, particularly at Thetford Mines, Quebec; Troodos, Cyprus; and Balangero, Italy (R.G. Coleman, written commun., 1995). The EPA classifies tremolite as asbestos if the particles have an aspect ratio of 3:1. The amount and distribution of tremolite asbestos in chrysotile deposits is poorly known. It is extremely scarce in the New Idria, Calif., deposits (Coleman, in press), and it makes up less than one volume percent of the dust in Quebec mines and mills (Mossman and others, 1990).

Topography, physiography

Serpentine-hosted deposits: These deposits are easily eroded. Serpentinite bodies commonly are well exposed and therefore are readily eroded. The asbestos deposit at Belvidere Mountain, Vt., is on a hillside in an area having relief of 200 m in a radius of 1.6 km (Chidester and others, 1951). The New Idria serpentinite body in San Benito County, Calif., occupies a high ridge, as illustrated in Mumpton and Thompson (1975), that includes rock exposures barren of vegetation. Evidence of contact dislocation shows that this serpentinite body is rising tectonically, exposing this soft material to long term erosion (Coleman, in press).

Carbonate-hosted deposits: Chrysotile-bearing serpentinite zones in Arizona are soft and weakly resistant to weathering. However, these zones commonly are exposed in cliffs and steep slopes, protected by the more resistant, overlying metalimestone beds, which reduces exposure of serpentinite and chrysotile to erosion.

Hydrology

Streams draining asbestos-bearing serpentinite can pick up chrysotile fibers. Most streams draining the Belvidere Mountain deposit, Vt. lead to the Gihon and Lamoille Rivers and Lake Champlain, but some reach Quebec via the Missisquoi River. Stream drainages from the northeast and southeast parts of the New Idria serpentinite, Calif., lead to the San Joaquin Valley. This area drains to the west via the San Benito River to the Pacific Ocean. Debris slides along the flanks of the serpentinite body and in the main drainage channels contain huge amounts of asbestos-bearing material available for removal and dispersion by streams (Cowan, 1979). During flood stage, streams flowing into the San Joaquin Valley from the New Idria mass have introduced sediment into the California aqueduct (Coleman, in press). Asbestos fibers also have been found in the water supply for San Francisco (Kanarek and others, 1980). Drainage from carbonate-type chrysotile deposits in Arizona reaches the watershed of the Salt River, which flows to Phoenix via several reservoirs.

Mining and milling methods

Serpentine-hosted deposits: Exploitation of these deposits is mostly by open-pit mining. Block caving and other underground methods have been used. Milling generally is a dry process and follows practices used, slightly modified, since the early days of this century (Mann, 1983). Ore is crushed, screened, and dried. Drying is accomplished using hot air, which is filtered after the fibers are dried. Processing and packaging methods have improved significantly in recent years, which makes it possible to handle asbestos in a nearly dust-free environment. Most producers grade and classify milled asbestos fibers as a function of fiber length, using a standard developed in Canada (Energy, Mines, and Resources Canada, 1976; Mann, 1983). A wet process for milling chrysotile was installed in 1990 at the Baie Verte Mines in Newfoundland (Stewart and others, 1990). In this process, mill feed is wet screened, classified, then dried in a propane-fired dryer. Impurities are collected in a thickener and pumped to tailings dumps. A wet process was used in 1991 at the KCAC Inc. mine in San Benito County, Calif, (Virta, 1991).

Carbonate-hosted deposits: Chrysotile mining in Arizona has been by small-scale underground methods using adits, room and pillar methods, and stoping with backfill. Milling of chrysotile ore in Arizona was stopped by court order in 1974. The milling process consisted of crushing the ore, beating it to free the fibers, then removing the fibers by screening and air separation (Bowles, 1955). Waste rock and unwanted fibers were consigned to tailings dumps.

ENVIRONMENTAL SIGNATURES

Drainage signatures

Stream channels that drain chrysotile-bearing serpentinite contain asbestos as a natural erosion product. Where serpentinite masses crop out in mountainous terrane, as in San Benito County, Calif., chrysotile-bearing debris in landslides, debris flows, and bedrock exposures provide extensive sources of asbestos materials to local streams. Some of these fibers have reached the California aqueduct on the west side of the San Joaquin Valley.

Asbestos mobility from solid mine wastes

Mine dumps and mill tailings at chrysotile deposits are sources of asbestos fibers for surface water and are more easily eroded than outcrops.

Soil, sediment signatures prior to mining

Soil developed on asbestos-bearing bedrock may contain asbestos fibers. The soil over the New Idria body is composed of chrysotile and brucite with some lizardite and (or) antigorite, plus minor amounts of other minerals.

Potential environmental concerns associated with mineral processing

The principal concerns include dust and tailings from asbestos milling operations. Asbestos fibers in tailings are available for airborne and fluvial transport.

Smelter signatures

Not applicable to asbestos.

Climate effects on environmental signatures

Where serpentinization is ongoing, meteoric water becomes saturated with calcium hydroxide and can precipitate brucite, portlandite, and carbonate minerals. In arid climates, weathering can lead to the precipitation of brucite, carbonate minerals, chrysotile, and talc (Coleman and Jove, 1993). In humid conditions, serpentinite can be dissolved leaving a residue rich in iron and smectite.

Chrysotile in some environments is known to survive for thousands to millions of years after being subjected to erosion and transport to distant sites. For example, accumulations of chrysotile fibers eroded from the New Idria, Calif., serpentinite have been identified in downstream sedimentary accumulations such as terrace deposits and alluvial fans (Coleman, in press). Chrysotile also is preserved in the Big Blue Formation of Miocene age, which contains abundant debris eroded from the New Idria serpentinite (Carlson, 1981).

Geoenvironmental geophysics

See exploration geophysics.

CONTROVERSY REGARDING HEALTH RISKS TO HUMANS FROM CHRYSOTILE ASBESTOS

The risk of asbestos to human health has been known at least since 1906 when workers in an asbestos weaving mill in France died (D'Agostino and Wilson, 1993). In the 1920s, a death from asbestosis (fibrosis of the lung) was reported and the disease was named (Sawyer, 1987). However, not until the 1960s were the biologic effects of asbestos fibers documented in great detail and a relationship clearly established between exposure to asbestos and lung disease, including cancer. As a result of concern developed from increasing knowledge of health hazards associated with asbestos minerals, the Occupational Safety and Health Administration (OSHA) in 1971 issued regulations restricting airborne asbestos in the workplace, and in 1987 OSHA established the current workplace standard of 0.2 fibers per cubic centimeter of air. However, the regulations do not discriminate between fibers of the different asbestos minerals. Since the establishment of these regulations, numerous studies have demonstrated that various asbestos minerals have significantly different associated health effects. For example, the few cases of mesothelioma (cancer of the pleura or peritoneum) in Canadian chrysotile miners and mill workers appear to be not from chrysotile but perhaps from small amounts of tremolite asbestos, and a study of British workers engaged in the manufacture of friction materials using only chrysotile showed no excess of deaths from lung diseases (Mossman and others, 1990). Health effects related to occupational exposure to chrysotile are the least of any asbestos mineral; people exposed to chrysotile alone, at abundances more than 10 times higher than recommended by the EPA, experience no excess lung cancer (Coleman, in press).

RISK ASSESSMENT

Hazards resulting from inhalation of asbestos fibers have been documented by the EPA and have been the topic of considerable scientific inquiry (Ross, 1981, 1984; Skinner and others, 1988; Mossman and others, 1990; D'Agostino and Wilson, 1993; Ross and Skinner, 1994; McDonald and McDonald, 1995). Although the relationship between asbestos and lung diseases is well documented, debate continues regarding the risk from low level exposure to asbestos fiber. In a report prepared for the California Environmental Protection Agency, risk related to asbestos was not ranked because data on low level exposure were considered inadequate (California Comparative Risk Project, 1994). Studies show that important factors to be considered in evaluating risk associated with asbestos inhalation include type of asbestos mineral, length and diameter of the asbestos fibrils, amount of asbestos inhaled, and the duration of the exposure. Yet, despite conclusions that risks from chrysotile asbestos are almost certainly lower than for other asbestos minerals (D'Agostino and Wilson, 1993), uncertainty in the degree of risk from exposure to chrysotile remains. The uncertainty results in part from disagreement concerning whether an exposure threshold exists and, if so, at what fiber concentration below which inhalation is safe (D'Agostino and Wilson, 1993).

The EPA has concluded that inhalation of any amount of asbestos is potentially hazardous, that a single asbestos fiber can be lethal (Abelson, 1990). This conclusion results from belief that a linear relationship exists between asbestos dose and health risk such that risk exists even at very low levels of exposure (D'Agostino and Wilson, 1993). According to this theory, any exposure to asbestos poses a risk. In a nonlinear relation, risk from exposure decreases rapidly at low levels and a threshold value can be reached below which the risk is zero. Recent studies suggest that low-level exposure to chrysotile asbestos in the environment has generated unwarranted concern based on speculation (D'Agostino and Wilson, 1993) and that the single-fiber view is unproved (Abelson, 1990). Other studies suggest that a "threshold" value, below which exposure to chrysotile asbestos causes no measurable health effects, can be identified (Ross, 1987).

Estimates of risk to human health from numerous activities, including everyday risks, have been quantified, and a few attempts have been made to quantify risk of exposure to chrysotile asbestos under different environmental conditions (D'Agostino and Wilson, 1993; Coleman, in press). For example, data show that risks from inhaling asbestos during recreational activities at the chrysotile-bearing New Idria, Calif., serpentinite or from exposure to asbestos in schools are low. Coleman (1995) concluded that "the apparent risk in making one trip by automobile to New Idria is 300 times greater than inhaling [chrysotile] fibers during a lifetime of recreation in this area." Risks from occupying schools containing chrysotile fibers are even lower and have been categorized as harmlessly small

(Abelson, 1990; Wilson and others, 1994).

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