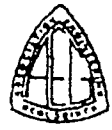




New Idria Serpentinite: A Land Management Dilemma

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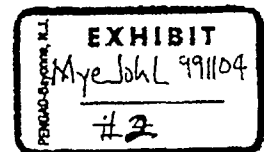


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ABSTRACT

The New Idria asbestos-bearing serpentinite represents a unique tectonic situation. Change in plate motion produced transverse compression across the San Andreas transform fault system in the vicinity of New Idria which produced shortening of the former continental margin resulting in sub-parallel thrusting, folding, and diapirism. This tectonic activity has exposed a huge body of serpentinitized mantle peridotite (45 sq mi) that may have been part of the Pacific Ocean crust basement. Continued wedging of these peridotites into the water-rich continental crust has caused a chain-reaction serpentinitization and expansion. Thousands of tectonic (milling) events acting on the serpentinite near New Idria created a huge deposit of short-fiber asbestos. The main serpentine mineral is chrysotile that forms very short fibers (~5 microns) having a specific surface area 3 to 4 times greater than other commercial asbestos fibers. Its natural chemical solubility reduces its biopersistence resulting in much lower toxicity to humans. During the last 15 million years the asbestos-bearing serpentinite of the New Idria body has been eroded and contributes fibers to alluvial deposits along the west side of the San Joaquin Valley and San Benito River Basin with little to no indication of excessive present-day asbestos-related respiratory diseases in this area. A study by the Bureau of Land Management concerning exposure of asbestos fibers to weekend off-road vehicle riders in the New Idria serpentinite area indicates that their risk of developing lung cancer is low. Knowledge of the geologic facts concerning the natural origin and distribution of asbestos-bearing serpentinite illustrates the dilemma of the U. S. Government attempting to remediate the small EPA superfund mining sites within this vast region of serpentinite.

INTRODUCTION

There is a standing conflict between government agencies as to what management actions are required at the closed Atlas and Johns-Manville asbestos mines which the U. S. Environmental Protection Agency (EPA) has designated as superfund sites. These idle mine sites are

within the New Idria serpentinite body and surrounding Bureau of Land Management (BLM) Clear Creek Management Area (CCMA) (Figure 1). Recreational value of this area is particularly high for off-road vehicles (ORV) and other ORV activities. The purported dangers of inhaling asbestos-fibers has not gone unnoticed by the BLM. The BLM has developed a resource management plan to address the asbestos issue (Hastey, 1994). The BLM environmental impact statement attempts to discuss the problems of multiple use, mining, ecology and EPA's jurisdiction of the superfund sites located on private land within the CCMA (Figure 1). The BLM resource management plan includes input from outside contractors, BLM personnel, and local citizens and representatives of ORV clubs who use the area. BLM proposes six alternative plans for management of the Clear Creek Area which are now being considered (Hastey, 1994).

There are basic differences concerning the use of CCMA land due to perceived human-health risks from inhaling asbestos fibers made airborne by ORV climbing on the soft serpentinite hills (Cooper et al., 1979; Pependorf and Wenk, 1983; and Ross, 1994). ORV causes accelerated erosion of the soft serpentinite and contributes to more rapid erosion of the asbestos laden serpentinite into the local streams. EPA has a mandate to ensure the protection of public health and the environment from "asbestos waste." The BLM is responsible for the balanced management of public lands based on the principles of multiple-use and sustained yield.

The thrust of this paper is to illustrate that the asbestos-bearing serpentinite formed in a very unique tectonic environment and is related to a change in plate motion along the San Andreas fault. The tectonic exposure of this serpentinite was followed by 15 million years of denudation and dispersal of the asbestos which pre-dates asbestos mining and recreational activities.

HISTORICAL ASPECTS OF MINING ACTIVITIES

The New Idria area is one of the oldest and best known mercury mining districts in California with more than 60,000 flasks of mercury produced since the original discovery in 1858 (Eckel and Myers, 1946). Toxic mercury pollution in the stream waters draining into Silver Creek obliged the closing of this mercury mining

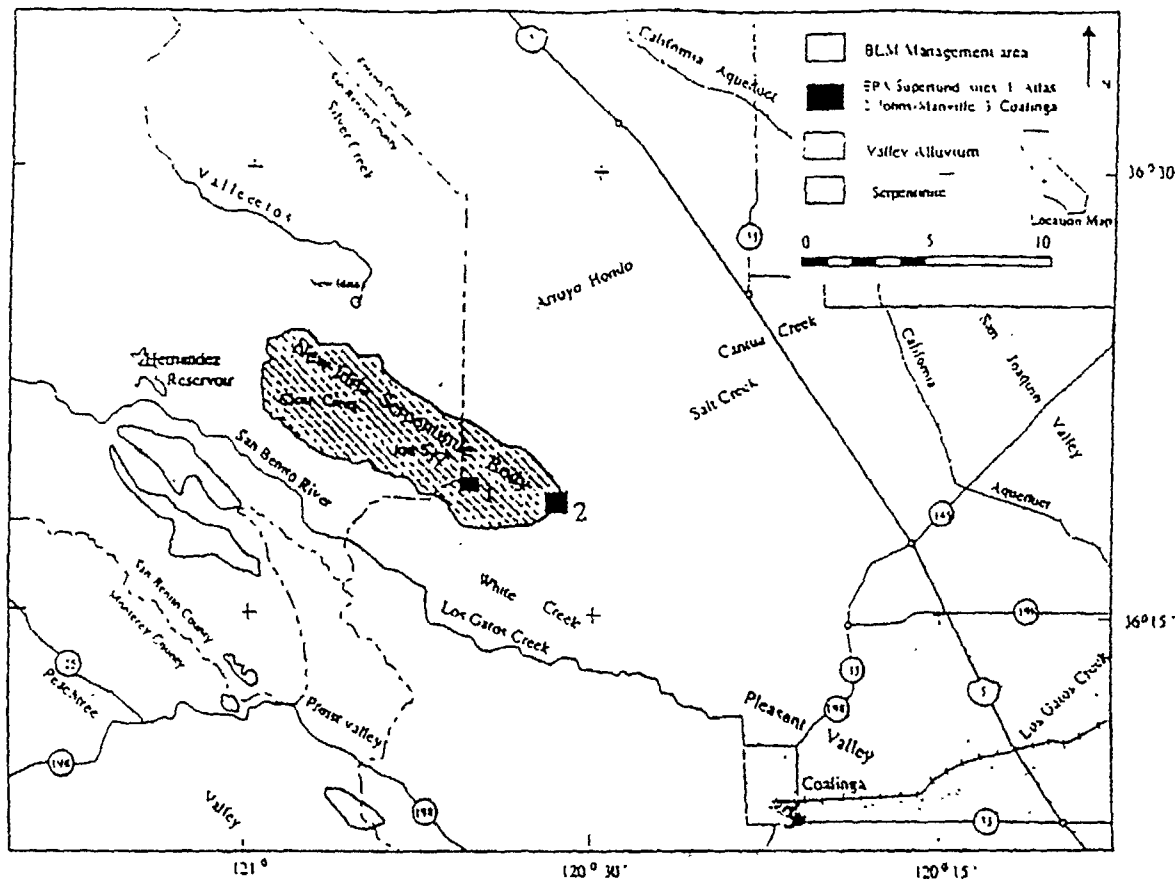


Figure 1. Clear Creek Management Area from BLM resource management plan and environmental impact statement (Hastey, 1994).

district in the 1970s (Boctor et al., 1987). Asbestos mining was originally only a small operation during the period from 1917 to 1920 which failed to prosper because high grade long fiber ore was not found and there was little demand for the short fiber ore from New Idria (Woolsey, 1922). This large deposit of short fiber asbestos was later "discovered" by geologists in the late 1950s. The short fiber asbestos could be easily milled and made available more cheaply to new markets in the Western United States such that a rush on the leasing of asbestos claims occurred in 1958 and 1959 (Bright, 1965). Union Carbide initiated its exploration program in 1959. The following year, Johns-Manville Corporation developed a joint venture with Kern County Land Company to form Coalinga Asbestos Company (Merritt, 1962; Munro and Reim, 1962; and Rice, 1963). Coalinga Asbestos Company constructed a plant site in Pine Canyon in the headwaters of White Creek on a stabilized Holocene serpentinite debris flow. Initial asbestos production was 12,000–15,000 tons/yr. In 1961, Hidden Splendor Mining Company, presently

known as the Atlas Minerals Company, acquired adjacent properties in the spring of 1961 and began operating a plant situated on the higher levels of the White Creek serpentinite debris flow which had a production capacity similar to that in Pine Canyon. Union Carbide also began mining operations in 1961, but constructed an ore processing mill near King City 55 mi west of their mine. The Union Carbide operation using a wet milling process to purify the asbestos ore trucked from their Joe 5 open pit mine (Merritt, 1962). In 1985, the Union Carbide operation was sold to its employees and is now called King City Asbestos Corporation (KCAC). KCAC produces a trade product called Calidra Asbestos. Through the research of Union Carbide scientists, it was established that Calidra Asbestos had unique characteristics that could be used in numerous manufactured products such as floor tiles, pipe, siding, and roofing material (Mumpton and Thompson, 1975). The very pure New Idria asbestos could also be used for paper and a filler in adhesives and resins. In the mid 1970s these three mining and milling operations produced

75,000 tons of asbestos tripling the production of Grade-7 asbestos in the United States at that time. The Johns-Manville (J-M) and Atlas mines were shut down in 1974 and 1979 respectively because of decreasing sales and increasing costs related to Federal Regulation. KCAC still operates the Joe 5 open pit mine supplying about 15,000 tons/yr of asbestos to the wet mill in King City.

A conference held at New York Academy of Sciences in 1964 discussed in great detail the biological affects of fibers in the lungs of asbestos workers revealing a "widening spectrum of asbestos malignancy" (New York Academy of Science, 1979). Thus, began a decade of intense medical research to establish the relationship between inhaling asbestos fibers and cancer of the lung or other organs. The Clean Air Act instituted in the early 1970s required that the Environmental Protection Agency (EPA) set national emission standards for hazardous air pollutants including asbestos. The Occupational Safety and Health Administration (OSHA) published rules in 1972 that were designed to protect employees working with asbestos. Mining operations are actually regulated by the Mine Safety and Health Administration (MSHA), whose rules are less restrictive than OSHA. Health effects of asbestos fibers in animal experiments were extrapolated to low doses causing fear of the carcinogenic aspects of asbestos fibers in schools or in natural settings such as the ORV use in New Idria serpentinite area. A National Academy of Science report (National Academy of Science, 1984) on non-occupational health risks of asbestiform fibers was endorsed by some in the medical research community thereby supporting the conclusion that there could be a correlation between inhaling low levels of asbestos fibers and cancer. This led to the notion that a "single fiber could kill" such as in the ambient air of offices and school buildings (Selikoff and Lee, 1979). Using the National Academy of Science report (National Academy of Science, 1984) as their guideline OSHA and EPA (Asbestos Hazard Emergency Response Act of 1987) issued regulations pointing out that asbestos fibers can be a potent carcinogen. Therefore OSHA and EPA set the maximum work place exposure of asbestos fibers at 0.1 fiber per cubic centimeter over an 8 hour work day.

Environmental sampling for asbestos was instituted nationwide. In 1980, EPA regulators discovered asbestos fibers in water and stream sediments in Arroyo Pasajero, which were further traced up-stream along Los Gatos Creek and its tributary White Creek. White Creek drains the southern part of the New Idria serpentinite body where the J-M and Atlas asbestos operations were located (Figures 1 and 2). Elevated levels of asbestos were also detected in water samples from the California Aqueduct System near Los Angeles. Additional studies of the asbestos fibers in these waters by EPA, U.S.

Bureau of Reclamation, and California Department of Water Resources pinpointed the source of the fibers as coming from the Arroyo Pasajero Ponding Basin located just west of the California Aqueduct, near Huron, a small town east of Coalinga (Figure 2). A similar report (Kanarek et al., 1980) on asbestos and epidemiological incidence in drinking water of the San Francisco Bay area created further concern by health officials. By 1983 these studies led to placing the idle Atlas and J-M asbestos mines on the Superfund National Priorities List as some of the nation's most serious hazardous waste sites. In 1991, EPA's regional Administrator signed documents defining the methods EPA planned to use to cleanup these two sites.

In the meantime, KCAC still operates the Joe 5 open pit mine in compliance of regulations established by the Mine Safety and Health Administration (MSHA) and EPA. KCAC's commercial asbestos product is primarily exported overseas, as the market for asbestos has continued to decline in the United States. However, with a 1991 court overturn of EPA's 1989 Asbestos Ban and Phaseout Rule of most asbestos-containing products, the decline in U. S. asbestos consumption appears to have leveled off at about 28,000 metric tons (Skinner and Ross, 1994)

The fact that the New Idria asbestos-bearing serpentinite body is not just confined to White Creek drainage area (Figures 1 and 2) and contains 20-30 volume percent of asbestos fibers in all of its natural exposures appears to have been overlooked when the superfund sites were selected. The New Idria serpentinite is presently being eroded by all of the streams draining it. Asbestos bearing layers are present within older terrace deposits along streams draining the New Idria serpentinite body. These asbestos layers provide a Holocene stratigraphic history of asbestos transport onto the alluvial fans of the San Joaquin Valley. Examination of stream terraces along the Los Gatos Creek a few miles east of Coalinga reveal that asbestos-bearing layers contain charcoal derived from transported wood fragments that give a C¹⁴ age of 500 B. P. (Atwater et al., 1990).

The anthropogenic disturbance of the New Idria serpentinite body by mining and recreation pales in comparison to the naturally occurring, and continuing erosion of asbestos-bearing clastic debris throughout the Holocene (Coleman, 1986). The following sections will develop the relationship between geologic evolution, tectonism, nature of the asbestos-bearing serpentinite, and its continuing erosion.

GEOLOGIC EVOLUTION OF SERPENTINITE

The New Idria serpentinite body forms the core of an elongate antiform that lies between the San Andreas fault on the west and the San Joaquin alluvial valley

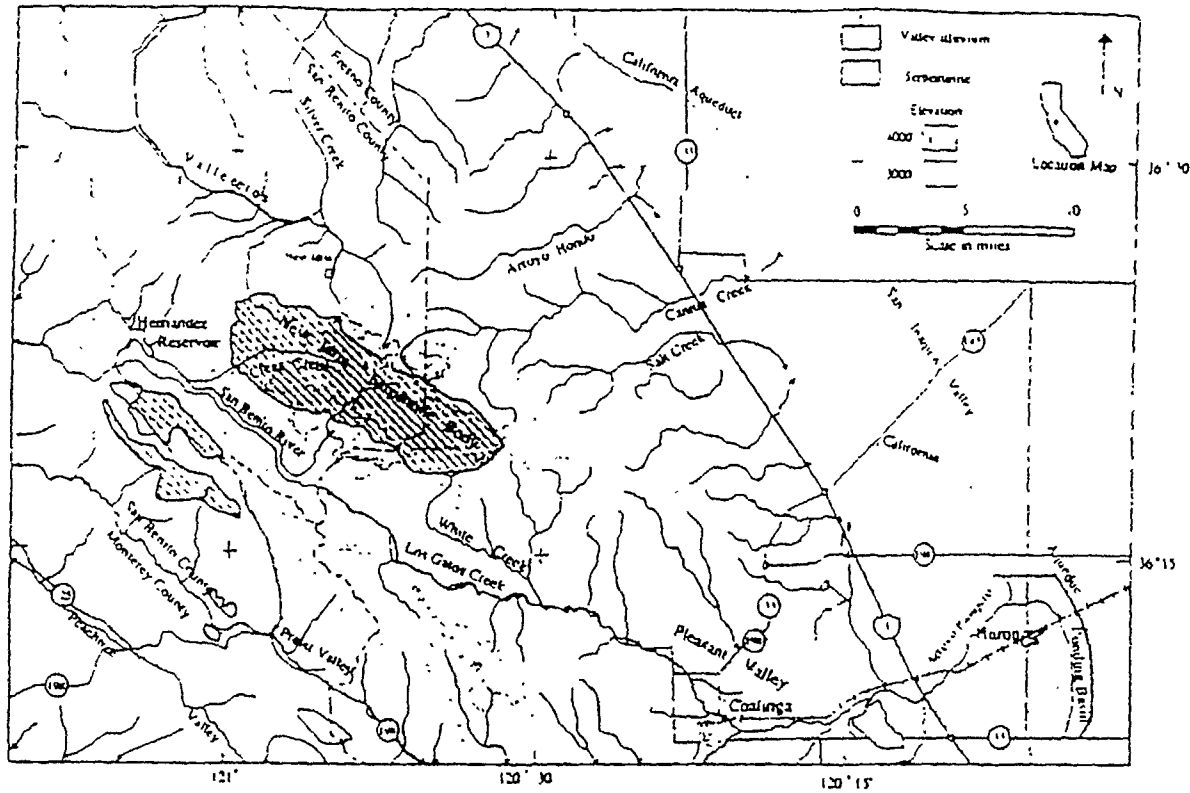


Figure 2. Geomorphology of the area surrounding the New Idria serpentinite mass.

on the east. Tertiary and Mesozoic sedimentary rocks surrounding the serpentinite body are folded and thrust into a series of anticlines and synclines whose *en-echelon* fold axes form acute angles with the northwest trending San Andreas Fault (Dibblee, 1971; Nilsen and Dibblee, 1979; Figures 3 and 4). The serpentinite body is in contact with the Franciscan subduction assemblages of Jurassic-Cretaceous age and the Upper Cretaceous Panoche and Moreno formations of the Great Valley forearc sedimentary sequences of marine sandstone and shale (Coleman, 1986). The basement for the west side of the Great Valley sequence is considered to be ophiolites that formed as part of an intra-oceanic arc in Late Jurassic (169-161 ma; Hopson et al., 1981; Robertson, 1989). Tertiary marine sediments, as young as Pliocene, unconformably overlie the Franciscan subduction complex and the Great Valley sequence (Dibblee, 1971; Nilsen and Dibblee, 1979; and Graham et al., 1989). The contact of the serpentinite body with the surrounding sediments is marked by zones of dislocation that record upward tectonic movement (Coleman, 1980). The northeastern contact along the New Idria serpentinite has been called a thrust as the subjacent Mesozoic and Tertiary sediments are overturned

by emplacement of the expanding serpentinite protrusion (Eckel and Myers, 1946; Coleman, 1957; Figure 3)

Synthesis of the geophysical data gathered by the USGS from the 1983 Coalinga earthquake and the Parkfield study produced an explanation for these basement structures (Rymer and Ellsworth, 1990; Wentworth et al., 1992). The surface expression of westward thrusting seen in seismic profiles is thought to be related to eastward thrusting of a tectonic wedge of the Franciscan subduction complex consisting of trench sediments and oceanic crust (ophiolites), as shown by (Wentworth and Zoback, 1989, 1990). Geophysical measurements cannot distinguish between Great Valley or Franciscan ophiolites or younger and deeper ocean crust from the Pacific plate, and so, published reconstructions usually show the basement beneath the Coalinga antiform as a continuous monolithologic unit consisting of Great Valley basement (ophiolite) (Griscom and Jachens, 1990; Namson et al., 1990; Walter, 1990; and Wentworth and Zoback, 1990).

The compressional regime between the San Andreas fault and the Great Valley fore-arc sequence produced eastward wedging of the stranded Franciscan package of trench deposits and underlying oceanic crust

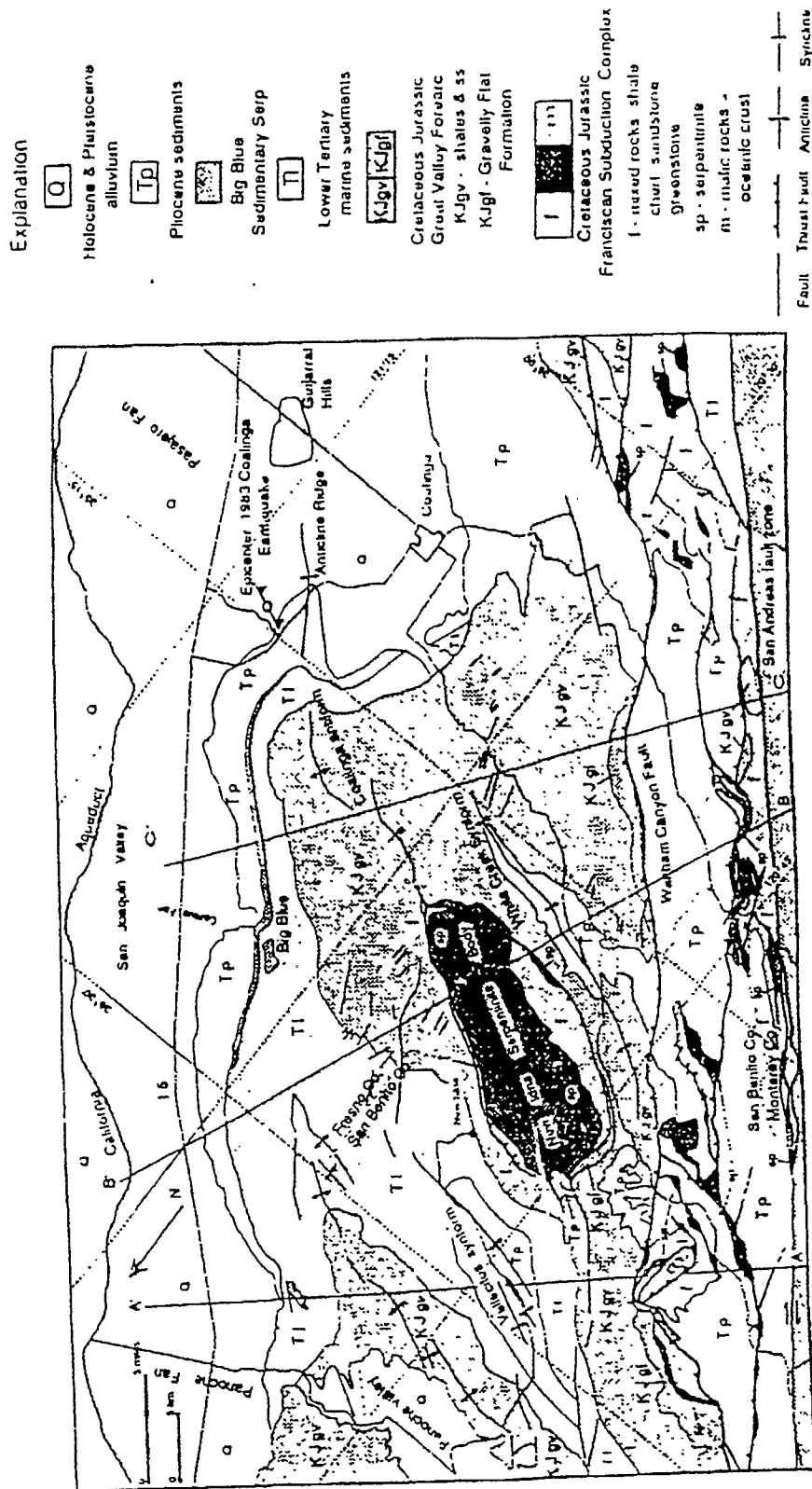


Figure 3. Geologic map of the New Idria serpentinite and surrounding area. Geology after Coleman (1957), Dibblee (1971), and Nilsen and Dibblee (1979)

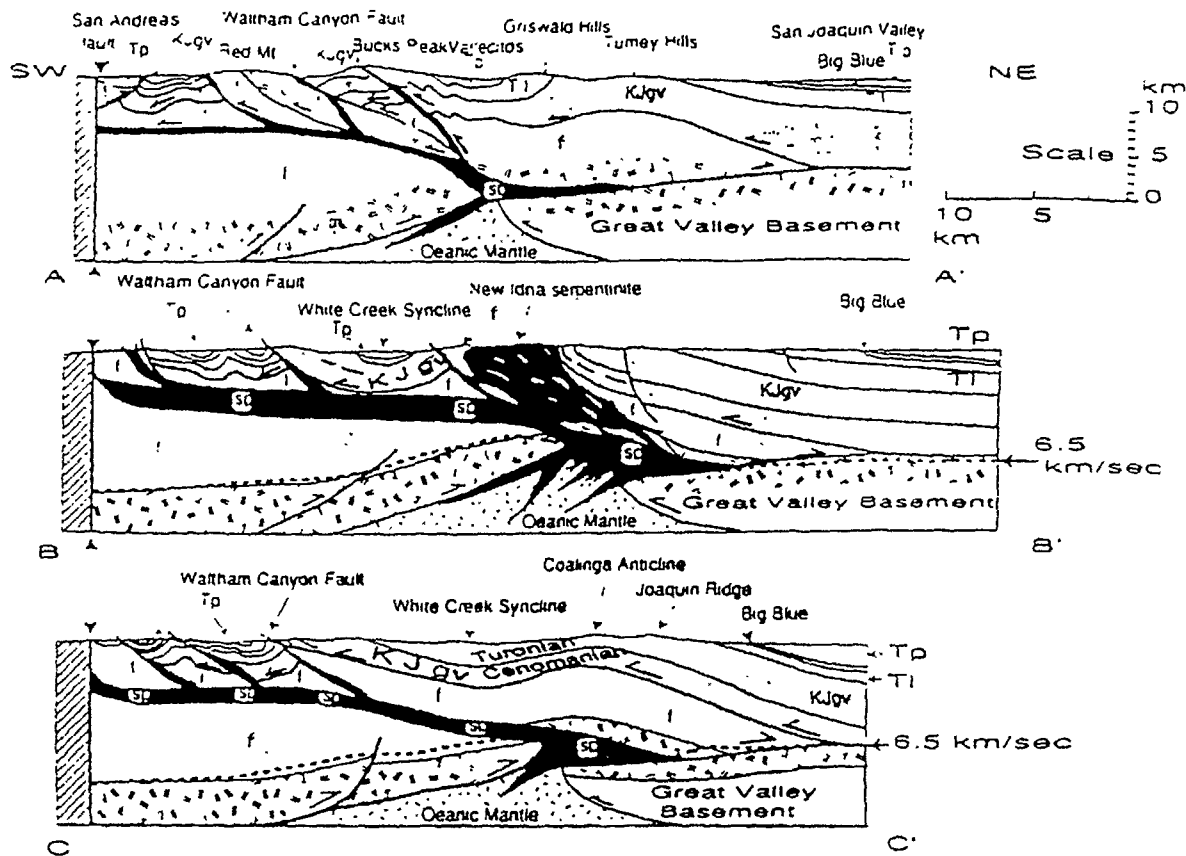


Figure 4. Geologic cross sections. See Figure 3 for locations and explanation of rock units. Vertical scale 1/2 horizontal.

(Wentworth et al., 1984). Detached and stranded slabs of oceanic crust consist of large volumes of peridotite which became serpentinitized by water pumped into the new compressional regime caused by change in plate motions (Page and Brocher, 1993). Accelerated water pumping into the peridotite as it wedged into the lower crust increased production of serpentinite accompanied by incremental volume increase greater than 15 percent in local areas (Coleman and Keith, 1971). A concomitant decrease in density accompanies serpentinitization enabling an upward buoyancy effect on the serpentinite which is surrounded by more dense country rock. The lighter and rheologically weaker serpentinite can move upward and laterally lubricate the west-directed blind thrust fault zones (Irwin, 1977; Coleman, 1980; Figure 4).

The first breaching of the New Idria serpentinite body in Early or Middle Miocene is marked by asbestos-bearing serpentinite clastic debris in the Big Blue Formation of Miocene age derived from the tectonically exposed serpentinite (Casey and Dickinson, 1976; Dickinson and Casey, 1976; Carlson, 1984; and Bate, 1984; Figure 5). It is estimated that 15 km^3 of debris mass wasted or was eroded during this early unroofing

(Figures 3, 4, and 5). This initial spectacular serpentinite protrusion (Lockwood, 1971) was followed by a continuous record of serpentinite (asbestos-bearing) deposition in the San Joaquin Basin and Vallecitos synform (Graham, 1995). The record of serpentinite erosion is verified by the presence of detrital serpentinite flakes in the Etchegoin sediments (5 ma), San Joaquin Formation (3 ma) and Tulare Formation (2 ma). The presence of active landslides on the flanks of the New Idria serpentinite body (Cowan and Mansfield, 1979) and the deposition of detrital serpentinite in terrace deposits as young as 500 B.P. (Atwater et al., 1990) is strong evidence that the New Idria serpentinite mass continues to move tectonically upward and will do so as long as the compressive regime prevails and subsurface serpentinitization of Franciscan ophiolite mantle continues.

USGS (Wentworth et al., 1992) studies show that blind thrusting during the Coalinga earthquake under the crest of the Coalinga anticline along Los Gatos Creek resulted in more than one meter of uplift. Integrating periodicity of earthquakes over a longer time period and estimating repeat times (200–1,000 yr) for similar intensity earthquakes gives an uplift rate of 1–2 mm/yr

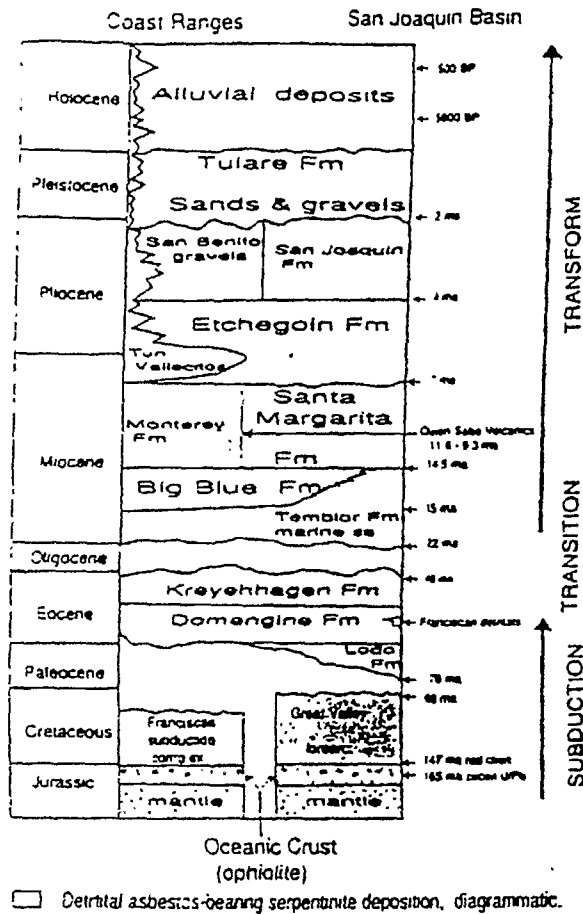


Figure 5. Sequence stratigraphy for the New Idria serpentinite and its surroundings.

(Stein and King, 1984; Atwater et al., 1990). Assuming the repeat times for seismic events (200-100 yrs) have remained constant for the last 20 ma, the region could have undergone more than 20,000 to 100,000 seismic events related to continued thrusting and uplift of the area (Stein and King, 1984; Atwater et al., 1990) Each of these seismic events would introduce more water into the system sustaining serpentinization and expansion (Coleman, 1971; Coleman and Jove, 1993). The long term deformation of the serpentinized peridotite leads to tectonization and milling. The exposed asbestos-bearing serpentinite represents the final product of this "tectonic milling" (Mumpton and Thompson, 1975).

NEW IDRIA SERPENTINITE BODY

Serpentinites generally are derived from ultramafic rocks that make up the Earth's upper mantle. Past plate tectonic movements have accreted large masses of mantle peridotite and its serpentinized equivalents within the active subduction zones of the western North

American continental margin. The instability of peridotite in the presence of water at crustal temperatures leads to its continuing hydrothermal alteration forming asbestos veins or disseminations within the serpentinized peridotite in the Earth's crust (Coleman and Jove, 1993).

The New Idria serpentinite body contains mainly highly sheared and crushed incoherent material that is made of soft, crumbly aggregates, and sheets of asbestos material (Mumpton and Thompson, 1975). The serpentinite has little strength at the surface, and the landforms which develop on it are rounded hills and easily eroded. The flanking landslide masses are derived from the rising unstable serpentinite body (Cowan and Mansfield, 1979; Figure 6).

The unique aspect of the New Idria serpentinite is that the original mantle peridotite has been completely altered. It contains up to 60 percent asbestos associated with lizardite, brucite, and magnetite with only a few rare scraps of primary mantle peridotite protolith consisting of olivine, pyroxene, and chromite. These few scraps of preserved peridotite contain original mantle mineral assemblages typical of depleted harzburgites commonly present in some of the less serpentinized peridotites of the California Coast Ranges (Loney et al., 1971). From the authors petrologic studies (Coleman, 1971, 1980) of California peridotites, harzburgite is the main mantle protolith with smaller amounts of dunite. Only rarely is clinopyroxene present, explaining the low silica activity during the main phases of serpentinization. The reddish-brown ribs of silica carbonate rock within the New Idria serpentinite body developed during a very late regional hydrothermal event which produced the mercury deposits.

As described above, the repeated tectonic activity related to compression has facilitated extreme shearing and pulverization of the serpentinite. The important minerals formed during serpentinization are chrysotile (asbestos), lizardite, brucite, and magnetite. Mineralogic studies of the New Idria serpentinite show that chrysotile is the predominant constituent (50-75 percent) in the asbestos ore samples (Mumpton and Thompson, 1975). Brucite content may be as high as 10 percent, more than double expected in other chrysotile asbestos deposits. Talc is only rarely reported and its absence indicates the very low activity of silica during serpentinization. The sheared and pulverized serpentinite is made up of flexible light greenish colored flakes resembling leather. The larger fragments may have kernels of massive green unshredded serpentinite consisting of lizardite with minor chrysotile. The outer surfaces of these larger pods of coherent massive serpentinite are completely sheeted and plated with the flexible leather-like chrysotile (asbestos), which retain slickenside marks of their tectonic transport. The widespread occurrence of brucite (Hostetler et al., 1966) and its destruction in the weathering zone produces Mg-HCO₃ waters

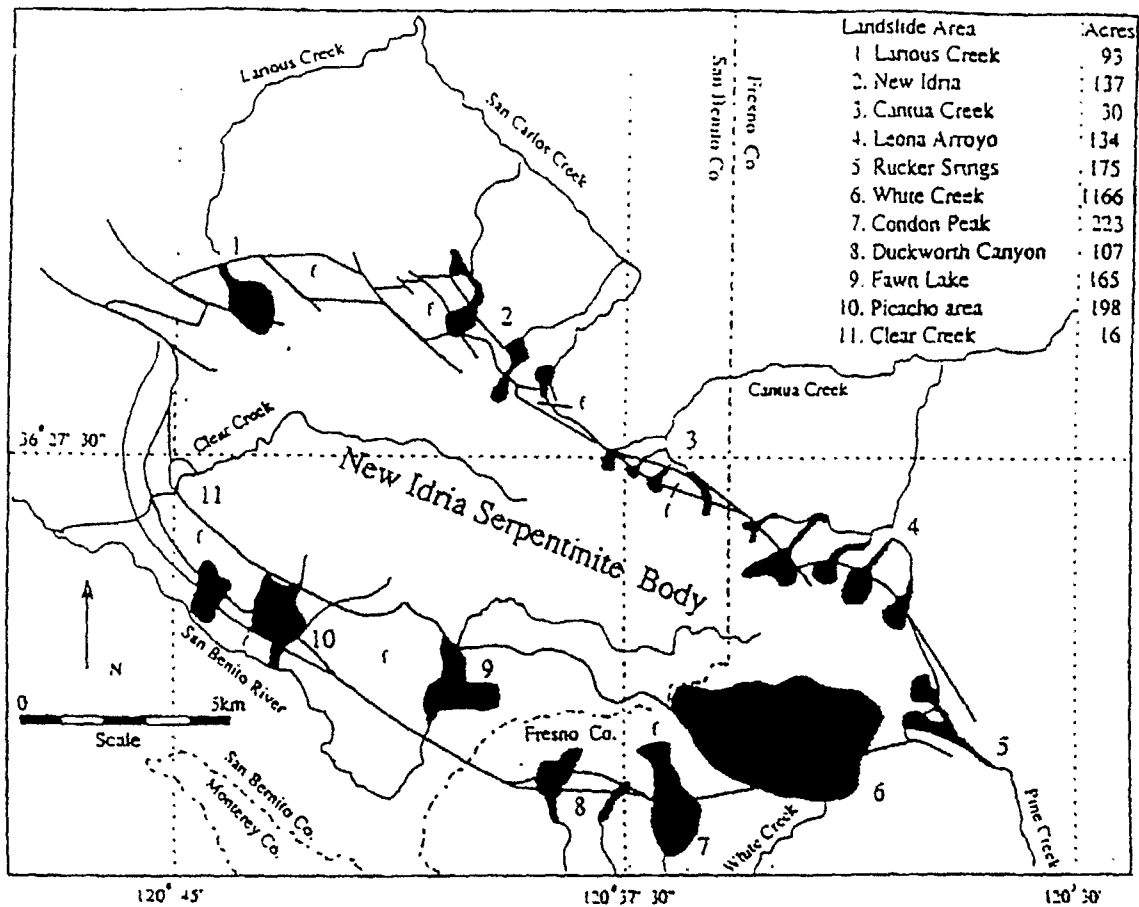


Figure 6. Distribution of landslides around the New Idria serpentinite mass. Information taken from 1:40,000 aerial photographs and Dibblee (1971). Estimation of landslide area only approximate.

(Mumpton and Thompson, 1966). Within the weathering zone hydromagnesite, artinite, coalingite, and pyroaurite are produced by brucite dissolution and are precipitated from $Mg-HCO_3$ waters during the dry season (Barnes et al., 1967). At deeper levels the $Mg-HCO_3$ waters loses bicarbonate promoting precipitation of secondary chrysotile (asbestos) (Mumpton and Thompson, 1975).

The formation of asbestos in New Idria is unusual since most asbestos deposits contain mainly cross-fiber asbestos veins (1 to 1/16 in. thick) which make up 10 to 20 percent of the serpentinite. In contrast, 50–70 percent of the serpentinite exposed at the surface of the New Idria serpentinite consists of sheared and flattened material that is soft, and powdery chrysotile (asbestos) within the sheared leathery flakes or agglomerates. The incompetent mass of chrysotile is easily eroded and is present as clastic debris in all the major streams draining the New Idria body. This rapid erosion of the serpentinite body has inhibited the formation of soils on most of its surface. The present drainage pattern

reveals that transportation of asbestos fibers by natural erosion is widespread and not confined to the south end of the body (Figure 2).

NATURE OF THE ASBESTOS FIBERS

Chrysotile is the main asbestos mineral present in these asbestos bearing deposits but is often associated with lizardite and antigorite which are non-fibrous forms of the serpentine mineral group (Skinner and Ross, 1988). Electron microscope studies on the New Idria material show that the fiber lengths are variable with an average length of 5 microns. The longer fibers are present in the leathery sheets and flexible platelets (Mumpton and Thompson, 1975). Physical data on the New Idria asbestos fibers (Mumpton and Thompson, 1975) are:

1. Diameter: 260–129 Å average with a narrow size distribution.
2. Length: 5 microns average range 1–20 microns.
3. Surface area: 60–70 m^2/g .

X-ray diffraction studies of the New Idria chrysotile show that it consists of a brucite-like layer with octahedral coordination of its cations coupled to tridymite-like layer of silicate tetrahedra and curled into a hollow cylinder typical of normal chrysotile fibers (Mumpton and Thompson, 1975; Campbell et al, 1978; and Wicks and O'Hanley, 1988). It is important to note that no amphibole asbestos has been reported in any of the mineralogical studies made of the New Idria asbestos deposits. A very minor amount of tremolite is present along the boundaries of some of the tectonic inclusions within the New Idria serpentinite. Epidemiological studies show that chrysotile asbestos free of amphibole fibers are not be linked to mesothelioma (McDonald and McDonald, 1995)

The significant features of the New Idria asbestos fibers is that they are very short, have a small diameter thereby reducing its cohesive properties, and have a specific surface area that is 3 to 4 times as great as other commercial short fiber chrysotile (Mumpton and Thompson, 1975). Easily respirable chrysotile fibers have the potential for deep penetration into human lung tissue, however the very fine nature and high surface area leads to a low bio-persistence rate. The low bio-persistence rate is related to its natural chemical solubility which is greater than most other chrysotile or amphibole fibers of similar length. Epidemiological evidence concerning the toxicity of the New Idria asbestos is scarce. An employee medical surveillance program in effect since 1963 by Union Carbide and KCAC of its employees involves a cohort of about 450 workers—40 of whom have been employed for over 15 years. The Southern Monterey County Medical Group and other physicians have not detected asbestos-related radiological changes, shortness of breath, or rales (asbestosis) in this cohort. Detailed autopsies on two deceased members of this cohort who had worked with asbestos over 25 years revealed no asbestos-related disease (KCAC Inc., 1995).

EROSION OF THE SERPENTINITE BODY

The New Idria asbestos-bearing serpentinite body occupies the highest elevations of the Joaquin Ridge (San Benito mountain 5,242 ft) forming mostly subdued surfaces within the outcrop of the serpentinite. The serpentinite body is surrounded by uplifted coherent sediments that form steep ridge and valley topography particularly along the northeastern flanks of the body. This high standing New Idria body is quite unusual considering how easily the New Idria serpentinite can be eroded (Figure 2). The major drainage away from the serpentinite body is radial and marks the uplift area of the serpentinite body. The main streams draining the area toward the San Joaquin Valley are Los Gatos Creek, Salt Creek, Cantua Creek, Arroyo Honda, and Silver

Creek all of which contribute asbestos-bearing sediments to the western alluvial fans of the San Joaquin Valley (Figure 2). The headwaters of the San Benito River are located within the serpentinite body and combine with Clear Creek to form a drainage system which is regulated by the Hernandez Reservoir. The San Benito River joins the Pajaro River which then enters the Pacific Ocean near Moss Landing within the Monterey Bay. All of these streams are intermittent and only during the wet season are they active and free flowing (Figure 2).

Those streams flowing into the San Joaquin Valley seep into the alluvium west of the California aqueduct but during flood stage sediments are introduced into the California aqueduct, as well as asbestos fibers from the New Idria serpentinite body. The streams draining the serpentinite area are actively eroding the body. The draining streams have V-shaped valleys particularly within the serpentinite area and around its flanks. An exception to the V-shape is the flat stream valley of the San Benito River as it flows northwesterly along the flanks of the serpentinite body. Well developed "mortar beds" (concrete-like gravels, cemented by carbonates) form during the dry season when evaporation of the super-saturated water precipitates carbonates (Barnes et al., 1967). Once the "mortar beds" form they are resistant to erosion and promote development of broad flat stream bottoms along the San Benito River within the serpentinite body and in the Hernandez Valley along the northwestern flanks of the body. Considerable serpentinite debris (asbestos-bearing) is locked in these carbonate cemented clastics, which are more resistant to erosion than the surrounding sediments. Perched terraces of these resistant "mortar beds" are preserved within the serpentinite body and in White Creek. The mortar beds mark the history of erosion and uplift of the serpentinite body.

The presence of landslides along the flanks of the serpentinite body are of special interest as they demonstrate large scale mass wasting of the serpentinite (Cowan and Mansfield, 1979). Twenty three Holocene landslides mapped on aerial photos have an estimated total volume of $17.60 \times 10^9 \text{ m}^3$. The debris slides developed within the serpentinite body are moving downward into the headwater streams and pose a potential hazard during heavy rainfall or seismic events (Harp and Keefer, 1990; Brabb, 1991; Figure 6). The debris caught in the steep valleys characteristically cause development of double drainage patterns. Consequent post-slide erosion clears these choked stream valleys contributing serpentinite clastics (asbestos-bearing) during the rainy seasons. The author has estimated that the White Creek landslide occupying much of the southwestern part of the serpentinite body contains $4.8 \times 10^6 \text{ m}^3$ of asbestos-bearing serpentinite (Figure 6). This huge debris slide contributes material directly to White

Creek which connects downstream with Los Gatos Creek, which in turn terminates within the large Arroya Pasajero alluvial fan on the west side of the San Joaquin Valley. The Arroyo Pasajero alluvial fan, a prominent feature on the west side of the San Joaquin Valley, consists of many layers of flood transported Holocene serpentinite clastic (asbestos-bearing) debris. The California Aqueduct gently curves around the Pasajero alluvial fan at the 100-m contour interval and is definitely vulnerable to contamination and damage from seasonal floods carrying asbestos-bearing material from the New Idria serpentinite body (Figure 2).

Alluvial fans at the termination of Cantua Creek and Silver Creek are similarly formed and also contain Holocene asbestos-bearing debris in their flanking terraces (Figure 2). In March 1995, a major storm produced an erosional scenario described above causing widespread flooding and deposition of asbestos-bearing debris upon these alluvial fans and in the San Benito River drainage system.

The present drainage pattern developed on the serpentinite body is inherited from earlier Holocene uplift and erosion. Woodward and Clyde (1989) and PTI (1993) estimate an erosion rate of 8 yd³ per acre or approximately 4.5 x 10⁻⁴ km/yr (4 mm/yr). Non-marine sediments containing serpentinite clastics (asbestos-bearing) that rest on the northwest edge of the serpentinite body (Rentschler, 1989) can be correlated with sediments within the Vallecitos synform (Figure 3). The youngest sediments are estimated to be 2-5 million years (Pliocene; Rentschler, 1989) and have a vertical displacement of approximately 2,300 ft (853 m) from the trough of the Vallecitos syncline to the crest of serpentinite body uplift. This vertical displacement can be used to estimate an uplift rate of 1.7 to 4 mm/year depending on the age of the sediments. The estimated current rates of 4 mm/yr are in excess of usual erosional rates of 1-2 mm year for mountainous areas and demonstrate long-term, rapid erosion and tectonic uplift of the New Idria serpentinite body in comparison with the rest of the Coast Range (Harrison, 1994). Implications of these high erosion rates coupled with continued tectonic uplift of the asbestos-bearing serpentinite body are significant and must be considered in light of any remedial action at the superfund sites.

PUBLIC LAND USE

California citizens' awareness of the management of public lands has produced a climate of conflict between the various users such as recreation, conservation, mining, and grazing, and the potential for toxic hazards. The New Idria serpentinite body is situated within the BLM Clear Creek Management Area (CCMA) which encompasses approximately 50,000 acres (Figure 1). Contained within the CCMA are approximately 9,600

acres of private land and 1,920 acres of California State Land. A large share of the private land within the CCMA is related to early mining claims. Some of the private land is used for cattle grazing. The BLM is responsible for a balanced management of these public lands based on multiple use and sustained yield. BLM claims to take into account the long-term needs of future generations related to the renewable and non-renewable resources (Hastey, 1994). As noted earlier, the EPA declared in 1983 the Atlas and Coalinga (Johns-Manville) areas as superfund sites which are within the CCMA (Figure 1). These superfund sites encompass approximately 1,300 acres or about 4 percent of the total exposed asbestos-bearing serpentinite body.

Another facet that requires regulation is the well known and unusual endemic vegetation within the serpentinite area (Kruckeberg, 1984; Proctor et al., 1993). A recent BLM study of the plant communities on the serpentinite produced a startling report that the San Benito evening primrose (*Camissonia benitensis*) is now a threatened species and is listed by the U.S. Fish and Wildlife Service Endangered Species Act of 1973 (Taylor, 1990). This discovery adds yet another aspect to the management of the CCMA, because the BLM is required by law to protect the habitat of endangered plant species on the serpentinite. Proposals are under way to include seven other species on the endangered list (Hastey, 1994).

The BLM management decisions become even more difficult in light of the new legislative constraints involving ORV use in CCMA. EPA requires the BLM to assess the risks of naturally occurring asbestos in the CCMA as had been done previously for the superfund sites at the asbestos mines. The ORV private groups are asking for common sense rulings concerning recreation in this area.

RISK ASSESSMENT OF SERPENTINITE AREAS

The occupational hazards related to inhaling large amounts of amphibole asbestos fibers are documented (Ross, 1993; Skinner and Ross, 1994; and McDonald and McDonald, 1995). A difficult problem remains in determining acceptable low-level exposures to the less dangerous chrysotile asbestos-bearing New Idria serpentinite. A significant question remains concerning management of the New Idria: Is the risk too high for unknowing citizens to use the CCMA area for recreation or for mining activities? Such uncertainty remains because of a fundamental scientific disagreement concerning the actual threshold risk (lowest safe limit of fibers/cc) for inhalation of asbestos fibers (McDonald and McDonald, 1995). There is no consensus on what the safe threshold should be for asbestos fibers at low levels and with intermittent exposure (McDonald, 1985).

An independent consultant was contracted by the BLM to evaluate the risk to human health caused by exposure various activities within the CCMA (PTI, 1992). Their study focused on the risks associated with inhalation of asbestos while using an ORV, or while camping and hiking in the CCMA. Data utilized was from three separate sources:

1. EPA.
2. BLM health and safety program.
3. An earlier study at the University of California (Cooper et al., 1979; Pependorf and Wenk, 1983).

The risk calculations prepared by PTI appear to be arbitrary. The PTI report combined their new data with that from the three previously cited data bases above and from a combination these data developed a relationship between excess lifetime cancer risk and the chronic daily exposure as follows:

$$\text{Excess Lifetime Cancer Risk} = \text{EC} \times \text{URF}$$

where:

EC = Chronic daily exposure to asbestos in air averaged over an individual lifetime.

URF = Unit risk factor for inhalation of asbestos (0.23 f/cc) (established by EPA from occupational studies on asbestos workers; PTI, 1992).

Risk estimates on the mean concentrations exposure due to ORV and other site uses was derived from the PTI data for BLM which gives 0.066 to 0.04 f/cc. These values are based on actual measurements from personal monitors attached to ORV motorbike riders under various conditions. Table 1 shows that these measured values yield risk levels between 2×10^{-5} to 5×10^{-6} RME (reasonable maximum exposure). The acceptable risk levels cited by the U.S. National Contingency Plan for Superfund sites are between 10^{-4} and 10^{-6} , values higher

Table 1. Upper-bound lifetime excess cancer risk estimates associated with activities at the Clear Creek Management Area (taken from PTI, 1992).

Exposure Scenarios	Excess Cancer Risk at Exposure Levels ^a		
	1-Day	RME ^b	High Estimate
Off-Road Riding	4×10^{-6}	2×10^{-5}	6×10^{-5}
Other Activities (camping, hiking)	1×10^{-5}	3×10^{-5}	— ^c
Combined Activities	1×10^{-5}	5×10^{-5}	9×10^{-5}

^aRisk estimates are based on inhalation exposures only.

^bRME: reasonable maximum exposure.

^cThe high estimate was derived from a site visitor's estimate of site use for off-road vehicle riding. The RME estimate for other activities was combined with this estimate.

than these are unacceptable. There are uncertainties in the BTI data set provided BLM when compared to earlier estimates by Pependorf and Wenk (1983), but all of these values provide a initial preliminary estimate of exposure for this environmental setting. Because these estimated risks are borderline other independent measurements should be made before final management decisions are made for CCMA.

The BLM is concerned with the risk aspect versus the recreational value of the CCMA. A recently completed BLM study proposes six alternative plans (taking into consideration the many factors discussed earlier (Hastey, 1994) It is obvious that the remoteness of the New Idria serpentinite body and the ORV activity combined with camping represent an important recreational resource. Excessive ORV use is not compatible with the environment and often can cause accelerated erosion in areas of intensive use (Webb and Wilshire, 1983).

Studies continue to show that if exposures are only to chrysotile asbestos, even if the exposure is more than 10 times higher than that recommended by the EPA, such exposures result in no excess lung cancer in cohorts monitored for periods up to 15 years (Weill et al., 1979; Thomas et al., 1982; Ohlson and Hogstedt, 1985; Churg, 1986; and Newhouse and Sullivan, 1989) Reports such as these indicate that inhalation of chrysotile asbestos fibers are dangerous only when doses exceed 10 f/cc; and such a dose is much higher than present OSHA recommended levels 0.1 f/cc. If these data are included in common sense risk analyses, it emerges that the immediate toxic aspects of the chrysotile asbestos for ORV enthusiasts and campers in New Idria is low. Using this information, one is forced to the conclusion that the perceived risk from the asbestos fibers in the New Idria area related to ORV activities actually amount to no more than a "phantom risk" (D'Agostino and Wilson, 1993).

CONCLUSIONS

The New Idria asbestos-bearing serpentinite body is a unique geologic phenomenon created by plate tectonic evolution of Western North America. Change in plate motion across the San Andreas fault system has produced shortening of the former continental margin which is manifested by sub-parallel thrusting and folding. Continued wedging of the peridotites into the continental crust developed a chain-reaction serpentinitization accompanied by expansion. Thousands of tectonic events acting on the serpentinite has produced a huge deposit of short-fiber asbestos by tectonic milling and recrystallization. Erosion of this tectonized serpentinite since Miocene (15 ma) has introduced asbestos-bearing clastic material into all of the sediments deposited along the flanks of the serpentinite body. The present configuration

and drainage patterns around the serpentinite mass show stratigraphic evidence from their associated stream terraces that Holocene deposition of asbestos-bearing serpentinite has been continuous and pervasive up to the present time (Figure 5).

Careful geologic, ecological, and land-use studies should always be made at waste sites so that the role of nature is understood and can be utilized for common sense remediation. The initial studies of any superfund site should also seek the input of local citizens or industry, who often retain important historical records of their land use.

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