Chiara Groppo (2002-2005)
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Asbestos hazard in western Alps: petrology, characterization and quantitative determination of fibrous minerals in the asbestos-bearing serpentinites of the Piemonte Zone (Susa and Lanzo valleys)

The word "asbestos", that means unquenchable, is used for a group of silicate minerals occurring with a fibrous habit, belonging to the serpentine and amphibole families. According to the Italian Legislation (D.L. 15/08/91) the six fibrous silicates defined as asbestos are: chrysotile, amosite and crocidolite (fibrous varieties of grunerite and riebeckite, respectively), anthophyllite, tremolite and actinolite. These minerals are made up of incombustible, chemically stable, inert, phono-absorbing, flexible and tensile fibers. The chemical and physical properties of asbestos made it, in past decades, one of the most important inorganic materials for industrial uses and technological applications. At the end of the 1950s the correlation between exposure to asbestos and development of pleural mesothelioma and bronchogenic carcinoma was established. Since the last decades, asbestos health hazard is considered not only an occupational problem, but also a potential environmental hazard. As a consequence, in most western countries, the current legislation imposed severe laws to regulate the use of potentially asbestos-bearing rocks and soils.
In the Western Alps fibrous minerals mainly occur in the Piemonte Zone of Calcschists with meta-ophiolites. The open questions from which this work was born are: i) Which fibrous minerals occur in the serpentinites from the Susa and Lanzo Valleys? ii) Where these minerals occur? Which are the genetic conditions that influence their growth? iii) In which percentage the fibrous minerals are present in the serpentinite rocks? On the basis of these open questions, the Thesis has been organized in 6 parts.

- **Part 1** – The six minerals defined as asbestos are presented; their potential patogenicity and the deseases correlated to the asbestos exposure are briefly discussed.
- **Part 2** – The geological setting of the Piemonte Zone of Calcschists with meta-ophiolites is briefly discussed, with special attention to the metamorphic evolution of the Ultramafic Lanzo Massif and of the Internal/External Piemonte Zone.
- **Part 3** – The topic of this chapter is the mineralogical and chemical characterization of the fibrous minerals occurring in the analysed serpentinites, i.e. serpentine minerals (chrysotile and antigorite), balangeroite, diopside, tremolite and carlosturanite. For each fibrous mineral, the crystallographic structure and optical properties are reported, and the chemical composition and vibrational properties (FTIR and -Raman spectroscopy) are discussed in detail. From these data it is evident that a rapid and unambiguous identification of fibrous minerals requires the combined use of several analytical techniques, particularly the optical and electron microscopy and the -Raman spectroscopy.

• **Part 4** – This chapter is dedicated to the petrological study of the serpentinites from the Susa and Lanzo Valleys, which has been carried out mainly by means of optical and electron microscopy, and □-Raman spectroscopy. In the first part of the chapter, the serpentinization processes are briefly discussed and the serpentinite microstructures and the metamorphic paragenesis are described in detail. The second part of the chapter is dealing with the metamorphic veins occurring in the serpentinites. The mechanisms by which a fibrous vein may form are firstly considered; the five generations of metamorphic veins recognised in the serpentinites are, then, described in detail and some hypotheses for their genetic conditions are suggested. The metamorphic P-T path estimated for the serpentinites on the ground of microstructural observations and thermobarometric data, is discussed in the light of □(Ca2+/Mg2+)-□(SiO2) and P-T diagrams, calculated with the pseudosection approach.
• **Part 5** - This chapter concerns the problem of the quantitative determination of the fibrous minerals in the rocks. In the first part, the traditional techniques used for the quantitative estimate of asbestos in solid materials are presented, i.e. fiber count at SEM or TEM, X-ray powder diffraction and IR spectroscopy. In the second part of the chapter two new methods are proposed. The first one is based on the use of FTIR spectroscopy for the quantitative asbestos estimate in a chrysotile + antigorite mixtures. The second is based on the image analysis of SEM images combined with □-Raman spectroscopy. This last technique gives both quantitative and morphological information.
• **Part 6** – In the final chapter, the main results obtained, the still open questions, and the future perspectives are summarized and briefly discussed.