



**Response of RJ Lee Group  
to  
Mr. Meeker's Letter (undated)  
to Dr. Vicki Barber,  
El Dorado Hills School District**

**Regarding  
Evaluation of EPA's Analytical Data from  
the El Dorado Hills  
Asbestos Evaluation Project**

**Exhibit B**

**Date: July 2006**

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### Preface

In October 2004, the U.S. Environmental Protection Agency (EPA) Region 9 conducted a series of tests in and around El Dorado Hills (EDH), California, to assess the potential exposure of residents to naturally occurring asbestos (NOA). EPA released a report of its results to the general public in May 2005 [El Dorado Hills Naturally Occurring Asbestos Multimedia Exposure Assessment El Dorado Hills, California: Preliminary Assessment and Site Inspection Report - Interim Final]. At the request of the National Stone, Sand & Gravel Association (NSSGA), RJ Lee Group, Inc. (RJLG) conducted a review of EPA's May 2005 report and underlying data and issued a report (dated November 2005) entitled "Evaluation of EPA's Analytical Data from the El Dorado Hills Asbestos Evaluation Project". EPA Region 9 issued a letter (Meer) dated March 9, 2006 to RJLG and NSSGA requesting the submission of supporting documentation to RJLG's November 2005 report. On April 20, 2006, EPA Region 9 issued a report entitled "Response to the November 2005 National Stone, Sand & Gravel Association Report Prepared by the R.J. Lee Group Inc [sic] 'Evaluation of EPA's Analytical Data from the El Dorado Hills Asbestos Evaluation Project'" (Region 9 April 20 Response). In addition to the sequence of reports listed above, Mr. Gregory Meeker, USGS and a consultant to the EPA, in an undated letter, prepared a "Response to Questions Submitted by Dr. Vicki Barber, Superintendent of Schools, El Dorado County, California regarding Asbestiform Amphiboles" (Meeker Response). Dr. Barber's questions were submitted to Dr. Robert Virta, USGS, in an email dated February 1, 2006.

The following is the RJ Lee Group (RJLG) response to Mr. Meeker's Letter (undated) to Dr. Vicki Barber, Superintendent of Schools, El Dorado County, California. Questions from Dr. Barber were submitted to Dr. Robert Virta, USGS. The statements from Mr. Meeker's Letter to Dr. Barber are shown in *italics*; those portions of Mr. Meeker's Letter being addressed by RJLG are shown in ***bold italics***; RJLG comments follow the italicized sections.

*"Response to questions submitted by Dr. Vicky Barber, Superintendent of Schools, El Dorado County, California regarding asbestiform amphiboles".*

*Prepared by Greg Meeker, Research Geologist, USGS Denver Microbeam Laboratory, U. S. Geological Survey, Denver, Colorado 80225*

*Three questions regarding asbestiform amphiboles were asked by Dr. Barber. Two of the questions are of a more general nature and are answerable without analysis of existing data and pertinent samples. The third question, however, does require analysis of data and samples, and that question will be addressed at a later time after the appropriate analytical work is completed."*

#### 1.0 *"Question 1*

*Concerning the mineralogical fact that asbestiform minerals can not be formed when the mineral has more than 0.3 aluminum atoms pfu or about 1.5 percent Al<sub>2</sub>O<sub>3</sub>? Is this consistent with the published literature on asbestos?"*

***[Meeker Letter]*** *"Although the vast majority of reported analyses of amphiboles in the asbestiform habit contain aluminum at levels below 0.3-0.5 atoms per formula unit (Dorling and Zussman, 1987), there are exceptions, and there is no research that demonstrates that fibrous and asbestiform amphiboles with higher Aluminum concentrations cannot form (for multiple definitions of asbestiform and related terminology, see Lowers and Meeker, 2002). Therefore, this is not a "mineralogical fact" as stated in the question above, only a fairly consistent observation. Research demonstrates that Aluminum in primary, unaltered, igneous amphiboles increases as a function of higher temperature and pressure (Anderson and Smith, 1995, and references therein). This observation, which appears to be linked to the ability of the larger aluminum cation to replace silicon in the tetrahedral site at higher temperatures, may explain the observed low levels of Aluminum of asbestiform amphiboles because they tend to form at lower temperatures and pressures (Dorling and Zussman, 1987). However, aluminum levels in amphiboles that form in lower temperature alteration environments will also be highly dependent on rock and fluid chemistry; many but not all asbestiform amphiboles form in aluminum-depleted rock types. Another subtle but important consideration is that most published analyses of amphibole asbestos generally refer to material classified using the commercial definition of asbestiform (e.g. fibrous minerals that display properties desirable for commercial use such as highly flexible, high tensile strength bundles of very thin fibrils) rather than definitions for fibrous amphiboles with morphologies that may grade from non-asbestiform prismatic and acicular habits toward or into the asbestiform habit. Therefore, it is difficult to apply any general rules regarding the maximum amount of*

*aluminum that can exist in a fibrous amphibole mineral formed by low temperature alteration and occurring as a natural component of soils or dusts generated from soils."*

**RJLG Response:** It is generally recognized that aluminum content such as that observed in the amphibole particles reported as asbestos in EPA's El Dorado Hills Study does not occur in asbestiform minerals. While there may be disagreement with the terminology used by RJLG in its November 2005 Report, no data are presented to suggest that the minerals in El Dorado Hills are an exception to the rule. While recognizing that asbestiform amphiboles do not contain significant aluminum, Meeker suggests that non-commercial asbestos deposits contain "fibrous amphiboles with morphologies that may grade from non-asbestiform prismatic and acicular habits toward or into the asbestiform habit." This statement is not relevant to the issue as the El Dorado Hills Report claimed exposures to asbestos. RJLG discussed the aluminum content of minerals having properties long recognized by science as asbestiform that, when found in sufficient quantity, have made commercial exploitation economically viable. See also Exhibit A, Response of RJ Lee Group to EPA Region 9 April 20 Response document for more discussion of this topic.

**[Meeker Letter]** *"The R.J. Lee Group report gave three primary references to support their contention that high aluminum (> 0.3 cations per formula unit) cannot exist in actinolite asbestos; Leake, et al. (1997), Verkouteren and Wylie (2000), and Deer, et al. (1997). Each of these references requires some discussion to be properly understood in the context used in the R.J. Lee Group report.*

*Leake et al., (1997) discussed aluminum content in actinolite only in the context of nomenclature; nowhere in the paper did they discuss aluminum content in asbestos. Therefore, this reference does not seem appropriate as cited in the Lee Group report."*

**RJLG Response:** Leake does not discuss the aluminum content of asbestos; the citation was in error.

**[Meeker Letter]** *"As for the aluminum content of actinolite (asbestiform or non-asbestiform); Leake et al. (1997) defined a maximum of < 0.5 aluminum cations in the tetrahedral crystallographic site. However, additional aluminum is also permitted in the octahedral crystallographic site. Thus, the amount of aluminum in actinolite is not limited to 0.3 cations or even 0.5 cations per formula unit as suggested by the R.J. Lee Group report, rather it is unspecified. Translating this to a weight percent oxide requires a full quantitative analysis for all of the other elements present; thus, it is not possible to quote a general weight percent limit such as 1.5 wt. percent for Al<sub>2</sub>O<sub>3</sub>. To reiterate, the "limits" discussed in Leake et al. (1997) only relate to nomenclature of the mineral and are based entirely on chemistry, not on growth habit."*

**RJLG Response:** Actinolite can contain substantial amounts of aluminum. The 1.5 wt. % Al<sub>2</sub>O<sub>3</sub> content is based upon work performed by Verkouteren and

Wylie<sup>1</sup> (as noted in the RJLG report) and Dorling and Zussman<sup>2</sup>. More discussion of this topic can be found in Exhibit A, RJLG's Response to the Region 9 April 20 Response.

**[Meeker Letter]** "Verkouteren and Wylie (2000) did attempt to correlate the aluminum content in tremolite-ferro-actinolite with morphology. To do this they selected 102 "museum quality" samples defining 34 as asbestiform, 24 as byssolite<sup>3</sup>, and 44 as massive. The criteria used for these definitions were somewhat subjective and appear to rely in part on visual observation and in part on the behavior of the sample material when ground in a mortar and pestle. With these caveats, the results of this study for the actinolite samples tested were as follows: The 11 "asbestiform" actinolite samples contained a maximum of 0.25 aluminum cations per formula unit (pfu), the 9 "byssolite" actinolite samples reached a maximum of approximately 0.8 cations pfu and the approximately 25 massive actinolite samples reached a maximum of 0.7 cations pfu. The tremolite and ferroactinolite samples did not show a similar discrimination between morphological types. Although this study suggested that asbestiform actinolite may generally have low aluminum content (<0.3) the study also showed that other fibrous amphiboles, specifically the byssolites, can have considerably more than 0.3 aluminum cations pfu. In nature, however, these morphologies are often not distinct, they can grade into each other, and both types can be found to co-exist, such as the can at the vermiculite mine near Libby, Montana (Meeker et al., 2003).

Deer et al, 1997, as in Leake et al., 1997, do not discuss the aluminum content in asbestiform actinolite, but only in actinolite in general and then only briefly with no specific supporting references. The pertinent statement in Deer et al. (1997) relating to this issue is "In most tremolite-actinolites the replacement of silicon by aluminum is small (< 0.3 aluminum pfu); the upper limit is arbitrarily defined by nomenclature." This statement is referring to replacement of silicon by aluminum in the tetrahedral site only. The limit of <0.3 aluminum pfu total aluminum suggested by the R.J. Lee Group report for asbestos was not addressed by Deer, et al. (1997). In addition, Verkouteren and Wylie (2000) demonstrate that highly fibrous actinolite (samples they described as byssolite) can contain significantly more than 0.3 cations pfu total aluminum.

*Of the preceding three primary references cited by the R.J. Lee Group to support the limit of 0.3 aluminum pfu in asbestos, only Verkouteren and Wylie, (2002) actually specifically address asbestos; that reference demonstrates that fibrous actinolite can contain significantly more than 0.3 aluminum pfu."*

**RJLG Response:** Meeker attempts to make a subtle distinction equating "fibrous" amphibole with asbestos; something never promulgated or critically

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<sup>1</sup>[RJLG footnote] Verkouteren, J.R. and Wylie, A.G., 2000, The tremolite-actinolite-ferro-actinolite series: Systematic relationships among cell parameters, composition, optical properties, and habit, and evidence of discontinuities: American Mineralogist, v. 85, p. 1239-1254.

<sup>2</sup>[RJLG footnote] M. Dorling and J. Zussman (1987). "Characteristics of asbestiform and non-asbestiform calcic amphiboles," Lithos, 20, p. 469-489.

<sup>3</sup>[Meeker Footnote] Byssolite is an imprecise term used to describe a fibrous, often brittle amphibole morphology in which the individual crystals are generally wider than asbestiform fibrils but thinner than acicular crystals. Byssolite crystals can be on the order of 1- 2  $\mu\text{m}$  in width (Veblen and Wylie, 1993) or "often wider than 1  $\mu\text{m}$ " (Wylie, 1979).

reviewed by EPA. The real issue is the low aluminum content of the tremolite/actinolite amphibole asbestos minerals – the minerals at issue in El Dorado Hills Study. Deer et al<sup>4</sup> note (page 141) that in “most tremolite-actinolites, the replacement of Si by Al is small (<0.3 Al pfu)” and (page 182) that “Electron probe analyses showed that specimens that contain more than a very small amount of aluminum do not have asbestiform habit.” Deer cites Dorling and Zussman<sup>2</sup> for the low aluminum content. Dorling and Zussman<sup>2</sup> show (Figure 16 of their paper) that aluminum atoms in the asbestos samples analyzed were present at less than 0.1 apfu. The Dorling and Zussman<sup>2</sup> findings were supported by Verkouteren and Wylie<sup>1</sup> who showed 85% of their asbestos samples contained 0.1 Al apfu or less. Meeker<sup>5</sup> notes that asbestos amphiboles have low aluminum content and he references a 1920 publication from Dana<sup>6</sup> as his source. The actual definition provided by Dana, however, does not support his claim as demonstrated in the following quote: “Asbestos. Tremolite, actinolite, and other varieties of amphibole, excepting those containing much alumina, pass into fibrous varieties, the fibers of which are sometimes very long, fine, flexible, and easily separable by the fingers and look like flax. These kinds are called asbestos.”<sup>6</sup>

**[MeekerLetter]** *“The 11 asbestiform actinolite samples described in the study had a maximum of 0.3 aluminum pfu, however, it is unclear how the morphology was defined by the authors (no particle size data was given) and the distinction between byssolite and asbestos used by the authors may not be appropriate for non-commercial or non-museums grade samples. It should also be noted that these results were by observation and analysis of the selected samples. No fundamental mineralogical property was specifically identified by Verkouteren and Wylie (2000), or by other studies, that would prevent higher levels of aluminum (> 0.3 cations pfu) in asbestiform amphiboles.*

*At least two additional references are pertinent to this discussion that were not cited in the Lee Group report. Gianfagna and Oberti (2001) describe massive to asbestiform fluoro-edenite with an average of 0.58 aluminum cations per formula unit (2.97-5.26 wt percent Al<sub>2</sub>O<sub>3</sub>) in the tetrahedral site.”*

**RJLG Response:** Gianfagna and Oberti<sup>7</sup> refer to a unique occurrence in a volcanic tuff in Italy and acknowledge that the compositional analysis of the asbestos component is uncertain. The above statement suggests that a hornblende mineral (fluoro-edenite) that occurs as asbestos is proof

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<sup>4</sup>[RJLG footnote] Deer, W.A., Howie, R.A., and Zussman, J., 1997, Rock-forming minerals - Double Chain Silicates: The Geological Society, v. 2B second edition, London.

<sup>5</sup>[RJLG footnote] G. Meeker (2002). Expert Report in the Libby Matter.

<sup>6</sup>[RJLG footnote] Dana, E.S., 1920, 'The system of mineralogy of James Dwight Dana 1837-1898: Descriptive Mineralogy', 6th edition: John Wiley & Sons, New York, 1134 p

that amphibole particles can contain significant quantities of aluminum and still be asbestos. However, the mineral discussed in the Gianfagna and Oberti study, fluoro-edenite, is not the same mineral at issue in El Dorado Hills Study. Actinolite/tremolite as reported in the Lab/Cor data, is present in El Dorado Hills, and is of a completely different chemical composition than fluoro-edenite. It should be noted that "Edenitic compositions are rare in amphiboles, and their paucity might suggest a structural instability."<sup>7</sup>

[Meeker Letter] *"Fluoro-edenite is likely to form a solid solution with tremolite due to the arbitrarily defined nomenclature boundaries identified in Leake et al (1997). This amphibole has been associated with increased incidence of mesothelioma in Italy (Gianfagna et al., 2003). The second reference (Thomas, 1982) described a synthetic fibrous to acicular hornblende with aluminum as high as 2.0 cations pfu in the tetrahedral site."*

**RJLG Response:** RJLG was, and is, referring to the amount of aluminum found in actinolite asbestos; the analyte of interest in the El Dorado Hills Study. RJLG does not dispute Mr. Meeker's comments about fibrous amphiboles as he defines them, only that he uses a broader definition of asbestos than that described by Campbell<sup>8</sup> or any mineralogical or regulatory reference.

[Meeker Letter] *"Both of these references, along with Verkouteren and Wylie, 2000, suggest that fibrous to asbestiform amphibole structures can accommodate appreciable aluminum under the proper formation conditions."*

**RJLG Response:** Mr. Meeker suggests that "fibrous to asbestiform" amphiboles can accommodate appreciable aluminum under proper circumstances; however, he does not give any evidence to support that the situation at El Dorado Hills constitutes such a special circumstance. See also Exhibit A, Response of RJ Lee Group to EPA Region 9 April 20 Response document for more discussion of this topic.

## 2.0 "Question 2.

*That nominal zero-degree extinction angles are a property of amphibole asbestos while extinction angles such as 10 degrees or more are an intrinsic property of monoclinic amphibole rock fragments (nonasbestiform cleavage fragments)? Is this consistent with the published literature?*

[Meeker Letter] *"This criterion is less studied and is certainly not settled science. A brief explanation is in order to understand the principle behind the question. Most amphibole particles*

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<sup>7</sup>[RJLG footnote] Gianfagna, A., and Oberti, R, 2001, Fluoro-edenite from Biancavilla: crystal chemistry of a new amphibole end-member: *American Mineralogist*, v. 86, p. 1489-1493.

<sup>8</sup>[RJLG footnote] Campbell, W. J., R. L. Blake, L. L. Brown, E. E. Cather, and J. J. Sjöberg (1977). "Selected Silicate Minerals and Their Asbestiform Varieties: Mineralogical Definitions and Identification-Characterization," Bureau of Mines Information Circular IC-8751.



(except orthorhombic) exhibit oblique extinction (they go dark) at specific maximum angles relative to the C crystallographic axis on a rotating microscope stage, when viewed between crossed polarized filters. This applies to single crystal particles including prismatic, acicular, byssolitic, and single asbestiform fibrils of sufficient diameter to observe optically. Cleavage fragments, which are particles that are broken along specific crystallographic planes, also exhibit this property. Asbestiform minerals, as defined for commercial use, are mostly composed of bundles of fibrils; fibrils are the smallest indivisible unit of asbestiform material. The individual fibrils in these bundles can be slightly rotated with respect to each other along the C crystallographic axis. This rotation causes these bundles to exhibit what amounts to a pseudo 0 degree extinction due to the averaging of multiple extinction angles of the individual fibrils in the bundle, which is compounded by the limited resolving power of optical microscopes.

Given this rather simplistic explanation, the notion that all asbestiform (and by inference hazardous) fibrous amphiboles, exhibit this property is not correct. The primary exception to this general observation is actinolite, and chemically related amphiboles. Verkouteren and Wylie (2002) noted that the property of parallel extinction is problematic for actinolite asbestos. They state: "Because of the range in optical properties, especially extinction angle, reliance solely on parallel extinction to distinguish asbestos from non-asbestiform varieties is not recommended." NIOSH (NIOSH 1994) acknowledged that "some" tremolite-actinolite asbestos exhibits parallel extinction, while OSHA (OSHA, 1992) stated that tremolite and actinolite asbestos "usually show" 0 degree extinction. It is extremely important to understand that the NIOSH and OSHA references are directed toward analytical methods that were specifically designed to identify commercial grade asbestos found in the workplace and in commercial products.

In contrast, Brown and Gunter (2003) note that fibrous amphibole from Libby, Montana exhibits both inclined and parallel extinction, and they remind the reader that the plane on which the fiber lies can also be responsible for parallel extinction regardless of morphology. Unpublished analyses in the USGS Denver Microbeam Laboratory also confirm the observations of Brown and Gunter and in addition, we have observed similar behavior (oblique extinction) in a NIOSH fibrous asbestos reference material (NIOSH Standard Reference Material TF-48). These observations demonstrate that for the tremolite-ferro-actinolite series (and also winchite-richterite as observed from Libby amphiboles), the use of parallel extinction to differentiate asbestiform from nonasbestiform material is unreliable. Furthermore, the implication that the property of oblique extinction somehow equates to the absence of toxicity is totally inappropriate as evidenced by the health problems at Libby, Montana.

Thus, although the 0 degree extinction property may apply to some if not most commercial grade asbestos, the optical property is by no means universal, it does not appear to be diagnostic of the tremolite-actinolite-winchite-richterite asbestos group, and it has not been demonstrated to directly correlate with toxicity. It is not at all surprising that non-commercial grade, fibrous and asbestiform amphibole occurring in natural environments could exhibit oblique extinction."

**RJLG Response:** The above note makes a subtle distinction between asbestiform materials that are "non-commercial grade" and those that are "commercial grade". There is no physical or regulatory basis for

distinguishing asbestos on a different basis in one environment from another. As noted above, the RJLG position is generally true vis a vis parallel extinction. There may be an exception to the rule; however, but there is no evidence that suggests the particles in the El Dorado Hills soil represent an exception. There are numerous physical properties that distinguish asbestos from nonasbestos particles. Asbestos TEM Laboratory characterized the morphology of the particles in the El Dorado Hills soil as "needles" (acicular), not asbestiform, and made no mention of parallel extinction in the 185 soil samples analyzed. Also, naturally occurring asbestos (NOA) will always have some nonasbestos amphibole associated with it, and therefore, it is logical that NOA samples will show a mixture of parallel and oblique extinction.

The PLM methods state that asbestos fibers have parallel extinction while nonasbestos particles have oblique extinction. As noted in the PLM method used by the EPA<sup>9</sup>, tremolite-actinolite will have oblique extinction (10 degrees - 20 degrees) for fragments. As noted in OSHA ID-191<sup>10</sup> (section 3.5): ". . . cleavage fragments of the monoclinic amphiboles show inclined extinction under crossed polars with no compensator. Asbestos fibers usually show extinction at zero degrees or ambiguous extinction if any at all." The draft ASTM method (P236)<sup>11</sup> that was circulated by NIST to all NVLAP laboratories states: tremolite asbestos and actinolite asbestos show extinction "parallel in most fibers." The EU method (1997)<sup>12</sup> states that "polarized light microscopy (PLM) can be used to exclude some elongated cleavage fragments on the basis of their non-parallel extinction angle" (page 13). As noted in EPA's own 1993 PLM method<sup>13</sup>, refractive indices are to be measured on tremolite-actinolite when the fiber exhibits extinction at a zero degree orientation (page 15).

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<sup>9</sup>[RJLG footnote] NIOSH 9002 Asbestos (bulk) PLM Method

<sup>10</sup>[RJLG footnote] Daniel T. Crane; US Department of Labor, Occupational Safety & Health Administration (OSHA): "Report of Analysis of Crayons for the Presence of Asbestos", June 12, 2000.

<sup>11</sup>[RJLG footnote] ASTM (1993). Proposed Test Method for Asbestos-Containing Materials by Polarized Light Microscopy, P236.

<sup>12</sup>[RJLG footnote] Schneider, T., Jorgensen, O., Sethi, S.A., Davies, L., Maclaren, W., Buchanan, D., Kidd, M., Burdett, G., Tempelman, J., Paoletti, L., "Development of a method for the determination of low contents of fibres in bulk material - Final Report - European Community Contract No. MAT1-CT93-0003," Arbejdsmiljøinstituttet, Final Report, November 1997, pp. 1 - 74

<sup>13</sup>[RJLG footnote] R. L. Perkins and B. W. Harvey (1993). Method for the Determination of Asbestos in Bulk Building Materials, EPA/600/R-93/116.

Wylie<sup>14</sup>, Dorling and Zussman<sup>15</sup> and Verkouteren and Wylie<sup>16</sup> all report that asbestos fibers have parallel extinction or (if too thin) anomalous extinction properties. See also Exhibit A, Response of RJ Lee Group to EPA Region 9 April 20 Response document for more discussion of this topic.

### 3.0 "Question 3.

*Do you agree that the dimensions of the particles reported by the EPA, based on the published literature, are consistent with a population of cleavage fragments versus a population of asbestiform fibers?"*

*[Meeker Letter] "Question 3 requires a thorough evaluation of the EPA data and will probably require analysis of additional samples. This question will be addressed at a later time after the appropriate analytical work is completed."*

### 4.0 "Concluding Remarks

*The responses given herein are intended only to address the specific questions submitted by Dr. Barber and are not intended as an evaluation of the study conducted by EPA or the review of that study conducted by the R.J. Lee Group."*

### 5.0 "References

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<sup>14</sup>[RJLG footnote] A.G. Wylie (1988). "Discriminating Amphibole Cleavage Fragments from Asbestos: Rationale and Methodology," Exposure Assessment and Control Asbestos/Other Fibrous Material, p. 1065 - 1069.

<sup>15</sup>[RJLG footnote] M. Dorling and J. Zussman (1987). "Characteristics of asbestiform and non-asbestiform calcic amphiboles," Lithos, 20, p. 469-489.

<sup>16</sup>[RJLG footnote] J.R. Verkouteren and A.G. Wylie (2000). The Tremolite-Actinolite-Ferro-Actinolite Aeries: Systematic Relationships Among Cell Parameters, Composition, Optical Properties, and Habit, and Evidence of Discontinuities. American Mineralogist, 85, p. 1239 - 1254.

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Wylie, A. G., 1979. Optical properties of fibrous amphiboles: *Annals of the New York Academy of Sciences*, v. 330, p. 611-619."