

Calabrian ophiolites: dispersion of airborne asbestos fibers during mining and milling operations

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Abstract. — Calabrian ophiolitic deposits find industrial uses in two areas depending on the conditions of the deposit: the first exploits the friability of rocks, to obtain the aggregate used in local concretes, while the second use consists of the production of the massive blocks of stones used for decorative elements, frames, paving, flooring, lapidary and jewels art, etc. We selected these two mining and milling methods to gain an understanding of their operations with the aim of assessing the risk of the worker's exposure to asbestos airborne fibers, and the possible dispersion of such fibers in the surrounding environment. Also, the working cycle relative to the production of lapidary material was investigated in order to assess the risk of the worker's exposure to airborne asbestos fibers. Furthermore, both squares and streets of the urban districts near the ophiolites quarries and milling plants were investigated by air sampling to determine the possible dispersion of asbestos fibers into these populated areas. Samples were collected onto membrane filters and analysed using Scanning Electron Microscopy (SEM). The qualitative characterisation of the fibers was carried out by Energy Dispersive Spectroscopy (EDS). The results show that the highest values of the mean tremolite fiber concentrations are obtained during the

diamond wire cutting operation (0.071 fiber/cm³) and the brooming process (0.059 fiber/cm³). Furthermore, about 42% of the respirable asbestos fibers are released during the cutting operations. Even though the worker's exposure to tremolite fibers did not exceed the regulatory limit specified, they should be supplied with suitable personal protection equipment in order to reduce asbestos risk exposure. Furthermore, the workers should be educated and informed about the risks relating to occupational exposure to asbestos fibers. The asbestos fiber concentrations obtained by environmental samplings performed in the urban districts do not exceed the limit of 1 fiber/litre, as World Health Organization recommends for urban areas. However, in order to reduce the dispersion of tremolite fibers the best *available techniques* should be adopted and used to reduce exposure.

RIASSUNTO. - I giacimenti ofiolitici della Calabria, grazie alle loro diverse proprietà, vengono utilizzati in due particolari tipologie di lavorazioni. Tali attività sono state esaminate al fine di identificare le principali fasi del ciclo lavorativo, le tecniche e le apparecchiature utilizzate. La prima tipologia, sfruttando la friabilità delle rocce, consente di ottenere il prodotto usato principalmente come inerte per la produzione di calcestruzzo e nel settore dell'edilizia. La seconda invece, consiste nella produzione di

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grossi blocchi di pietra compatta usati per lavorazioni più particolari, quali ad esempio, elementi decorativi, cornici, pavimentazioni, arte lapidea, monili.

L'obiettivo del presente lavoro è di valutare l'eventuale rischio di esposizione a fibre di asbesto aerodisperse durante i processi di lavorazione dei materiali provenienti dagli affioramenti ofiolitici e la possibile dispersione di tali fibre nell'ambiente circostante. Atal finesonostatie seguiti i campionamenti personali durante la lavorazione dei materiali ofiolitici ed alcuni campionamenti ambientali nelle vicinanze delle cave e degli insediamenti produttivi. I campioni di aria, raccolti sulle membrane filtranti, sono stati analizzati utilizzando il Microscopio elettronico a Scansione corredato di Microanalisi a raggi X per la caratterizzazione qualitativa delle fibre.

La valutazione dell'esposizione professionale ha evidenziato che la concentrazione delle fibre di tremolite è inferiore ai limiti previsti dalla vigente normativa ma è, tuttavia, necessario che vengano adottate le norme di protezione indispensabili ai lavoratori potenzialmente esposti a rischio amianto. Inoltre, è necessario che gli stessi siano formati ed informati sui rischi connessi all'esposizione ad amianto durante il lavoro. Dai risultati emerge che la concentrazione media di fibre respirabili di tremolite è maggiore durante le operazioni del taglio delle lastre con il filo diamantato (0,071 f/cm³) seguito dal processo di bocciardatura (0,059 f/cm³). È stato appurato, inoltre, che circa il 42% delle fibre riscontrate all'interno dell'impianto viene rilasciato durante le lavorazioni del taglio. I valori delle concentrazioni di fibre di asbesto ottenuti dai campionamenti ambientali effettuati nei comuni sedi delle cave e degli insediamenti produttivi non superano il limite raccomandato dalla World Health Organization pari a 1 fibra/litro per le zone urbane. Al fine di contenere la diffusione delle fibre di amianto nell'ambiente devono essere adottate delle *best available techniques* disponibili sul mercato per altre realtà produttive in cui il controllo della dispersione di fibre è essenziale sia per motivi di igiene che di sicurezza.

KEY WORDS: *ophiolites, asbestos, tremolite, airborne fibers.*

INTRODUCTION

The ophiolites, a group of basic and ultrabasic magmatic associations of rocks, due to their typical

dark greenish colours are called greenstones. In Calabria, in the south of Italy, the greenstone fields of the Mount Reventino have a considerable importance as they are an important and economic resource. These materials are used in buildings, in the production of the ornamental stones, and as decorative jewels. Unfortunately these deposits contain asbestos fibers that may be released during the mining and milling of these greenstones. If these fibers are respirable they may penetrate into the lung tissue and consequently, may lead to an asbestos-related disease (e.g., asbestosis, lung cancer or mesothelioma) (Selikoff and Lee, 1978; McDonald and McDonald, 1998; Suzuki and Yuen, 2002; Senyigit *et al.*, 2004)

The classification scheme of the greenstones and their use in relation to their of asbestos content are defined in the Ministerial Decree of 14 May 1996. Such classification is based on the petrographic information. The ophiolites of the Calabrian Arc are considered to have been part of the neo-Tethys oceanic lithosphere that once separated the European and African Plates (Guerrera *et al.*, 1993; Cello *et al.*, 1996). The Calabrian Peloritan Arc links the southern Apenninic chain to the Maghrebian chain (Amodio-Morelli *et al.* 1976) and is subdivided into northern (Sila and Catena Costiera) and southern sectors (Bonardi *et al.*, 1980; Tortorici, 1982). The nappe system of the northern Calabrian Peloritan Arc is subdivided into three main tectonic complexes: the Apennine Complex, the Liguride complex and the Calabride Complex (Ogniben, 1973). In the literature, the Calabrian Liguride Complex has been subdivided into several tectono-metamorphic units: the Diamante-Terranova unit, the Malvito unit, the Gimigliano-Monte Reventino unit and the Frido unit (Amodio-Morelli *et al.*, 1976). The Gimigliano-Monte Reventino unit consists of serpentinites, metabasalts, metagabbros/metadolerites with a metasedimentary cover made up of marble alternating with calcschists and quartzites (Piluso *et al.*, 2000). The serpentinites (with closely associated opicalcites) are mainly composed by serpentine, actinolite and chlorite with minor relicts of spinel, orthopyroxene and olivine. The metabasites are mainly represented by greenish to greyish epidote-chlorite-actinolite schists. The mineral association includes chlorite, epidote, actinolite, white mica, albite, quartz and lawsonite. The banded texture is characterised by

thin alternating layers of albite and subordinate quartz together with epidote, amphibole and chlorite (Piluso *et al.*, 2000).

METHOD AND TECHNIQUES

The greenstones, due to their different properties, are used in two particular manufacturing processes. The first type exploits the rocks friability allowing it to be used principally as the inert filler for concrete production. The second use consists of the production of the large blocks of stones used mainly for decorative elements, frames, pavements, indoor flooring, lapidary and jewels. And in turn there are two different milling process used.

The production of the friable material is subdivided in two phases, the first takes place directly in the quarry with selection of raw material and the second occurs at the crushing and sieving plant where the material, transported from the greenstone quarry, is unloaded inside the hopper and crushed. Next it is moved by a conveyor belt to vibrating-sieves where it is subdivided in to homogeneous size classes. The final processing phase consists of loading the material on trucks for transport. It is worth nothing that the crushing and sizing plant is equipped with a clarification system of recycled water and mud.

The ophiolitic site, where the rock is more massive, situated, for example, near the urban districts of Conflenti, are characterized by a quarrying activity of the large blocks of stone. The working cycle, in this case, differs somewhat as a function of the end use of the product. Regardless, of the product, the first step is cutting the blocks and transporting them out of the quarry. Recall the blocks are cut into slabs by either a diamond-wire or diamond-blades.

Based on the thickness, hardness, colour and veins within the slabs, a series of the different superficial treatments are performed to obtain different products. The polishing process produces a product used for pavements and decoration. The brooming process is obtained by rotating plates equipped with Widia-tips, that gives slaps a rough and irregular look. These products are used for street pavements and outdoor decoration. The slaps obtained by the polishing or brooming process are cut with diamond blades to obtain

tiles which represent the finished product. For some applications, the slaps are glued together. These working processes are performed in a wet abatement system, except for the stone-mason or stone-breaker, which are performed directly on the blocks and slabs with chisels.

The working cycle relative to production of lapidary material was investigated in order to assess the risk of the worker's exposure to asbestos airborne fibers.

In order to verify the presence of asbestos both bulk and air samples were characterized. Analyses of fibrous minerals were carried out on natural samples of the ophiolitic rocks occurring in the neighbouring Platania and Conflenti areas. Fig. 1 show the Geological map of the Calabrian Peloritani Arc, northern sector (Piluso *et al.*, 2000), and the location of the area of study.

The personal exposure data were collected by personal samplings according to Italian Law Decree 277/91. The portable samplers Acquaria (mod. Personal) and metallic selectors were used with a flow rate of one l/min. Polycarbonate filters with a pore size of 0.8 μm and a diameter of 25 mm were used, and the volume of air was established in relation to the quantity of the airborne dust.

Both squares and streets near the quarries and the greenstone processing plants of the urban districts of Decollatura, Platania and Conflenti were sampled. Temperature, relative humidity (R.H.) and wind velocity (W.V.) were determined by a thermoigrometer (mod. Testo 445).

The sample filters were prepared according to the analysis method specified by a Ministerial Degree 6/9/94: *Quantitative determination of airborne asbestos fiber concentrations in indoor environments*. A portion of each filter was transferred onto an aluminium stub, and then coated with a thin layer of gold to increase the conductivity, and analysed with a Scanning Electron Microscope (Leo1430). The qualitative characterization of the fibers were carried out by Energy Dispersive X-ray Spectroscopy (EDS, IXRF Systems mod.500). Based on the Poissonian distribution, the method variability was estimated.

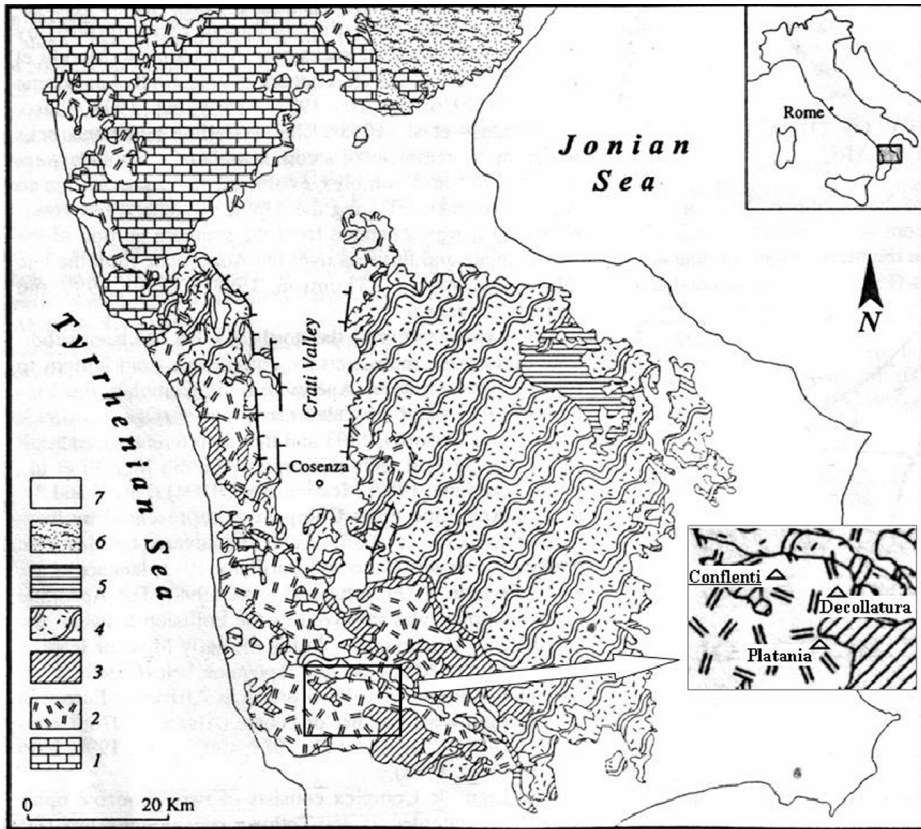


Fig. 1 – Geological sketch map of the Calabrian Peloritan Arc, northern sector (Piluso *et al.*, 2000), and the location of the studied area. 1. Apennine Units Complex; 2. Ophiolite Units; Continental crust Units; 3. Castagna unit; 4. Calabride Units; 5. sedimentary cover of the Calabride Units; 6. Liguride Complex of the Calabrian-Lucanian boundary; 7. Miocene-Oligocene sedimentary sequences.

RESULTS

The fibrous variety of tremolite $\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$, a relatively common mineral in metamorphic rocks, was found in the bulk samples from the greenstone outcrops (Figs. 2-3). Fig. 4 shows an SEM photograph of an airborne asbestos fiber deposited on the surface. The presence of the variety of tremolite was confirmed by a qualitative fiber analysis. Fig. 5 shows an example of the EDS spectra of a tremolite fiber.

The values of personal exposure and the corresponding values of the upper and lower confidence limits, for the Poissonian distribution, obtained for each duty during the lapidary production are shown in Table 1. The results show

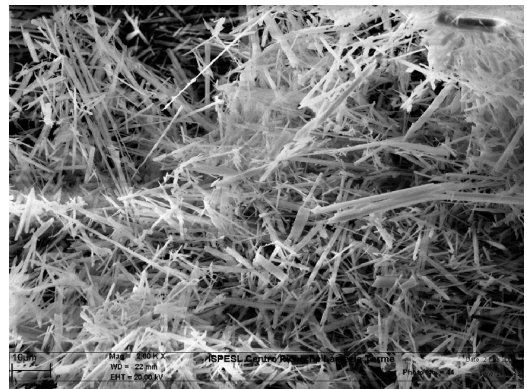


Fig. 2 – SEM micrograph of the bulk sample using x 2000 magnification.

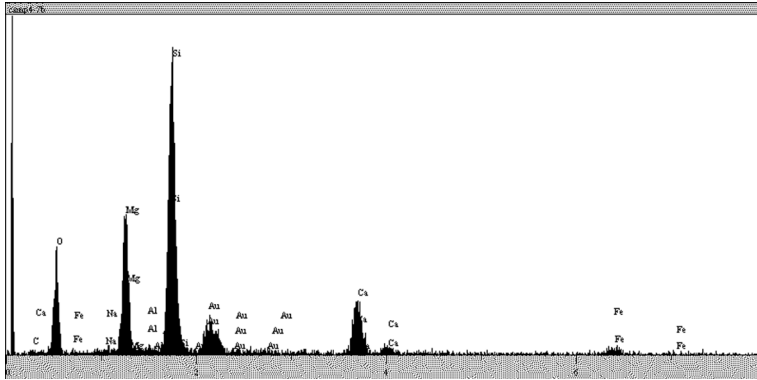


Fig. 3 – EDS spectrum of a bulk sample.

that the highest values of the mean asbestos fiber concentration are obtained during a diamond wire cutting operation (0.071 fiber/cm³) and the brooming process (0.059 fiber/cm³). Furthermore, about 42% of the respirable asbestos fibers are released during the cutting operations as Fig. 6 indicates. Last, the results of the air samplings performed in urban districts of Decollatura, Platania and Conflenti are shown in Table 2. The highest mean concentration of asbestos fibers was found in urban district of Decollatura (0.18 fiber/

litre) and assumed to occur because of the presence of the greenstone working plant in that area.

DISCUSSION

Our sampling showed that both types of greenstone outcrops contain fibrous tremolite. The presence of amphiboles gives the greenstones particular physical properties that make them suitable for different industrial applications. In

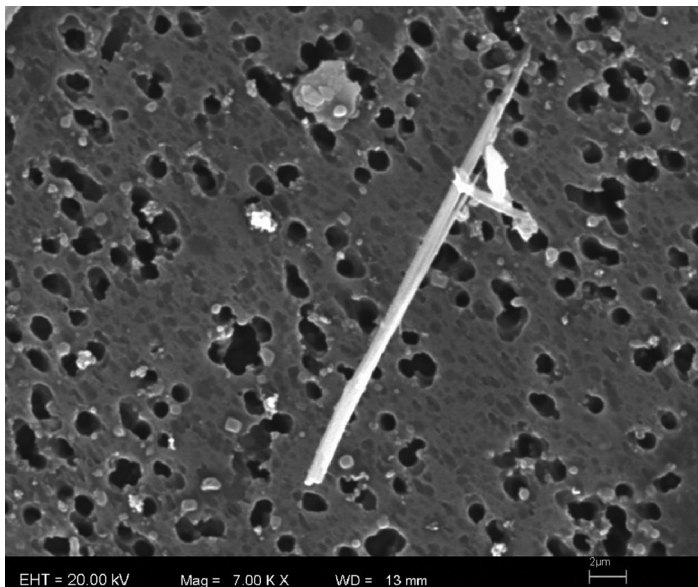


Fig. 4 – SEM micrograph of airborne tremolite fiber using x 7000 magnification.

TABLE 1 — Mean asbestos fiber's concentrations obtained by personal samplings during lapidary production

Duty	No. of	Conc.	LCL	UCL
	samples	Mean value (fiber/cm ³)	(fiber/cm ³)	(fiber/cm ³)
Diamond wire cutting operator	5	0.071	0.042	0.093
Diamond blade cutting operator	6	0.036	0.021	0.049
Stone-breaker operator	5	0.029	0.006	0.064
Brooming	6	0.059	0.042	0.087
Polishing	5	0.040	0.025	0.074
Gluing	5	0.030	0.023	0.042

fact, the outcrops with a light green colour are rich in **amphiboles, fragile, and easily broken into pieces**; for this reason they are used for concrete production and as aggregate. The rocks with a dark green colour contain fewer amphiboles and are more durable; they are used in pavements, indoor flooring, and lapidary production.

The estimation of the airborne asbestos concentration confirms that the fibers diffusion generated during quarrying activities depends on the type of the material extracted (Falcone *et al.*, 2005). The fiber concentrations are higher in the quarry characterized by friable material than in the quarry with the presence of the massive blocks; however, during natural weathering the diffusion of asbestos fibers is very low.

The evaluation of the worker's exposure to asbestos fibers during lapidary material production showed that the respirable fiber concentrations of tremolite are lower than the limit of 100 fiber/litre currently recommended. Evaluating the principal phases of the working cycle, the cutting operation produced the largest of respirable fibers. In this process about 42% of the asbestos **respirable fibers were released; during both diamond blade cutting (13%) and diamond wire cutting (29%)** operations. The appropriate abatement systems should be used to decrease the fibers diffusion; for example the continuous use of water jets during the various working phases contributes to the reducing of worker's exposure. The asbestos fibers concentrations obtained by environmental

TABLE 2 — The respirable fiber concentration of tremolite obtained by environmental samplings carried out in urban district next to the quarries and greenstone working plants

Urban district	No. of samples	Conc.		
		Mean Value (fiber/L)	LCL (fiber/L)	UCL (fiber/L)
Decollatura ^a	8	0.18	0.06	0.92
Conflenti ^b	4	0.03	0.00	0.40
Platania ^c	3	0.00	0.00	0.40

^a Temp. 21.1 °C; R.H. 56.1%

^b Temp. 21.5 °C; R.H. 51.0 %; W.V.1.9 m/s. W.V.0.9m/s.

^c Temp. 17.5 °C; R.H. 63.5%; W.V.1.0 m/s.

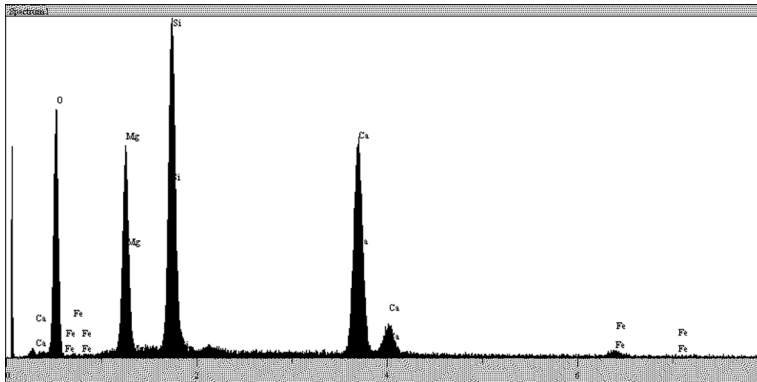


Fig. 5 – EDS spectrum of airborne tremolite fiber.

samplings carried out in the urban districts of Decollatura, Platania and Conflenti don't exceed the limit of one fiber/litre, as World Health Organization (*WHO "Air quality guidelines for Europe"*, 1987) recommends for urban areas.

CONCLUSIONS

The results of this study show that the personal exposures to airborne asbestos fibers are kept below the current limit values in Italy; however, the workers should be supplied with suitable personal protection equipment in order to reduce asbestos risk exposure even further. In order to reduce the dispersion of tremolite fibers the best available techniques should be adopted and used in other production areas where fiber control is essential

for hygiene and industrial safety. Furthermore, the workers should be educated and informed about the risks relating to occupational exposure to asbestos fibers. The presence of the ophiolitic sites does not seem to place the local population at an elevated risk; however, further study is needed on the dispersion of the fibers, particularly in the district of Decollatura where, unlike the other areas, a greenstone milling plant is situated in the urban centre.

Examinations of the asbestos fibers by SEM analysis show that their dimensions are variable. Further examination is necessary to determine the dispersion of finest asbestos fibers. These fibers can cross the pulmonary-pleural barrier and therefore may lead to increases in mesothelioma and other benign pleural manifestations as recent

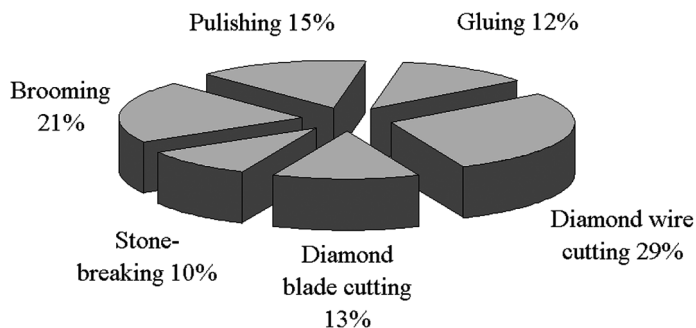


Fig. 6 – Percentages of tremolite fibers found during principal working phases.

researches demonstrate (Chiappino, 2006; Tomatis *et al.*, 2006).

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