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Serpentinite-derived soils in southern Italy: potential for hazardous exposure

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ABSTRACT - The aim of the present study was to investigate on serpentinite rocks and related derivative soil samples in order to understand their potential contribution to the health problems caused by asbestos exposure. With this intent, agricultural soil samples as well as serpentinite rocks from which soils derive have been collected at San Severino Lucano village (Basilicata region, southern Italy); this site was chosen because of spatially isolated from other urban centers as well as any factory. In our study, we adopted different analytical techniques such as Polarized Light Microscopy (PLM), X-Ray Fluorescence (XRF), X-Ray Powder Diffraction (XRPD) and Scanning and Electron Microscopy combined with Energy Dispersive Spectrometry (SEM/EDS). Results pointed out as all of the collected soil samples contain asbestos minerals (e.g., chrysotile, tremolite-actinolite), clay minerals, plagioclase and oxides in various amounts. In our opinion, since the dispersion of fibres could be associated with carcinogenic lung cancer, in areas where Natural Occurring Asbestos (NOA) can be found, the institutions should publish local maps indicating areas with mineralogical concern and take precautions to avoid hazardous exposure of population.

The concentration levels of four toxic elements (Cr, Co, Ni, V) in almost all the serpentinite rocks and their derivative soils developed within San Severino Lucano village exceeds the regulatory thresholds for public, private and residential green use.

Keywords: NOA; serpentinite-derived soil; heavy metals; southern Italy.

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1. INTRODUCTION

Naturally occurring asbestos fibres are generally associated with serpentinite or altered ultramafic rocks. Over the last decades, many studies have focused on rocks containing NOA with the aim of determining the potential health risks to exposed neighboring populations (Bloise et al., 2012, 2014; Punturo et al., 2015; Baumann et al., 2015). The term "asbestos" represents a group of six fibrous silicate minerals belonging to the serpentinite (chrysotile) and amphibole (tremolite, actinolite, anthophyllite, amosite, crocidolite) mineral groups (e.g., World Health Organization WHO, 1986; NIOSH 2008). It has plenty been exploited for use in industrial and commercial products, mainly in building materials (e.g. insulation), heat-resistant fabrics and friction products (e.g. brake pads). Naturally occurring asbestos (NOA) is a generic term used to refer to both regulated and non-regulated fibrous minerals when encountered in natural geological deposits (Harper, 2008). Nowadays, only the six varieties above listed are considered as potential environmental pollutants by the Italian laws, however also asbestiform minerals such as balangeorite, carlosturanite, antigorite, diopside and fluoro-edenite (Compagnoni et al., 1983, 1985; Gianfagna, 2003; Compagnoni and Groppo, 2006) could be potentially dangerous if inhaled. In Europe and several other countries, asbestiform minerals are currently classified as asbestos when they have length >5 μm and aspect ratio (i.e., length divided by width) ≥3:1 (World Health Organization WHO 1986, Directive 2003/18/CE, NIOSH 2008).

Asbestos fibres dispersion in the environment is extremely dangerous because their inhalation may cause many types of cancer pathologies; it is confirmed by many studies which shown that death from lung diseases such as malignant mesothelioma, can be associated with environmental exposure to asbestos (International Agency for Research on Cancer, IARC, 2009).

On the basis of the effects of asbestos on biological systems, several authors ascribe the asbestos-fibres toxicity to the synergetic effect of fibre size, bio-persistence and chemical composition (Gualtieri et al., 2017). However, it is generally accepted that none of the theories alone is adequate to explain the pathogenic mechanism of asbestos. Some study suggests that the cytotoxicity of asbestos may be also related to the minor and trace elements present as impurities in their structure (Bloise et al., 2016 a,b). Indeed, asbestos minerals, for different structural reasons, have a high capability to host a large number of toxic elements and some researchers claimed that asbestos fibers may play a passive role in producing diseases as carriers of trace elements. The human health risks are based on the potential fibres inhalation when they become airborne; NOA can be released into the atmosphere by natural weathering processes (e.g. erosion) or with human activities such as excavation, road construction, driving or walking on unpaved surfaces and agricultural activities which may disturb NOA outcrops causing the formation of potentially inhalable airborne dust (Punturo et al., 2015; Bloise et al., 2016c). Moreover, heavy metals may be released to natural water (e.g. Apollaro et al., 2011, 2012), contributing to human health. An association with neighborhood exposure to asbestos and an increased risk of deaths from lung diseases has been documented among the people who live near Naturally Occurring Asbestos (NOA) deposits around the world (e.g. Acosta et al., 1997; Burragato et al., 2005; Constantopoulos, 2008; Pereira et al., 2008; Navarro et al., 2013; Gaggero et al., 2017; Worliceck, 2017), including the Basilicata region (Italy) (Bloise et al., 2017a). Indeed, in this region, an increased number of lung disease were related to the environmental exposure to asbestos tremolite (Bernardini et al., 2003; Burragato et al., 2004; Pasetto et al., 2004).

In this frame, this paper reports the results of a detailed study on rocks and soils that developed on serpentinite bedrocks cropping out within the San Severino Lucano village (Basilicata region, Italy) (Fig. 1), in order to assess the presence of NOA potentially hazardous to human health and environmental quality. The geographic isolation and its distance from other main sources of asbestos for instance, are among some major aspects, which make the village an engrossing case study, besides local interest.

To this aim, we collected twelve serpentinite rocks and twelve related soil samples and cross-checked the data obtained from different analytical techniques (i.e., MOLP, XRPD, XRF, SEM–EDS), in order to perform a detailed characterization and to relate NOA release in the environment due to agricultural activity.

2. AREA DESCRIPTION

This study area (Fig. 1) is comprised within the Pollino National Park, which is located between the Basilicata and Calabria regions of southern Italy. The area is characterized by the terrains of the Liguride Complex which consists of three main tectonic units of Upper Jurassic to Upper Oligocene age (Ogniben, 1969; Vezzani, 1970; Monaco and Tortorici, 1995; Cirrincione et al., 2015): (1) the Calabro-Lucano Flysh (Monaco et al., 1998), a non-metamorphosed ophiolithiferous unit which partly corresponds to the North-Calabrian Unit; (2) the metamorphic terranes of the Frido Unit, characterized by HP/LT metamorphism (Vezzani, 1969; Amodio-Morelli et al., 1976; Cavalcante et al., 2012); (3) syn-orogenic turbiditic sequences, i.e., the Saraceno Formation, the Albidona Formation, and a sequence composed of alternating shales, mudstones and sandstones, the latter corresponding to the Perosa unit as defined by Vezzani (1966). The ophiolites of the Southern Apennine Liguride Units occur in the Frido Unit and in the North-Calabrian Unit. In particular, ophiolitic rocks of the Frido Unit consist of lenticular metabasites interbedded with cataclastic and highly fractured serpentinites (Sansone et al., 2011, 2012) that, together with serpentinites, slates, and metalimestones form sequences with a maximum thickness of several dozen meters In particular, we focused on the Village of San SeverinoLucano (40°1'0" N, 16°8'0" E) and its surroundings, on an area that encompasses about 20 km^2 (Fig. 1).

3. METHODS AND MATERIAL

Field survey carried out at San Severino Lucano village showed that the serpentinites are green coloured and present mainly two varieties: foliated and massive. Moreover, serpentinite outcrops are rarely covered by vegetation (Fig. 2a) due to the toxic composition of the surface formation (soils) derived from these rocks. Only few plants are able to survive under this extreme chemical composition (García Barriuso et al., 2011). For this reason, serpentine outcrops are highly exposed to weathering. Locally, serpentinites are very brittle, as indicated by the large number of fracture surfaces that may be filled by asbestiform minerals. Either alluvial and residual soils related to the serpentinite parent rock were collected (Fig. 2b) and analyzed, for a total of twelve serpentinite rocks and twelve related soil samples, respectively (Tabs. 1 and 2). Sampling sites are indicated in figure 1. Collected specimens were treated and studied in order to investigate their petrographic and mineralogical features and to highlight the occurrence of asbestiform minerals, if any.

To this aim, on thin sections obtained from the serpentinite collected, we carried out a petrographic and mineralogical investigation by using a Zeiss Axiolab Microscope with Polarized Light (PLM). X-ray powder diffraction patterns (XRPD) were obtained on a Bruker D8 Advance X-ray diffractometer with CuKa radiation, monochromated with a graphite sample monochromator at 40 kV and 40 mA. Scans were collected in the range of 3°-66° 2θ, with a step interval of 0.02° 2θ and step-counting time of 3 s. EVA software (DIFFRACplus EVA) was used to identify the mineral phases in each X-ray powder spectrum, experimental peaks being compared

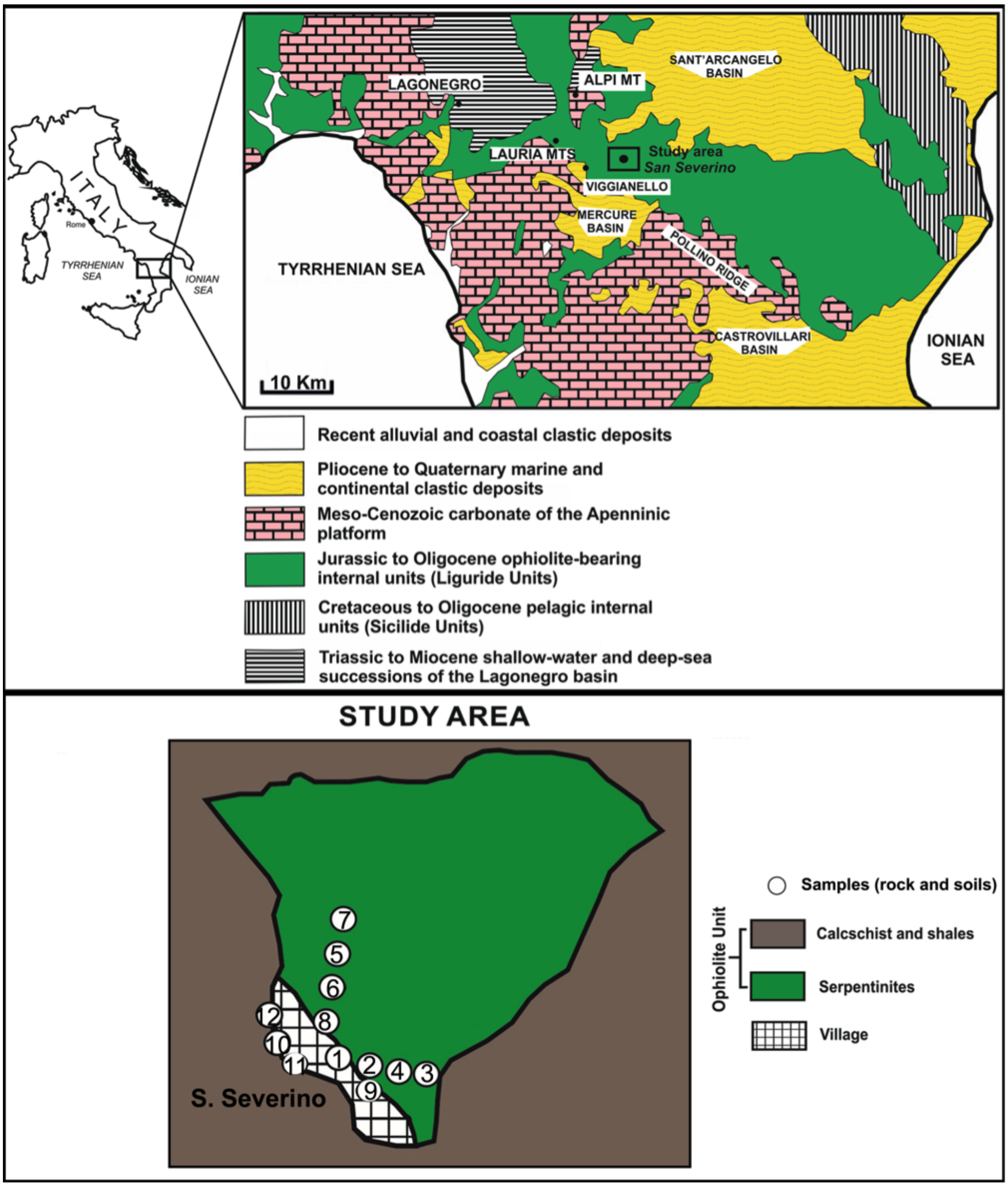

Fig. 1 - Geological map of the Calabria-Lucania border (modified after Bloise et al., 2017a) and study area location with sampling sites.

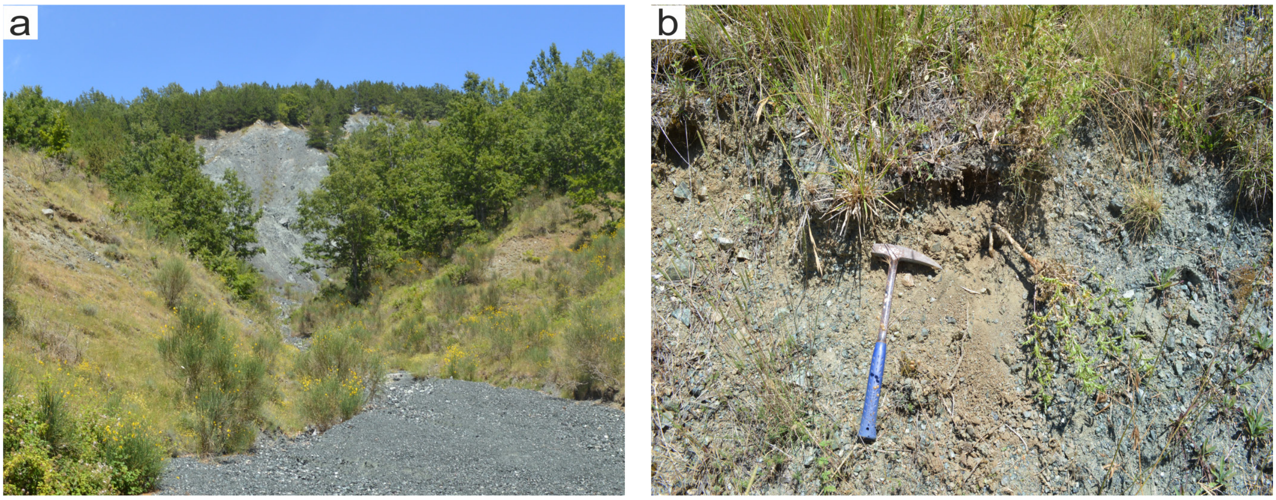

Fig. 2 - Products developed after serpentite alteration: **a)** alluvial debris; and **b)** derivative agricultural soil.

Sample	Lithotype	Locality	Site description	Lon (East)	Lat (North)	Phases detected
Rpol_1	Serpentinite	S. Severino Village	Entry of the Village	597417	4429775	Srp, Di, Mag, Chl
Rpol_2	Serpentinite	S. Severino Village	Entry of the Village	597405	4430523	Srp
Rpol_3	Serpentinite	S. Severino Village	Road cut outside the Village	597808	4430474	Srp, Di, Tr, Chl, Mag, Mnt
Rpol_4	Serpentinite	S. Severino Village	Road cut outside the Village	597569	4430504	Srp, Di, Tr, Chl, Mnt
Rpol_5	Serpentinite	S. Severino Village	Road cut outside the Village	597270	4431103	Srp, Di, Tr, Mag, Mnt
Rpol_6	Serpentinite	S. Severino Village	Road cut outside the Village	597268	4430927	Srp, Di, Mag
Rpol_7	Serpentinite	S. Severino Village	Road cut outside the Village	597323	4431363	Srp, Di, Chl, Mag
Rpol_8	Serpentinite	S. Severino Village	Road cut within the Village	597223	4430711	Srp, Di, Chl, Mag
Rpol_9	Serpentinite	S. Severino Village	At the base of the slop, outside the Village	597569	4430504	Srp, Di, Tr, Mag
Rpol_10-11	Serpentinite	S. Severino Village	Road cut within the Village	596890	4430715	Srp, Di, Chl, Mag
Rpol_12	Serpentinite	S. Severino Village	Road cut within the Village	596831	4430823	Srp, Di, Mag,

Tab. 1 - Studied localities, coordinates and, for each collected serpentinite sample, mineralogical assemblage detected by X-ray powder diffraction (XRPD) and scanning electron microscopy combined with energy dispersive spectrometry (SEM/EDS). Mineral symbols after Kretz (1983). Amphiboles present in the samples were classified according to the amphibole diagram classification (Leake et al., 1997).

Sample	Lithotype	Locality	Site description	Lon	Lat	Phases detected
Spol_1	Soil	S. Severino Village	At the entrance of the Village	597417	4429775	Srp, Di, Qtz, Mnt-Chl,
Spol_2	Soil	S. Severino Village	At the entrance of the Village	597405	4430523	Srp, Di, Qtz, Mnt-Chl, Tr
Spol_3	Soil	S. Severino Village	Road cut outside the Village	597808	4430474	Srp, Di, Qtz, Mnt-Chl, Tr
Spol_4	Soil	S. Severino Village	Road cut outside the Village	597569	4430504	Srp, Di, Qtz, Mnt-Chl, Tr, Chm, Chl,
Spol_5	Soil	S. Severino Village	Road cut outside the Village	597270	4431103	Srp, Di, Qtz, Mnt-Chl, Tr, Chm, Ms
Spol_6	Soil	S. Severino Village	Road cut outside the Village	597268	4430927	Srp, Di, Qtz, Mnt-Chl, Tr, Chm, Ms, Tlc,
Spol_7	Soil	S. Severino Village	Road cut outside the Village	597323	4431363	Srp, Di, Qtz, Mnt-Chl, Chm,
Spol_8	Soil	S. Severino Village	Road cut within the Village	597223	4430711	Srp, Di, Qtz, Mnt-Chl, Tr, Chm,
Spol_9	Soil	S. Severino Village	At the base of the slop, outside the Village	597569	4430504	Srp, Di, Qtz, Mnt-Chl, Tr, Chm,
Spol_10	Soil	S. Severino Village	Road cut within the Village	596890	4430715	Srp, Di, Qtz, Mnt-Chl, Tr, Chm, Mo
Spol_11	Soil	S. Severino Village	Road cut within the Village	596890	4430715	Srp, Di, Qtz, Mnt, Tr, Chm
Spol_12	Soil	S. Severino Village	Road cut within the Village	596831	4430823	Srp, Di, Qtz,

Tab. 2 - Studied localities, coordinates and, for each collected derivative soil sample, mineralogical assemblage detected by X-ray powder diffraction (XRPD) and scanning electron microscopy combined with energy dispersive spectrometry (SEM/EDS). Mineral symbols after Kretz (1983). Amphiboles present in the samples were classified according to the amphibole diagram classification (Leake et al., 1997).

with 2005 PDF2 reference patterns. For a better determination of mineralogical composition by XRPD, the soil samples were pre-treated with H_2O_2 and pre-heated for 24 h at 530 °C, in order to remove the organic compounds. The soil samples have been investigated from a petrographic, mineralogical and geochemical point of view by using various analytical techniques, in order to point out eventual asbestiform minerals and to point out the enrichment in heavy metals respect to the serpentinite rocks from which soils themselves derive. For SEM analysis, samples were examined without any grinding treatment with the Tescan-Vega\\LMU scanning electron microscope, equipped with an energy-dispersive X-ray spectrometer (EDS) Edax Neptune XM4 60, operating at 15 kV accelerating voltage and 20 nA beam current conditions. X-ray fluorescence spectrometry was carried out with Axios instrument from analyticalon fused glass diluited by $Li_2B_4O_7$ (1:5) and by using external calibration with international rock standards. L.O.I. (Loss on Ignition) was determined by gravimetric method. Values of representative major and trace elements (ppm) are reported in tables 3 and 4, respectively.

4. RESULTS

At the mesoscopic scale, serpentinite rocks show the typical dark green coloration and massive structure, with widespread presence of veins with varying thickness. The main mineral constituting these veins is serpentine whose individuals are in most cases arranged perpendicular to the vein elongation. Thin sections obtained from specimens show at the polarizing microscope that the serpentine group minerals as the main constituents and magnetite±talc±Cr-spinel±chlorite as the other mineral phases present. Rare relics of olivine and pyroxene are observable (Fig. 3a); in most cases, original crystals have been completely replaced by pseudomorphic aggregates of serpentine minerals and by small magnetite grains. The pseudomorphic replacement of olivine by serpentine causes the formation of fractured olivine grains into which serpentinization advances uniformly, from all fractures and grain boundaries, to produce mesh textures (Fig. 3b); the mesh core is clearly distinguishable from the mesh rim. Secondary magnetite commonly develops along the former olivine grain-boundaries and fractures emphasizing them (Fig. 3c). The pseudomorphic replacement of pyroxene by serpentine begins from grain boundaries and fractures by following along cleavage planes; in most cases the primary pyroxene is easily recognizable because the cleavage is preserved (Fig. 3d). Many vein systems are filled by serpentine group minerals and by talc (Fig. 3 e,f), in particular serpentine fibres are found with perpendicular orientation to the vein elongation (“cross” serpentine).

4.1. XRPD characterization

Results from the XRPD showed that the most abundant minerals in all serpentinite rocks are serpentine minerals, while tremolite was found in four samples out of twelve. Diopside and magnetite are ubiquitous, whereas and

Wt%	SiO_2	Al_2O_3	MgO	CaO	K_2O	Fe_2O_3	L.O.I
Rock							
RPOL1	39.8	0.9	41.2	2.2	0.0	8.7	7.4
RPOL2	39.1	0.7	40.3	0.6	0.0	9.1	10.1
RPOL3	40.7	1.7	42.2	3.5	0.0	7.9	4.0
RPOL4	40.7	1.0	43.2	3.0	0.0	8.9	3.2
RPOL5	41.9	1.3	40.9	4.6	0.0	10.1	1.3
RPOL6	39.6	0.9	41.7	1.7	0.0	8.1	8.0
RPOL7	40.1	1.0	41.2	2.1	0.0	8.6	7.1
RPOL8	43.2	1.7	43.2	5.2	0.0	4.3	2.4
RPOL9	38.6	0.8	40.2	2.3	0.0	8.8	9.2
RPOL10_11	40.0	0.9	42.2	2.4	0.0	8.4	6.1
RPOL12	39.9	0.9	41.5	2.2	0.0	8.1	7.4
Soil							
SPOL_1	38.5	3.8	40.0	2.0	0.1	6.1	9.6
SPOL_2	41.0	5.9	36.7	3.2	0.4	6.0	6.7
SPOL_3	40.2	4.2	41.2	1.9	0.1	5.5	6.9
SPOL_4	39.3	5.5	39.4	1.2	0.3	7.2	7.2
SPOL_5	41.0	5.0	39.2	2.9	0.1	5.3	6.5
SPOL_6	40.9	4.2	39.6	2.3	0.2	5.3	7.5
SPOL_7	45.4	4.4	38.7	0.6	0.3	5.2	5.3
SPOL_8	39.1	4.7	41.1	1.8	0.1	5.0	8.3
SPOL_9	39.8	3.8	42.2	2.1	0.0	5.5	6.6
SPOL_10	40.0	4.9	39.1	2.0	0.3	4.6	9.1
SPOL_11	40.8	5.2	38.6	1.9	0.3	5.1	8.1
SPOL_12	39.9	3.4	41.0	1.8	0.1	5.9	8.0

Tab. 3 - Major oxide values (wt%) in bulk serpentinite rock and derived soil samples. L.O.I. (Loss On Ignition) is also reported.

ppm	Co	Cr	Ni	V
Rock				
RPOL1	88	2658	2281	91
RPOL2	107	1725	2489	66
RPOL3	87	2175	1726	88
RPOL4	97	2622	2379	67
RPOL5	112	2865	2073	82
RPOL6	97	3077	2074	65
RPOL7	105	2553	2100	68
RPOL8	62	1065	1177	217
RPOL9	99	2247	2004	62
RPOL10_11	99	2527	2140	76
RPOL12	97	2207	2018	73
Soil				
SPOL_1	122	2680	2131	91
SPOL_2	137	2942	1735	117
SPOL_3	79	1888	1576	75
SPOL_4	123	3425	1670	137
SPOL_5	139	2652	1203	144
SPOL_6	148	3828	1942	139
SPOL_7	103	1644	1505	78
SPOL_8	125	1997	1854	86
SPOL_9	71	1956	1547	78
SPOL_10	116	1711	1718	65
SPOL_11	103	2052	1574	81
SPOL_12	111	1536	1843	56

Tab. 4 - Selected heavy metals values (ppm) in bulk serpentinite rock and derived soil samples.

clay minerals (chlorite, montmorillonite) were detected in some samples (Fig. 4; Tab. 1). As far as soils, X-ray diffraction study revealed that serpentine group minerals mainly constitute all samples, together with diopside inherited from rocks, secondary clay minerals (e.g. montmorillonite-chlorite; chamosite, muscovite) and quartz. Moreover, the relatively sharp reflections diagnostic of the presence of tremolite probably present in low amount in the serpentinite rocks, which were observed only in fourXRPD pattern from serpentinite rocks due to the overlapping of serpentine reflections, are now clearly visible. Indeed, in serpentinite-derived soils, tremolite was detected in nine samples out of twelve (Fig. 4b; Tab. 2).

4.2. SEM–EDS characterization

Morphological observations by means of SEM in soil samples, show a large amount of fibrous minerals with acicular habit trapped in aggregating agents like organic matter, clay and iron oxides. Morphology of representative fibres is shown in figure 5 a,b. These fibers have variable size (length 13-18 µm and diameter about 1 µm) and in most cases tend to split up along the fibers elongation axis. Their identification is not easy just by observing images at SEM, therefore, representative chemical analyses by means of EDS have been useful to complete their preliminary characterization. The results of microanalytical investigation carried out on some occurring fibers pointed out that they are chrysotile and amphiboles with tremolite-actinolite main composition and minor anthophyllite.

4.3. Major, minor and trace elements

Selected element values for either serpentinite rocks and derivative soils are set out on tables 3 and 4. Results showed that the average values of most major elements are quite similar in the two groups, being $SiO_{2\text{average}} \approx 40$ wt%, MgO_{average} wt% is 41.6 (rock) and 39.7 (soil), and CaO_{average} is 2.7 wt% (rock) and lower in soil (1.98 wt%). On the contrary, soils are enriched in $Al_2O_{3\text{average}}$ (4.48 vs 1.07 wt%) and in K_2O (below detection limits in rocks). As far as minor (Cr, Ni) and trace (Co, V) elements values are higher in soils compared to rocks, whereas the opposite happens for Ni, being more abundant in rocks (Tab. 4). The distribution of the selected elements (potentially harmful elements, PHEs) is comparable to results observed in similar lithotypes and derivative soils (e.g. Censi et al., 2011, 2011a; Guagliardi et al., 2013, 2016 a,b).

5. DISCUSSIONS

Considering the results of this case study, we can assess that the population that lives within serpentite rich geological context is clearly exposed to serious health risks due to soil pollution from heavy metals. In particular, chromium could be a cause of several human health problems such as stomach and lung cancer (e.g., Shekhawat et al., 2015). It is also worth mentioning that among the minor elements known as being dangerous for human health, Ni is the toxic metal of greatest concern (Nackerdien et al., 1991). In fact, contact with nickel compounds can cause a variety of adverse effects on human health, such as cardiovascular, kidney diseases and cancer of the respiratory tract (Seilkop and Oller, 2003). Cobalt breathing in high amount may cause several human health problems such as asthma and pneumonia (ATSDR, 2004). Finally, excessive amounts of vanadium in the human body can increase the possibility of uremia and/or lung cancer (e.g., Crans et al., 2004). In the study area, chromium, vanadium, cobalt and nickel are geogenic in serpentine soils and not anthropogenic. In fact, in chrysotile samples, the trace metals represent an almost exclusively isomorphs substitute for magnesium (Bloise et al., 2009, 2010, 2017b; Ballirano et al., 2017). Although, heavy metal substitution in chrysotile is usually more restricted than in the other serpentine minerals (i.e., lizardite and antigorite). Moreover, the concentration of heavy metal is highly variable among the different asbestos detected (i.e., chrysotile and tremolite), due to the different geochemical processes involved in their formation. In a recent work, Bloise et al. (2016b) show that metals, such as

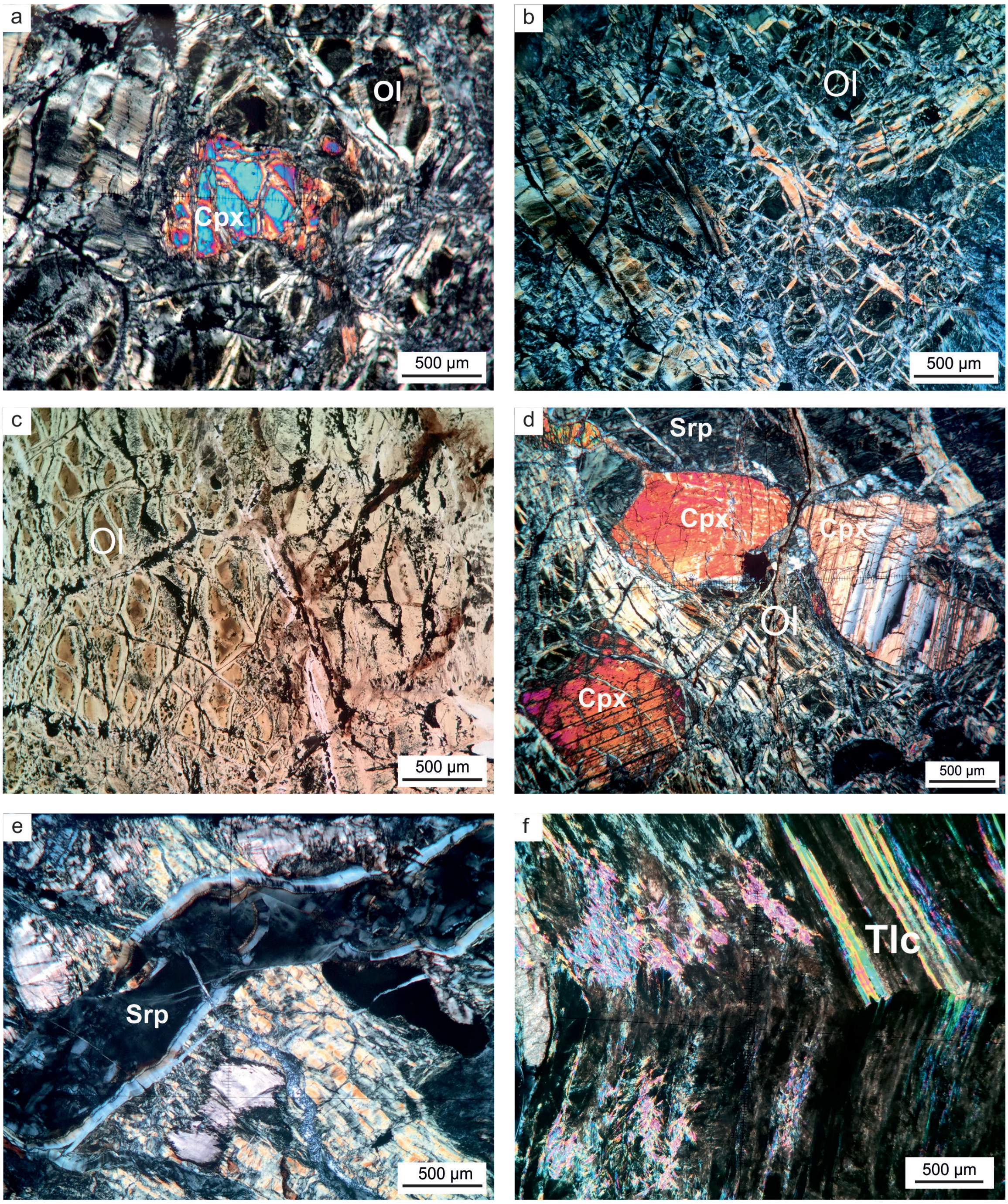

Fig. 3 - Photomicrographs of: a) relic of clinopyroxene and olivine partially replaced by serpentine; b) olivine pseudomorph replaced by serpentine showing mesh texture (crossed polarizers); c) serpentine over olivine with mesh textures in plane-polarized light; fractures are emphasized by secondary magnetite; d) clinopyroxene partially replaced by serpentine with olivine pseudomorph between them; serpentine matrix is observable at the top; e) serpentine vein cross-cutting the main rock); f) arrangement of serpentine and talc fibers inside a vein (crossed polarizers);

Co and Ni in tremolite asbestos from Val d'Ala (Italy) were present in a high amount. Ni and Co in tremolite occupy the specific crystallographic M(1) and M(3) sites as in synthetic calcic amphibole (Ballirano et al., 2017).

Finally, the comparison of the concentrations of PHEs (V, Cr, Co e Ni) is investigated through a series of correlation plots in which the concentration of SiO_2 is taken as the reference variable (Fig. 6). From diagrams, it is evident that in either studied soils and rocks, the maximum admissible contents established by the Italian law shows that these elements in our samples are very high and exceeds the regulatory thresholds (Italian Legislative Decree No. 152 of 03/04/2006) for public, private and residential green use for V, Cr and Co (limit A corresponding to 90, 150, 20 ppm respectively), while nickel (limit A: 120) is also exceeded the legal limit for industrial and commercial use.

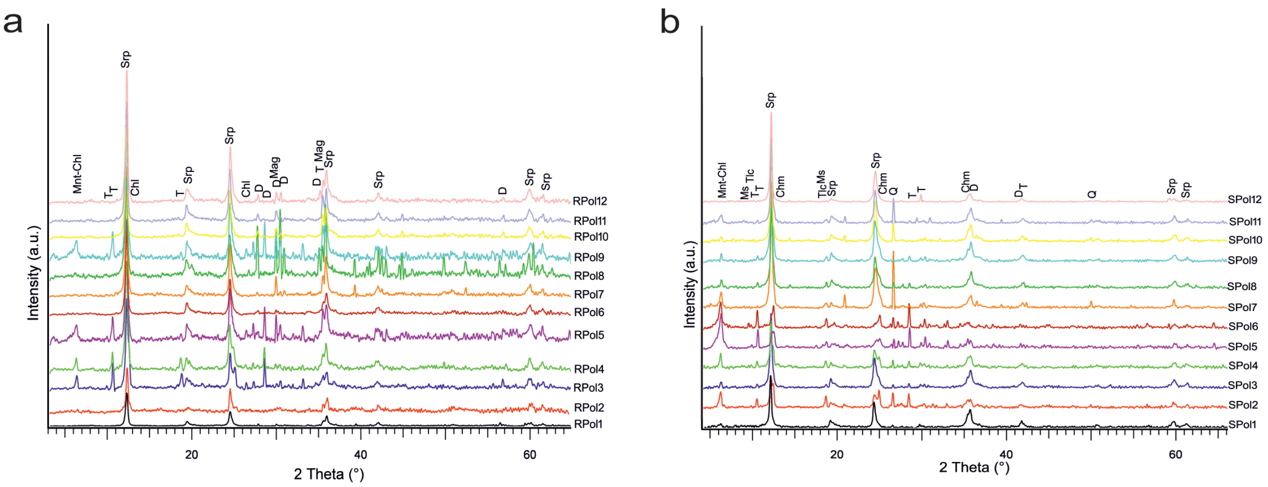

Fig. 4 - XRPD pattern from: a) serpentinite rocks and b) derived soils. Peaks were assigned according to literature (Mineral Powder Diffraction File: Data Book, JCPDS-International Centre for Diffraction Data).

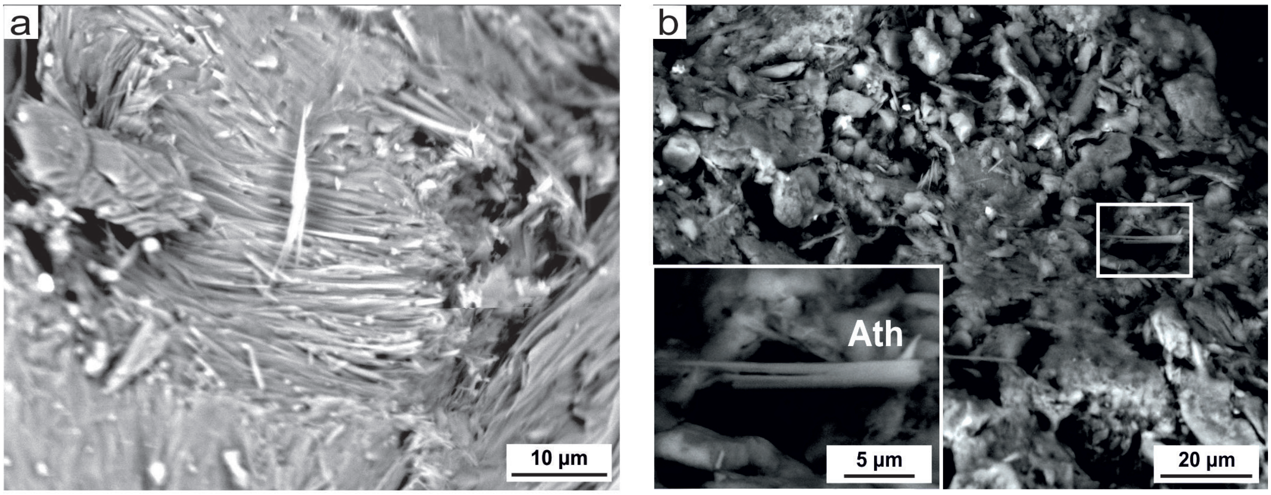

Fig. 5 - Selected Scanning Electron Microscope images of: a) representative morphology of asbestos fibers in serpentinite rocks and b) representative morphology of asbestos fiber in soil samples; Ath=Anthophyllite. Rectangle is zoomed image.

6. CONCLUSIONS

The multidisciplinary study on serpentinite rocks and derivative soils was carried out in the area of San Severino Lucano (Basilicata, Southern Italy) in order to determine the presence of naturally occurring asbestos, by means of different analytical techniques. This study outlined that in both rocks and derivative soils, there are asbestos minerals such as chrysotile and asbestos tremolite. Indeed, either chrysotile and asbestos tremolite were found in soils, suggesting that human activities can disturb and provoke the release of inhalable asbestos in the atmosphere, triggering thus mechanisms of hazardous exposition for population. Even if they usually occur in aggregates that cannot be suspended in the air, agricultural activities can destroy these soil aggregates with the formation of dust containing inhalable asbestos fibres, which evolve into airborne increasing thus the exposure to them. Moreover, the present study revealed that serpentinite rocks cropping out near to San Severino village towns act as a perennial source of contamination for the agriculture lands. Since the dispersion of fibres could be associated with carcinogenic lung cancer, in our opinion in areas where NOA can be found, the institutions should publish local maps indicating areas with mineralogical concern and realization of constructions (e. g. road) must have dust control measure to avoid hazardous exposures. Finally, the values of trace metals in our samples are very high and by adopting the thresholds for soils, elements such as Cr, Co, Ni and V exceeds the regulatory thresholds for public, private and residential green use.

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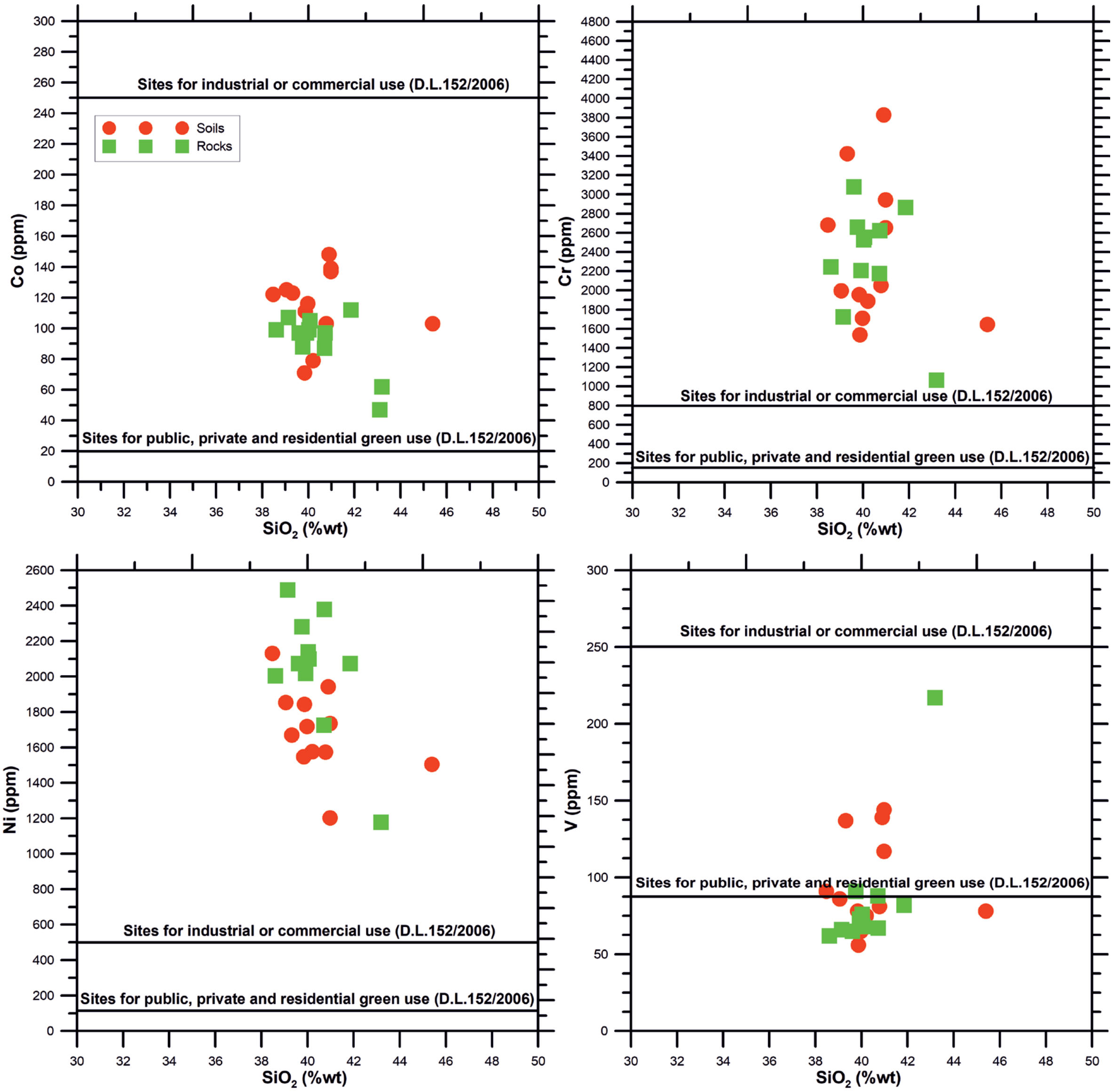

Fig. 6 - Correlation diagrams of SiO_2 versus Co, Cr, Ni and V for soils and rocks of the studied area. Thresholds values regulated by Italian law (D.L. 152/2006) are also indicated for each heavy metal.

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