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EVALUATION OF ASBESTOS EXPOSURE IN DUMANLI VILLAGE (ÇANAKKALE-TURKEY) FROM A MEDICAL GEOLOGY VIEWPOINT: AN INTER-DISCIPLINARY STUDY

Erdinç YİĞİTBAŞ[a*], Arzu MİRİCİ[b], Uğur GÖNLÜGÜR[b], Coşkun BAKAR[c], İsmail Onur TUNÇ[d], Fırat ŞENGÜN[a] and Özgür IŞIKOĞLU[a]

[a] *Çanakkale Onsekiz Mart Üniversitesi (ÇOMÜ), Mühendislik Fakültesi Jeoloji Mühendisliği Bölümü, Çanakkale*
[b] *ÇOMÜ Tıp Fakültesi, Göğüs Hastalıkları Anabilim Dalı, Çanakkale*
[c] *ÇOMÜ Tıp Fakültesi Halk Sağlığı Anabilim Dalı, Çanakkale*
[d] *Ardahan Üniversitesi, İnsani Bilimler ve Edebiyat Fakültesi, Coğrafya Bölümü, Ardahan*

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ABSTRACT

Biga Peninsula has many varied and interesting medical geologic problems, as well as being rich in natural geological resources. Mainly these problems are natural radioactivity, mineral dust, metal/mineral contamination in drinking water, acid rock/mine drainage, and problems related to geothermal and drinking water. With this view exposure to asbestos was surveyed and the results of this survey were evaluated by earth scientists and medical doctors. This inter-disciplinary study was done in Dumanlı village (Çanakkale-Turkey) in the Biga Peninsula, NW Turkey. Studies have been carried out in earth sciences and the health sciences simultaneously. The asbestiform minerals around Dumanlı village are contained in sheared serpentinites which occur as tectonic slices and lenses within Çamlıca metamorphics. These tectonic slices and lenses are bounded by strike-slip faults and probably obtained their final tectonic positions in a transpressional regime during late Cretaceous-early Eocene time. Asbestiform minerals occur within stretching-shear zones in the strike-slip system. Petrographic and mineralogic indications show that the asbestiform minerals are clinochrysotile, lizardite, antigorite and actinolite. In parallel with earth science studies; verbal autopsy, pulmonary function tests and radiological examination studies were carried out. A significant correlation between asbestos exposure and radiographic pathology was identified in the region and it was understood that the duration of exposure in these cases varies from 23-80 years.

1. Introduction

In addition to the rich geological structure of the Biga Peninsula, it is an area with open potential for varied and interesting problems related to medical geology (Figure 1). The main medical geology problems may be listed as natural radioactivity, mineral dust, metal/mineral pollution of drinking water, acid rock/mine drainage, and problems related to geothermal and drinking water, etc. Though there are individual studies on these topics in the region (Örgün et al., 2007; 2008; Baba et al., 2008; Save, et al., 2009; Baba and Gündüz, 2010; Bakar et al., 2009*a*, *b*; 2010; Bundschuh, et al., 2013; Atabey, 2008; 2013; Yiğitbaş et al., 2012), as in all of Turkey, in-depth research on the topic of medical geology is required in the Biga Peninsula. Working from this perspective, asbestos exposure was investigated in a sample area in the Biga Peninsula and preliminary results were evaluated by medical and earth science experts.

Asbestos is a group of fibrous silicate minerals widely used in the past due to their insulation, electrical properties, and resistance to high voltage, chemicals and heat. Its use in more than 3000 trade

* *Corresponding author: Erdinç Yiğitbaş, erdinc.yigitbas@gmail.com*

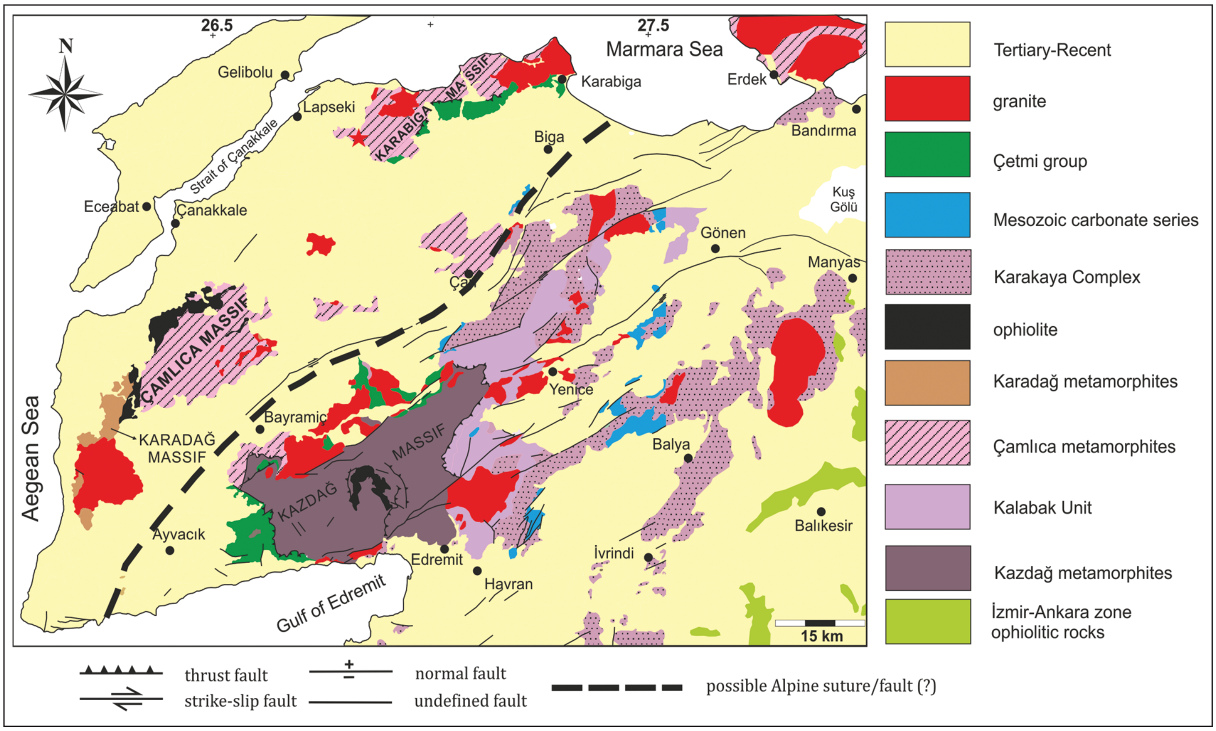

Figure 1- Simplified geological map of the Biga Peninsula (after Tunç et al. 2012). Small red colored star on the map shows the location of Dumanlı village, where this research performed.

products in sectors such as roofing materials, floor tiles, concrete pipes and textiles led to widespread distribution in areas open to the public and in the residential environment.

Asbestiform minerals used for industry may be collected into two main groups. These are 1) serpentine asbestos (chrysotile, lizardite, antigorite) and 2) amphibole asbestos (crocidolite, amosite, anthophyllite, tremolite, actinolite). The main reasons asbestiform minerals were commonly used in industry was their resistance to heat and burning, high voltage resistance, very low conductivity of heat and electricity, durability-stability in various chemicals, resistance to friction, wear and burning, and easy ability to take any form when used with a variety of materials (İrkeç, 1990 and references there in).

Chrysotile, in the serpentine group, was widely used in many industrial applications throughout the world as a trade asbestos type. It is very flexible, undulated and has high heat resistance. However it is not durable in acid environments. According to estimates more than 95% of asbestos used in trade in the United States of America was chrysotile asbestos; the majority from Canadian and Russian mines (Craighead, et al., 1982; Selikoff and Lee, 1978). When the results of many studies on the topic of asbestos to date are examined, serious negative effects on health occur due to asbestos minerals. The possibility of asbestos being related to lung diseases entered the agenda at the beginning of the 1900s. Pancoast, et al. (1918) investigated the results of asbestos and dust inhalation on the lungs nearly one hundred years ago with radiological methods. Cooke (1924) stated that a woman working for 18 years in an asbestos factory developed pulmonary fibrosis. The relationship between asbestos and malignant mesothelioma was described in a study by Wagner (1960) of mine workers in the 1960s. A short time later, exposure outside of occupation and regionally increased mesothelioma incidence was determined in a study by Newhouse and Thompson (1965) and later after Selikoff (1968) published his paper, the topic of occupational and environmental potential health problems of asbestos in countries producing asbestos began to be debated and research on the topic began to be published. Inhalation of asbestos either environmentally or occupationally causes pulmonary fibrosis (asbestosis), lung cancer, pleural or peritoneal mesothelioma and pleural changes (thickening, plaques, effusion) (Barış et al., 1979; Niklinski, et al., 2004; Doğan, 2002; Emri and Demir, 2004).

Lung and bronchial cancers are among the most common and deadly cancers in the world. According to World Health Organization data, one of the leading cancers resulting in death globally is lung cancer (WHO, 2013) and of all lung cancers it is estimated that 4-12% develop as a result of asbestos exposure (Henderson et al., 2004). Diffuse malignant mesothelioma (DMM) is a deadly tumor in mesothelial cells or mesenchymal cells under the pleura, pericardium or peritonea (Chretien et al., 1985). The relationship between DMM developing in pleura and peritoneum and asbestos exposure is clear. However apart from exposure to asbestos, idiopathic and other accepted reasons for DMM include fibrous minerals such as erionite, radiation, pleural scarring and SV 40 virus (Craighead et al., 1982).

While the prevalence of pleural mesothelioma is generally high among those exposed to asbestos the prevalence of peritoneal mesothelioma is lower. Peritoneal mesothelioma cases are mainly seen in those subject to intense exposure to asbestos. The latent period of mesothelioma caused by asbestos may be 30 years or more and exposure to low concentrations may increase latency; however death is seen within 1 year of diagnosis (Emri and Demir, 2004; Şenyiğit, et al., 2000; Lanphear and Buncher, 1992; Browne, 1994). Unlike lung cancer it has no link to cigarette intake and has be proven to develop as a result of asbestos inhalation. The results of experimental studies have shown that all types of asbestos may cause lung cancer and mesothelioma (Doğan, 2002; Suzuki and Yuen, 2002; Roggli, et al., 1993; Churg, 1988; Berman, et al., 1995; Dufresne, et al., 1995). However there is an important difference between amphibole and chrysotile asbestos in terms of potential to form malignant mesothelioma. While amphibole asbestos, such as amosite, crocidolite and tremolite, has greatest potential, chrysotile has lower potential.

Long and thin asbestos fibers are more fibrogenic than short asbestos fibers (<5 μm) as shown experimentally in both intratracheal and respiration studies (Adamson and Bowden, 1987; Lemaire, 1985; Davis and Jones, 1988; Davis, et al., 1986). In chronic respiration experiments using short chrysotile fibers in rodents, no fibrotic lesions were observed (Platek, et al., 1985). The potential for cell proliferation, damage, injury and alveolar macrophages releasing oxidants is greater with exposure to long fibers (Adamson and Bowden, 1987; Donaldson, 1989; Mossman, et al., 1989). The carcinogenicity of the asbestos fibers is affected by the diameter of the fibers. Fibers with diameter less than 0.25 μm are extremely carcinogenic (Doğan, 2002; Berman, et al., 1995).

Natural release of asbestiform minerals from source rocks occurs due to degradation and erosion processes and is concentrated by surface erosion. In seasonally dry climates fibers dry and become more susceptible to erosion. Destruction of rocks containing asbestos deposits for aims such as agriculture, mining, settlement, etc. is an important and risky anthropogenic factor increasing the rate of release of asbestos from source rocks (Derbyshire, 2005).

Turkey, among many countries with large asbestos reserves globally, has the highest prevalence of endemic pulmonary diseases related to asbestos (Karakoca, et al., 1997). The reason for this high prevalence is the high population living in rural areas and regional geologic characteristics. In Turkey mafic-ultramafic rocks and greenschists, commonly containing asbestiform minerals, are seen in virtually every outcrop. As a result the health of organisms living in areas where rocks containing asbestiform minerals outcrop may be negatively affected. Respiration of asbestos fibers in Turkey results from the use of loose rocks containing talc and asbestos, known as “white soil” by local people, as material for lime, plaster, roofing and ground stabilization (Atabey, 2009). Leading the list of wrong applications as reason for the most intense intake of asbestos by respiratory pathways, is the use of serpentinite containing asbestos in rural areas as aggregate for stabilized roads. Unfortunately this great error continues to date commonly in many regions of the country (Atabey, 2009; Yiğitbaş, et al., 2013).

Mineralogical analysis of plaster used in dwellings in rural areas has found mostly tremolite in addition to chrysotile and anthophyllite asbestos (Doğan and Emri, 2000). However in the Cappadocia region in Central Anatolia with widespread outcrops of volcanic-volcaniclastic rocks, the plaster material in houses in the rural area has been found to contain fibrous zeolite (erionite) (Baris, et al., 1987; Atabey, 2007). Experimental studies have shown that erionite has 300-800 times more carcinogenic potential compared to chrysotile and when administered intrapleurally is 100-150 times more potent than crocidolite (Carthew, et al., 1992). In fact in the Cappadocia region a variety of research showing that some important health problems result from fibrous zeolite minerals has been completed (Barış, et al., 1987; Atabey, 2007). All this research shows that important health problems may be caused by respiration of asbestiform minerals in the natural geologic environment.

The inter-disciplinary study forming the topic of this paper was completed in Dumanlı and part of Çamyurt villages in Lapseki county of Çanakkale province in the northwest of Biga Peninsula in northwest Anatolia. After 4 cases of mesothelioma were discovered in this region in 2011 by Çanakkale Provincial Health Directorate, a study group of earth scientists from Çanakkale Onsekiz Mart University (ÇOMU) Geological Engineering Department, experts from ÇOMU Medical Faculty Chest Diseases and Public Health departments together with experts from Çanakkale Provincial Health Directorate was founded and research began. Studies continued simultaneously and in parallel in earth sciences and health sciences. Earth science studies began by obtaining a geological map to determine whether any asbestos deposits were in Dumanlı and Çamyurt villages and surrounding areas. Determined asbestos outcrops were marked on the geology maps and samples were taken. Samples were evaluated with SEM and XRD analyses after petrographic determination. The conditions and mechanism of formation of asbestos veins found was modeled within a regional tectonic framework, to determine similar formations within the region and to predict the areas for future asbestos exposure research. With this aim, in parallel to the earth science study, verbal autopsy studies to determine the causes of death in the region over the past 5 years were carried out by public health experts. Chest disease experts completed and evaluated respiratory function tests and radiological examinations of 139 people currently living in the area.

2. Geographic and Geological Setting

The Biga Peninsula is geographically bounded to the north by the Sea of Marmara and the Dardanelles, to the west by the Aegean Sea and to the South by the Gulf of Edremit. The Peninsula is linked to the Anatolian Peninsula to the east between Edremit-Akçay. The Dumanlı and Çamyurt villages in this study are in the northern part of the Biga Peninsula, which is the most northwestern part of Anatolia (Figure 1). Dumanlı and Çamyurt villages are 25 and 19 km from Lapseki, the county seat. According to data from the Turkish State Meteorology Service the climate of Çanakkale, the site of the study area, is between steppe-humid according to De Martonne's climate classification with an aridity index of 13.48 (MGM, 2014*a*). According to the Turkish State Meteorology Service Wind Atlas the study area is within the windiest region in Turkey (MGM, 2014*b*). This situation naturally causes asbestiform minerals to mix more with the air and be inhaled more by organisms.

The Biga Peninsula geologically is formed of a variety of tectonic units representing continental units of the Sakarya continent along with oceanic assemblages with different sources and very old ages (Yiğitbaş, et al., 2009; Şengün, et al., 2011; Tunç, et al., 2012).

Two metamorphic belts outcrop along a northeast-southwest trend in the Biga Peninsula. The southern belt is represented by the Kazdağ Massif, while the northern belt is represented by the Çamlıca, Karabiga and Karadağ Massifs. It has been proposed that a suture zone exists covered by thick Tertiary-Quaternary volcano-sedimentary rocks between these two different metamorphic belts. This suture zone is evaluated as the remains of the Paleotethys or Intra-Pontide Ocean (Okay, et al., 1991; 2008; Okay and Göncüoğlu, 2004; Duru, et al., 2004; 2012). Another interpretation is that the zone in the region, evaluated as an Alpine oceanic suture, is a strike-slip fault zone called the West Pontide Fault Zone (Yiğitbaş et al., 1998; Elmas and Yiğitbaş, 2001; 2005; Elmas et al., 2011).

Dumanlı village and surrounding areas, where this research was centered, was mapped in detailed fashion by the geological team (Figure 2). The village of Dumanlı is located on the Çamlıca Metamorphics, formed of mainly micaschist, gneiss and calcschist lithologies. On Figure 2 the distribution of this unit in the study area is shown by the brown color. These metamorphic rocks, especially in the north and west sections of the village, contain severely sheared serpentinite slices. On Figure 2 the serpentinite is shown by the green color. The contacts between the serpentinite slices and metamorphic rocks are close to vertical (60-90°) inclined to the northwest or southeast (Figure 3A). Horizontal or close-to-horizontal fault lines have developed on the contact faces (Figure 3B). These observations, together with the outcrop pattern of the serpentinites, show that the contact between the serpentinites and Çamlıca metamorphics formed due to the effect of right-lateral strike slip tectonics.

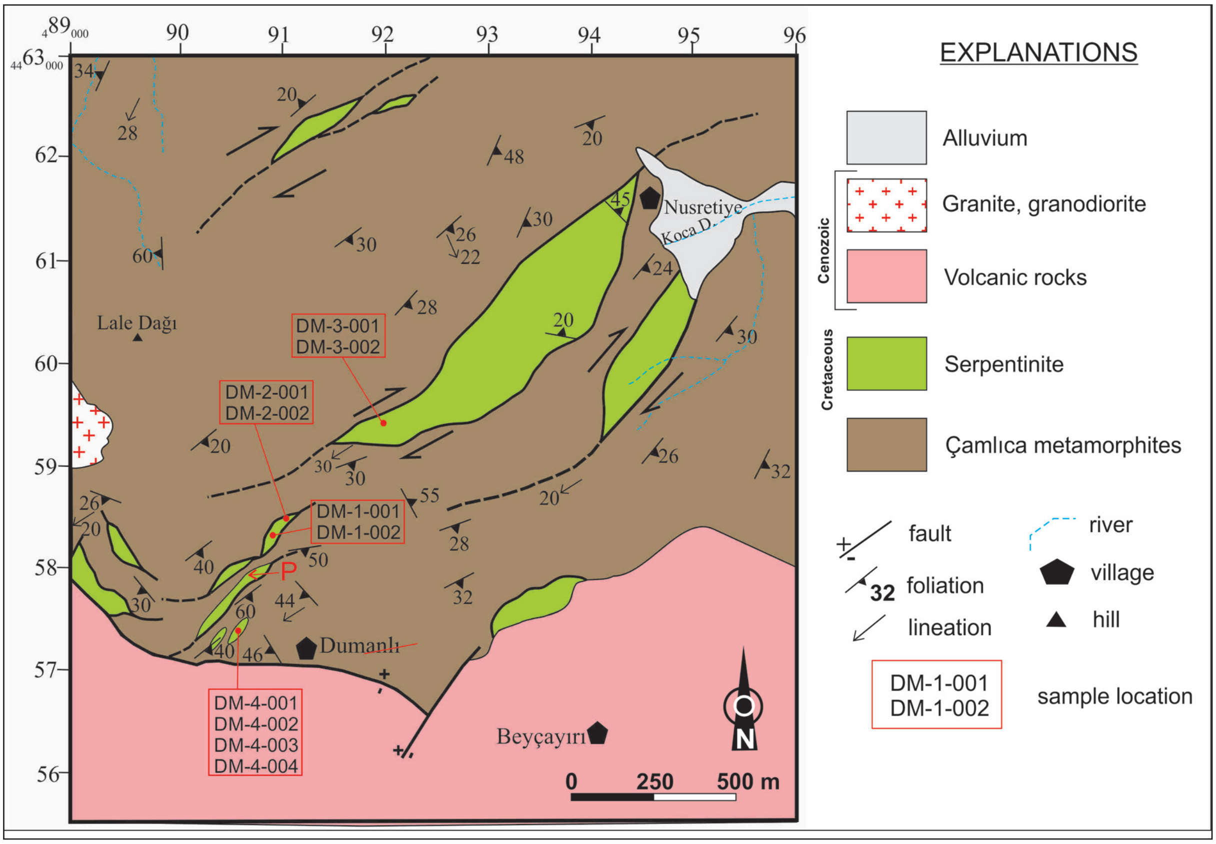

Figure 2- Geological map of Dumanlı village and surroundings. The locations of the photos in Figure 3A and 3B, are shown as “P” on the map.

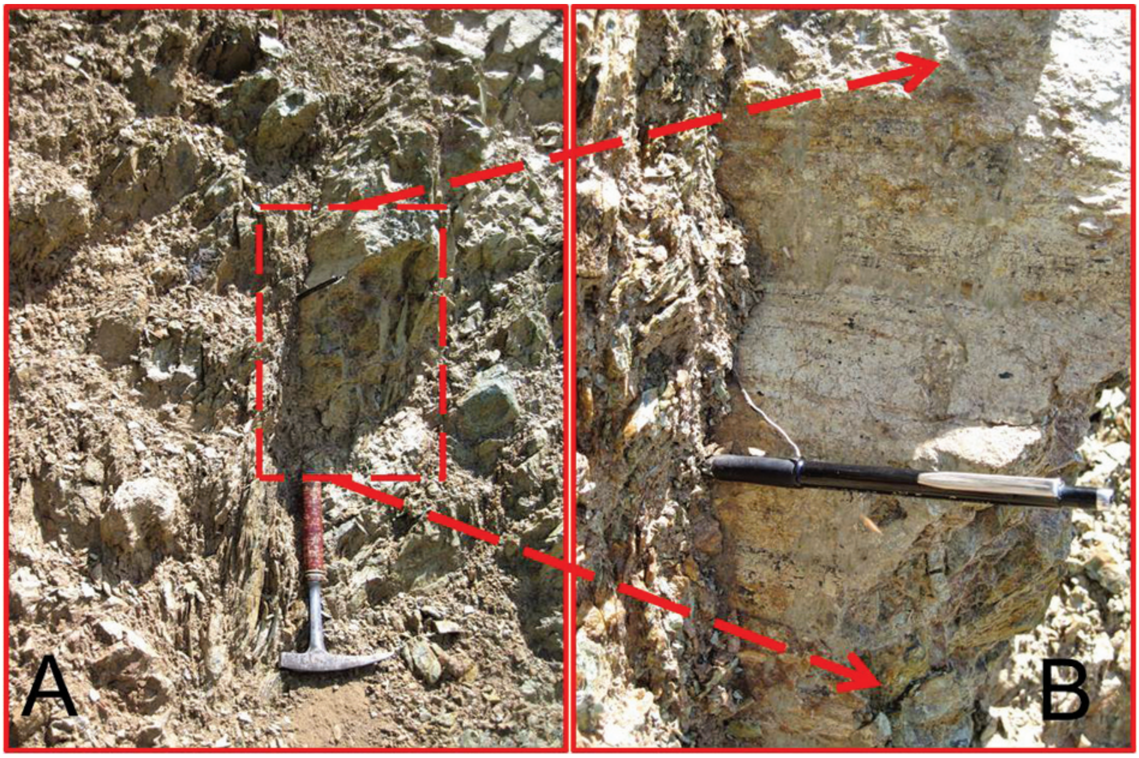

Figure 3- A) Contact relationship between the metamorphic rocks and the serpantinite lenses in the Çamlıca metamorphites. B) Close look to the contact plane.

In the mapping area the foliation in the Çamlıca metamorphics, although inclined at different angles, generally trends NE (Figure 2). The measured lineations have a dip of at most 20-30° southwest. Thus the lineation and foliation data of the metamorphic rocks, together with the contact with the contained serpentinites, show they were shaped by a right-lateral strike slip shear zone with reverse component. The asbestiform minerals developed in cracks and fractures perpendicular to the instant stress direction along the main shear zone, in T-fractures at right angles to the main shear zone in this strike-slip right-lateral shear zone (Figure 4).

In areas close to Dumanlı village there are 4 different locations where the village residents are exposed to asbestos in a variety of ways. These are locations DM-1: Tepecik (Figure 5A), DM-2: Odacıkyanı, DM-3: Kıygınaçığı and DM-4: Değirmenalanı (Figure 5B). Of these, DM-1: Tepecik and DM-4: Değirmenalanı, in particular, contain very well-developed asbestos deposits and are the closed locations to the village. DM-1: Tepecik location is about 1 km to the north of the village, while DM-4: Değirmenyanı location is 750 m west of the village. These locations were observed due to excavations for aims such as roadworks, etc. Due to the region's morphological structure and plant cover it is possible that there are other undiscovered asbestos locations.

Observations in the field have clearly shown the presence of asbestos minerals in serpentinite outcrops surrounding Dumanlı village (Figures 6A and 6B). Easily identified by the naked eye, these minerals were petrographically identified using a polarizing microscope (Figures 6C and 6D).

The presence of asbestos deposits in serpentinite outcrops in Dumanlı village and surrounding area clearly identified in the field and with a polarizing microscope were also analyzed with SEM and XRD. The SEM (Scanning Electron Microscope) and XRD (X-ray Diffractometer) results are illustrated in figures 7A and 7B. The fibrous habit, white crystals

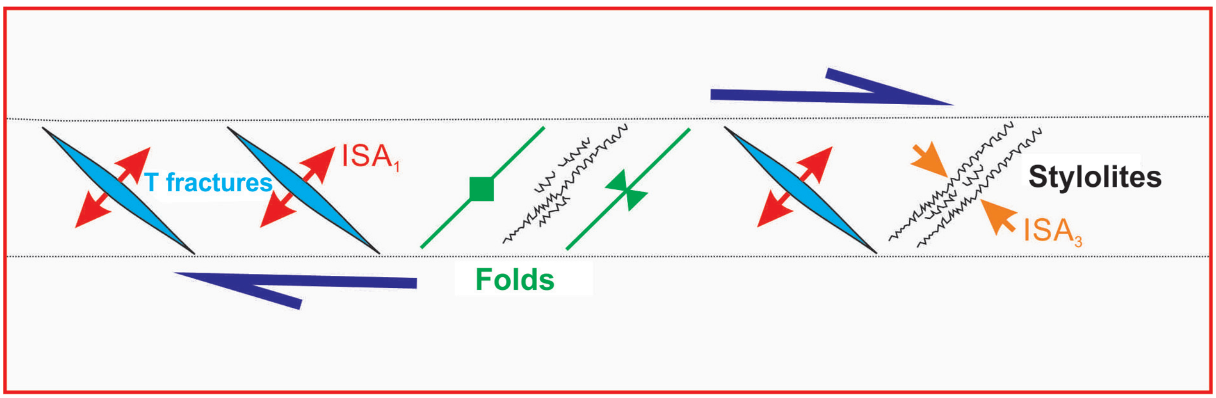

Figure 4- The model showing the T fractures, which bearing asbestiform minerals and some other important small-scale structures in a dextral strike-slip shear zone. ISA: Instanteous Stretching Axes. (For further information please see Fossen 2011).

Figure 5- A) Photos showing the DM-1 Tepecik location, located in the north of Dumanlı village and B) DM-4 Değirmenyanı location, located in the west of Dumanlı village.

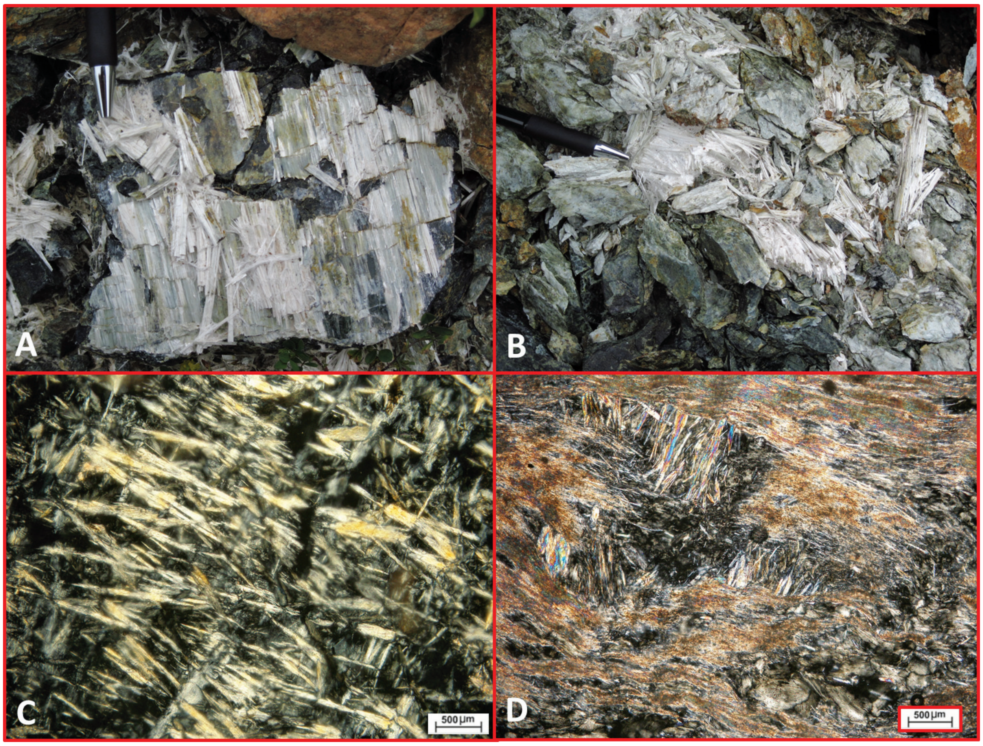

Figure 6- A,B) Asbestos fibers can be seen clearly within the serpentinites in the DM-1 Tepecik location. C,D) Micrograph photos of asbestos-bearing serpentinites, under polarized microscope. Chrysotile-asbestos minerals can be seen clearly in both two micrograph photos.

observed under SEM were determined to be antigorite ($Mg_3Si_2O_5OH_4$), lizardite $(Mg,Al)_3(Si,Fe)_2\ OH_4$ and clinochrysotile ($Mg_3Si_2O_5\ OH_4$) according to XRD results.

In the area near Çamyurt village, where one mesothelioma case was observed in 2011, no serpentinite outcrops were found. The village is located on Cenozoic volcanic-volcaniclastic rocks. As a result, just as Çamyurt village underwent detailed medical scanning similar to Dumanlı village, the volcanic rocks outcropping in the village and surrounding region were sampled and investigated. In four of the samples taken the presence of zeolite was identified under polarizing microscope (Figure 8). These were sent for SEM and XRD analysis to determine the minerals and within the volcanic/volcaniclastic rock samples hoylandite ($CaAl_2Si_7O_{18}H_2O$), Al chabazite ($NaAlSi_4O_{20}$), quartz (SiO_2) and microcline ($KAlSi_3O_8$) minerals were identified, though erionite was not found. However Çamyurt village requires more detailed investigation of both medical scanning and and the region's volcanic rocks, as a significant portion of the houses in Çamyurt village are constructed of this type of rock.

3. Medical Geology

The rocks containing asbestos outcropping at DM-1 and DM-4 locations were severely destroyed due to road works or other human requirements (Figure 5), thus just as the surficial contact of asbestiform minerals with the air increased, the grain/crystal sizes were reduced. Additionally the material taken from these locations were used as aggregate for roads in both Dumanlı village and surrounding villages, thus the asbestos was spread over a much wider area, causing an increase in the exposure area.

In parallel and simultaneous to the earth science studies in the study area a variety of studies were completed by Public Health and Chest Disease experts. At meetings the people of the village were informed and scanning was completed with a mobile microfilm device. Microfilm was taken for 133 people with macrofilm taken for 7 people. After microfilm scanning on 2nd and 3rd visits to the village, verbal autopsy was completed and respiratory function tests were carried out for the adult population. The death information in Dumanlı village between the years 2007 and 2011 was collected by

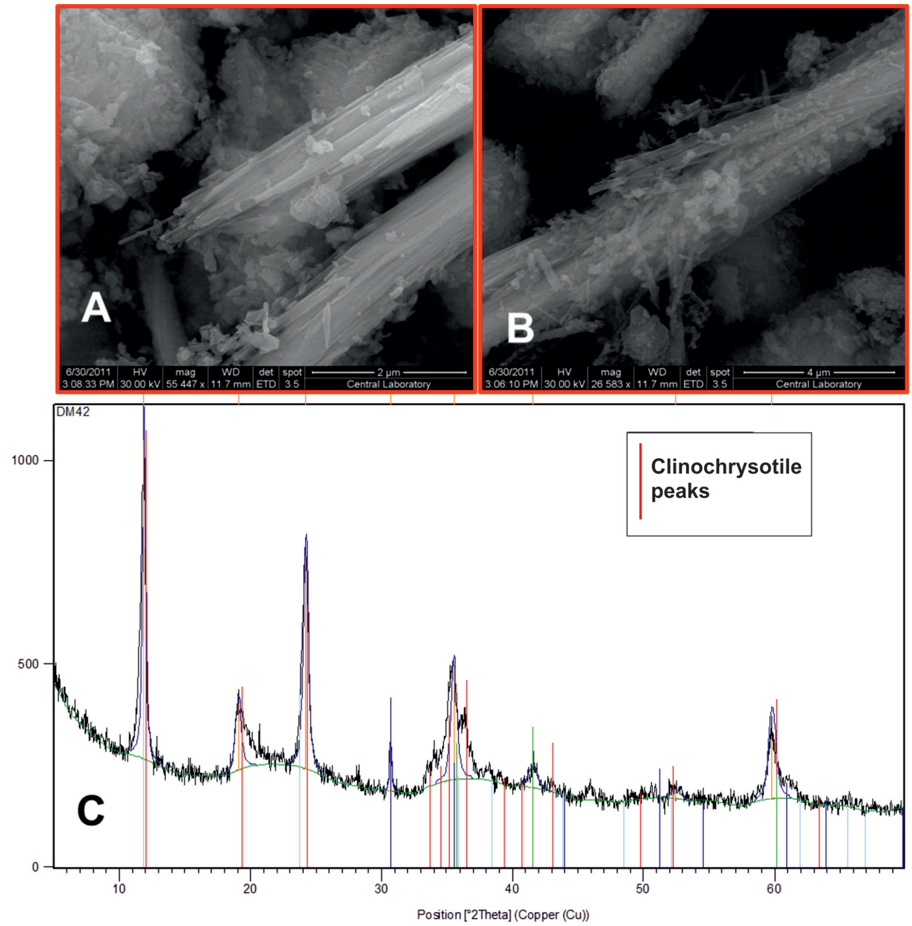

Figure 7- A and B) SEM images are showing the asbestiform crystals in the serpentinite sample. C) Clinochrysotile peaks of serpentinite sample, determined by XRD

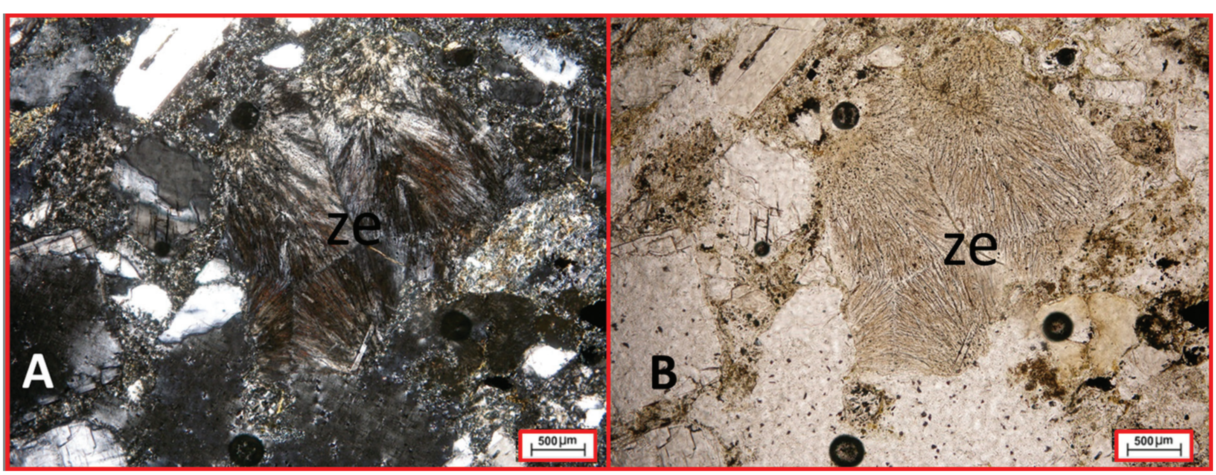

Figure 8- Micrograph photos of zeolite bearing tuffs in Çamyurt village and surroundings. A) Polarized light and B) Natural ligth images. Radial crystal agregas, which are shown as "ze" are most probably zeolite minerals.

verbal autopsy method, by public health expert C. Bakar. The verbal autopsy form, which was developed by The World Health Organization (WHO) and used in the World Health Survey (WHS) and the National Burden of Disease and Cost Effectiveness studies, used to be able to perform the verbal autopsy research (Ministry of Healt of Turkey, 2003). This form consists of mostly close-ended questions. The basic principle is to determine the cause of death based on the current disease before the person's death and their specific symptoms. Thus; sex, place of death and cause of death data of the deaths in the last five years period in Dumanlı village, is given in table 1, as a result of verbal autopsy studies.

The results indicated that the village with population of 216 (116 men and 100 women) had 9 deaths in the previous five years (2007-2011). Two of the deaths were due to lung cancer, one due to larynx cancer and one due to mesothelioma. The other four deaths were linked to other diseases. In 139 people living in the area 30 had pleural calcification, while 4 had pleural thickening. There was a significant correlation between radiological pathology and asbestos exposure found, with exposure duration varying between 23-80 years in these cases.

Table 1- The death data of the last five years (from 2007 to 2011) in Dumanlı village (Çanakkale)

AVERAGE OF AGE	**74,7±10,9 Year**
SEX	**NUMBER OF DEATHS**
Male	6
Female	**3**
PLACE OF DEATH	
At home	5
At Çanakkale Public Hospital	3
Çanakkale Onsekiz Mart University Hospital	1
CAUSE OF DEATH	
Lung cancer	2
Larynx cancer	1
Mesothelioma	1
Gastric cancer	1
Cerebrovascular diseases	1
Alzheimer and hip fracture	1
Myocardial infarction	1
Unknown	1
Total	9

4. Conclusion and Recommendations

a) Surrounding Dumanlı village, linked to Lapseki county in Çanakkale, deposits of asbestiform minerals with varying scales are found. These deposits developed along T fractures during emplacement of serpentinite lenses within Early Paleozoic Çamlıca metamorphics in the region.

b) Serpentinites containing asbestiform crystals have been used and continue to be used widely and without control for a variety of aims. It was possible to determine a positive correlation between radiological pathology and exposure to asbestos. Informing people living in areas determined to be exposed to asbestiform minerals, and those in the study area, of the harm caused by interaction with asbestos may reduce the interaction with asbestos.

c) When the mechanism and geological causes of formation of asbestiform minerals in the Biga Peninsula are investigated, it is strongly possible that other areas may face similar problems. As a result medical problems that may be caused by exposure to asbestiform minerals in the region should be carefully monitored.

d) Exposure still continues. As the material containing asbestiform minerals was used as aggregate for road works, the effective exposure area has expanded and the surface area/grain size rates have increased, increasing the asbestos concentration of exposure. To prevent the increase in effective area and severity due to using material containing asbestiform minerals for road works and similar human needs, local and central government should be informed about the topic.

e) When the geological characteristics of the region are considered in the Biga Peninsula, apart from asbestos, similar research into erionite exposure and the effects of this exposure on human and environmental health are necessary.

The types, physical and chemical characteristics of the asbestiform minerals exposed in the region should be determined in detail and compared with the type, physical and chemical characteristics of fibers in lung tissue of people who become sick as a result of asbestos exposure.

Acknowledgement

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