UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A RECONNAISSANCE STUDY OF THE ASSOCIATION OF ZEOLITES WITH MESOTHELIOMA OCCURRENCES IN CENTRAL TURKEY

based on a report to the U.S. Geological Survey

by

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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INTRODUCTION

Recent findings by medical workers on the association of certain zeolite minerals with the high incidence of pleural mesothelioma in two small Turkish villages have caused considerable excitement both in medical circles and in the synthetic and natural zeolite businesses. The 42 cases diagnosed between 1970 and 1977 in one community of 600 population in a region of altered volcanic tuff represent a virtual epidemic of this rare type of lung cancer which normally strikes only about one person in a million. Cancer workers around the world expect that detailed environmental and epidemiological studies of the disease in these areas will shed considerable light on the cause of this particularly lethal form of malignant disease. Scientists and engineers developing uses for zeolite materials in industrial and agricultural technology, however, are justly concerned that the preliminary results currently available on this situation will be used by environmental organizations and regulatory agencies to label an entire group of minerals as carcinogens on the basis of what is little more than circumstantial evidence.

Although there is no question as to the large number of cases of mesothelioma in these areas of central Anatolia, the work to date suffers from a lack of sound geological and mineralogical input. Ataman (1978) in a brief note states that a "correlation" exists between mesothelioma and zeolites in this region. The geological data needed to document a direct relationship between the presence of zeolites in the volcanic tuffs surrounding the villages in question and the rate of malignant lung disease in the inhabitants have not been obtained, nor has evidence that suggests a cause-effect relationship between zeolites and cancer been reported.

To provide fundamental information on the distribution of zeolite minerals in areas of central Turkey where high incidences of pleural mesothelima have been reported and to evaluate from first-hand knowledge the incomplete data in the published reports and news releases of medical workers engaged assessing the problem, the following reconnaissance investigation was made.

HISTORICAL BACKGROUND

The Cappadocia region of central Turkey has long been recognized as an area of outstanding scenic and cultural value (see Figures 1-3). Centered around Nevşehir (Figure 4), about 250 km southeast of Ankara, and bounded by the city of Kayseri on the east and saline Tuz Gölü on the west, the region abounds with incised valleys which have been cut into plateaus of soft, volcanic tuff spewn out during Neogene times by the predecessors of the inactive volcanoes Erciyes Daği (Mt. Argaeus (3917 m), the second highest peak in Asia Minor) and Melendiz Daği. In a high plateau area (elevation = 1000-1300 m), wind and running water have produced a "badlands" topography containing a myriad of multicolored cones and columns of all sizes and shapes, commonly capped by resistant conglomeratic blocks or more highly cemented layers of tuff. The beauty of Göreme Valley, in the heart of the region, is on a par with many of our own National Parks and Monuments (Figure 1).

It is these same cones and columns that gave refuge between the 4th and 14th centuries to communities of early Christians who hewed the tuff into lightweight dimension stone and who carved dwellings and worship chambers into the soft rock itself. More than 300 monastic caves have been found cut into the cones, their walls and ceilings embellished with religious art ranging from simple crosses and geometrical figures to intricately designed frescoes of the Byzantine era (Figure 2). For a thousand years a Christian civilization prospered in Cappadocia, becoming troglodytic during times of Roman persecution and Arab border raids, but emerging to live in harmony with the Seljuk Turks who settled in the area in the 11th century. The population exchanges between

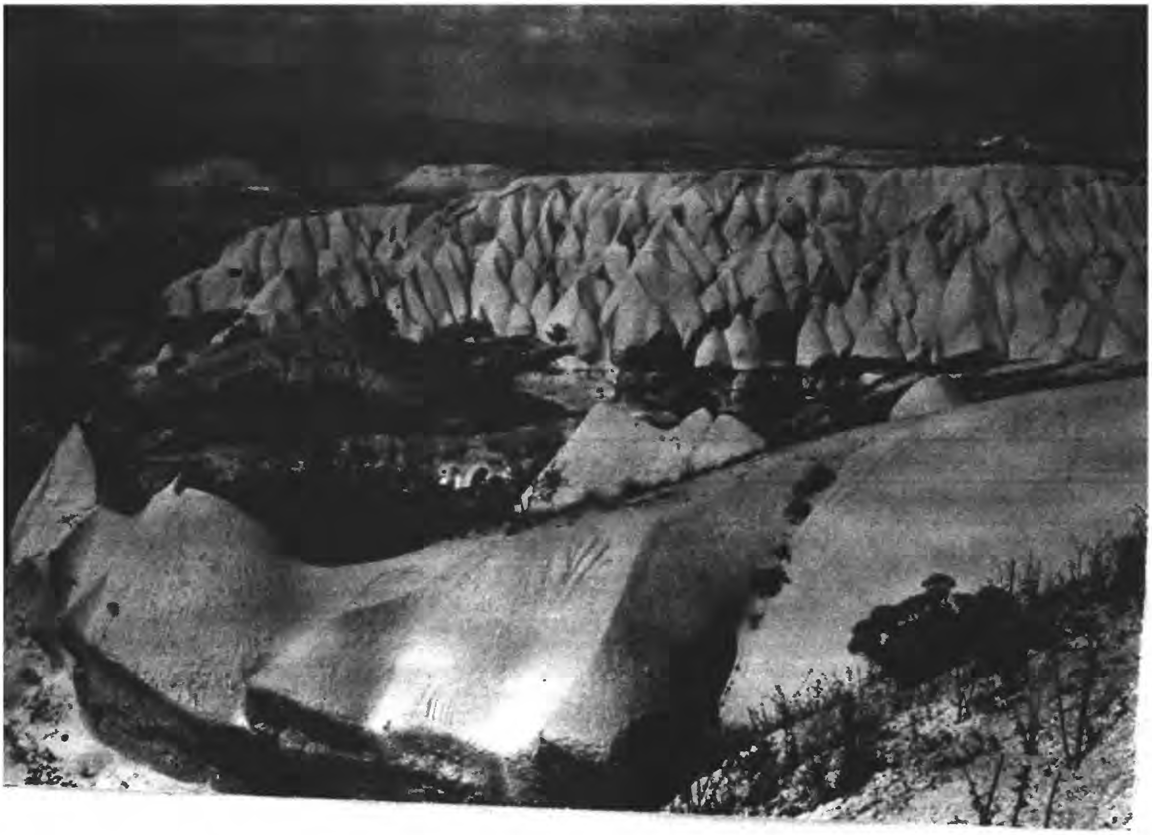

Figure 1. Scalloped mounds of Neogene tuff near Üçhisar, at the head of Göreme Valley, 15 km east of Nevşehir, Turkey.

Figure 2. "Fairy chimneys" of Neogene tuff near Üçhisar, at the head of Göreme Valley. Note the numerous caves cut into the soft, friable tuff.

Greece and Turkey in 1924 greatly diminished the Christian community, and most of the underground chapels were abandoned. Many, however, were set aside by the Turkish government as archeological antiquities or as cultural attractions, and a flourishing tourist trade exists today in the area. Dozens of Islamic villages are still present amidst the mounds and "fairy chimneys" of tuff, and the people live a simple agricultural life. Although the original caves are now used for food storage and for housing livestock, almost all of the freestanding public buildings and private dwellings in the villages are constructed of blocks of the soft, indigenous volcanic tuff (Figure 3).

Reports of Mesothelioma

In the middle 1970s, reports began to emerge concerning the environmental health of residents of several of the small peasant villages in Cappadocia. Professor Y. I. Bariş (Chairman, Department of Chest Diseases, Hacettepe University, Ankara) noted an extremely high incidence of malignant pleural mesothelioma in the village of Karain, about 25 km east of Nevşehir (Figure 4 (Bariş, 1975; Bariş and others, 1975; Bariş and others, 1976). From a population which fell from about 800 in 1970 to 600 in 1977, 42 cases of this disease were diagnosed. In a second village, Tuzköy, about 25 km northwest of Nevşehir, 7 cases were found in a population of about 2900. In addition, numerous residents of these two villages suffer from fibrous pleuritis, a lung condition similar to silicosis. Undiagnosed mesothelioma has apparently been common in these villages for several hundred years, and Bariş and others (1976) quoted a local saying that "The peasant of Karain falls ill with pain in his chest and belly, his

Figure 3. Freestanding dwellings constructed of indigenous tuff amidst mounds and "fairy chimneys" of Neogene tuff in Üçhisar. Note the numerous caves cut into the more resistant portions of the tuff.

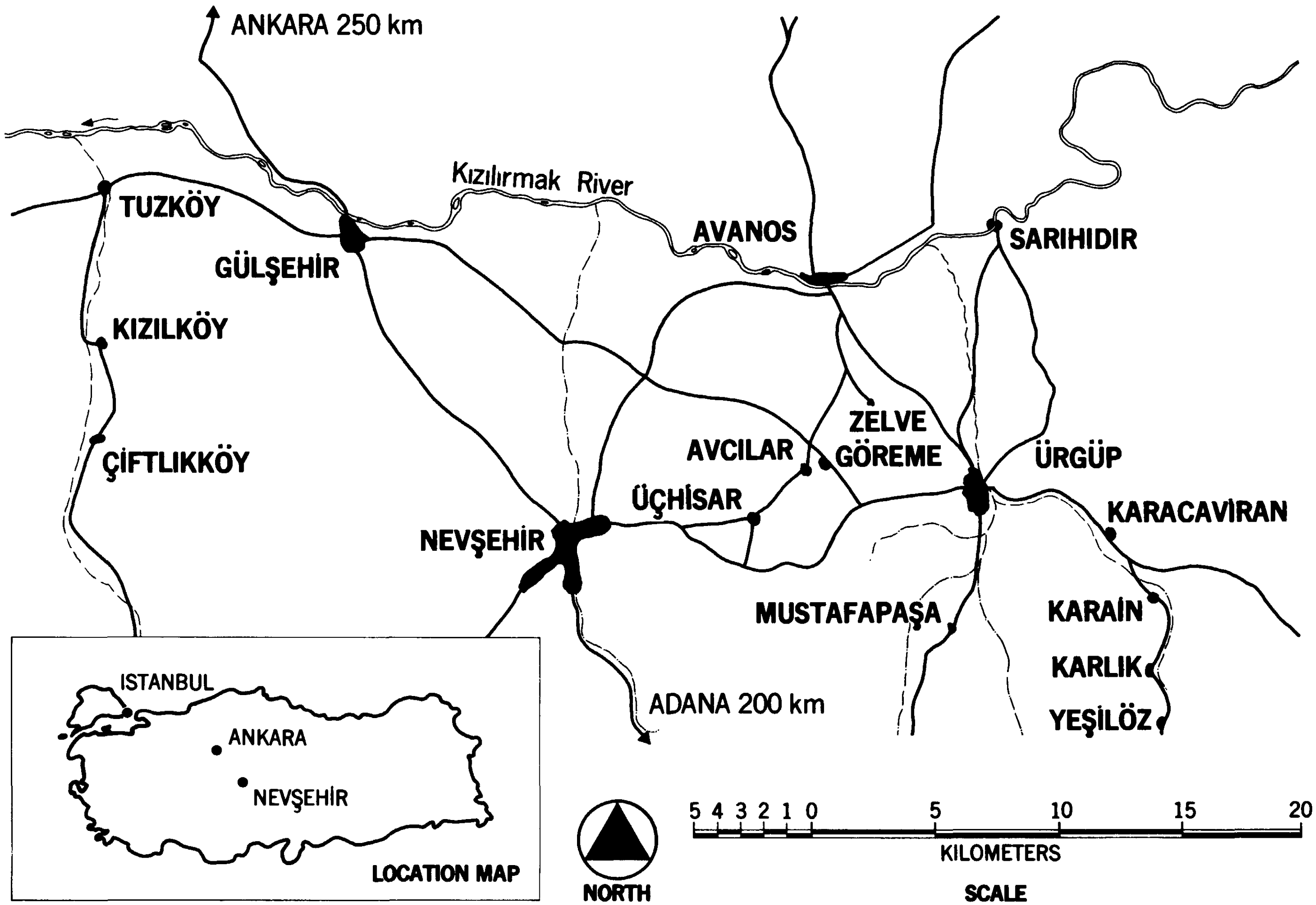

Figure 4. Map of the Cappadocia region between Karain and Tuzköy, central Turkey.

shoulder drops, and he dies."[1]

Pleural mesothelioma is a relatively rare form of lung cancer in which thick layers of malignant tumor form on the outer lining of the lung. It is particularly painful and almost invariably results in death within a few months of diagnosis. Between 1959 and 1977, 4,359 cases of this disease were diagnosed worldwide, a rate of approximately 0.03 to 0.06% in the general population (McDonald and McDonald, 1977). The McDonalds also noted that approximately 62% of all cases of mesothelioma can be associated with a definite or probable exposure to asbestos materials, either occupational or environmental, although 10% of these exposures were not verified in the original studies or were of the single-incident type. Exposure to crocidolite or amosite appears to be more closely connected with the disease than exposure to chrysotile (McDonald and McDonald, 1977; Ross, 1978), and the mesothelioma rate among shipyard workers who used these materials extensively during World War II is significantly higher than that of other asbestos workers as well as that of the general population. Similar high incidences of mesothelioma have been reported for crocidolite miners in northwest Cape Province of South Africa (Wagner and others, 1960) and in Western Australia (McNulty, 1962). None, however, approach the rates reported by Bariş and his coworkers.

According to P. C. Elmes (Director, Medical Research Council Pheumoconiosis

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[1]Bariş has also stated in private talks and at scientific meetings that the name of the village itself means "pain in the belly", from the Turkish words *karin* and *agrisi* (meaning *pain* and *abdomen*). This is unlikely, and a more realistic origin of the village name is from *kara* (*black* or *dark*) and *in* (*cave*). Another Karain near the Mediterranean seaport of Antalya is famous for archeological finds of the Paleolithic period. Most of these discoveries have been a dark, limestone cave, hence the "black-cave" origin of the name.

Unit, Llandough Hospital, Cardiff, Wales), (personal communication) the size and shape of the asbestos particle are critical in its ability to cause lung cancer and mesothelioma. He suggests that unlike the equidimensional particles of respirable size (0.2 to 3 μm), which are engulfed by macrophagocytic cells in the alveoli and eventually removed from the lung, elongate particles with equivalent spherical diameters in this range become trapped in the alveoli region. Their length prevents them from being taken up by the macrophages, and therefore they remain imbedded in the lung walls. Here they cause scarring and, according to Elmes, "...are associated with a considerable increase in primary lung cancer." Straight, stiff fibers, about 0.2 μm in diameter and 5 to 10 μm in length, apparently migrate through the lung wall into the pleural space. On the basis of intrapleural injection experiments with rats (e.g., Wagner and others, 1973; Stanton and Layard, 1978) Elmes suggests that fibers other than asbestos could also trigger pleural mesothelioma if they are of the right dimensions.

Bariş (1975; Bariş and others, 1975; Bariş and others, 1976) reported that in both of the Cappadocian villages the disease affects men and women equally, usually during middle age or somewhat later in life. Smoking habits appear to have no effect on the probability of developing the disease, as the men smoke and the women do not. All patients from Karain had a family history of mesothelioma and/or neoplastic disease, and the disease appears to be "...familial but not due to a genetic defect" (Bariş, 1975, p. 178), although this last statement is not well documented. In this part of Turkey, there is almost no migration from one village to another; some of the youth may leave the village for the city, but few return. All of Bariş' patients were peasant farmers who had either lived their entire lives in these two villages or who had been born and raised there. Only one patient who had not been born in either of the two villates contracted the disease; however, this woman had moved to Karain when she married and lived there for 35 years afterward. Of great significance is the fact that no cases of mesothelioma have been diagnosed in any other village in the region, including several as close as 3 and 4 km distant. (Bariş, oral communicatic

On the basis of numerous "fibers" found in the ashed lung tissue of one patient from Karain (obtained by needle biopsy) Bariş suggested that asbestos was here also the cause of the mesothelioma in the two villages. However, there are no asbestos mines or mills in the region, and there appears to be no unusually high usage of asbestos products by the inhabitants. Lacking evidence of occupational exposure to asbestos materials, Bariş attempted to link the high incidence of the disease with what he described as "asbestos" fibers found in the drinking water of Karain, presumeably carried there by streams from unspecified, distant sources. The geology and drainage pattern of the region, however, argue against this possibility. In 1977, he brought his findings to the attention of the International Union Against Cancer (IUAC) in Geneva, and in October of that year, a team consisting of P. C. Elmes, J. Milne (IUAC), and I. Thornton (Imperial College, London) visited the Cappadocia region, examining patients and collecting samples of road dust, building blocks, and other natural products used by the inhabitants of the villages (see Elmes, 1977; Milne, 1977). The mesothelioma diagnoses of Bariş were subsequently confirmed histologically in Great Britain, and the rock and dust samples were examined there by optical and electron microscopy.

Analytical transmission electron microscopy of two samples from Tuzköy by F. D. Pooley (Department of Mineral Exploitation, University College, Cardiff, Wales) revealed an abundance of "fine fibers" less than 0.25 µm in diameter and up to 5 µm in length. The fibers were shown to have an elemental composition close to that of the zeolite mineral, erionite. Cursory X-ray powder diffraction of the two samples suggested the presence of another zeolite, chabazite. All Tuzköy samples collected by Elmes and Milne team contained both erionite and chabazite, as well as "fibrous volcanic glass" consisting of "very fine needles" (Elmes, 1977, p. 11, 13). Erionite needles were detected in a road dust sample from Karain (Pooley, 1978); however, no zeolites were identified in any of the samples collected from the control (non-mesothelioma) villages of Kizilköy and Yeşilöz (see Figure 4).

Public Announcement of the Problem

At a December 1977 meeting of the Society for Occupational and Environmental Health, held in Washington, D.C., the preliminary findings of the IUAC investigation were presented orally by J. C. Wagner (Llandough Hospital, Cardiff, Wales) and F. D. Pooley. On the basis of the morphological similarity of the erionite in samples from Karain and Tuzköy with crocidolite and other asbestos minerals, Wagner and Pooley pointed out that this needle-shaped zeolite could well be the cause of mesothelioma in the two Turkish villages. Wagner invoked Baris' "pain-in-the-belly" derivation of the name Karain, and implied that zeolites should now be considered as possible carcinogens along with asbestos minerals. The data presented were extremely preliminary and contained no information about the overall distribution of zeolite minerals in the hundreds of neighboring villages where mesothelioma had not been reported, some in the same geological formations as Karain and Tuzköy. This, however, did not prevent many of the health workers in the audience from federal regulatory agencies from placing the zeolite group of minerals on their "lists" of suspected carcinogens.

It was obvious that Pooley and others involved in the investigation were generally unfamiliar with the zeolite group of minerals, which numbers about 40 natural species and more than 60 synthetic analogues, and of their distribution in volcanogenic sedimentary rocks. Additional information was requested of Pooley and Bariş, and in late January 1978, two small fragments of Tuzköy building block were received by the author from Wales. X-ray powder diffraction and optical microscopy quickly confirmed the presence of zeolites in these samples. Both were found to consist of major quantities of unaltered volcanic glass in a groundmass of micrometer-size chabazite. Substantial quantities of pyrogenic quartz and feldspar were also noted, along with traces of calcite, erionite, and cristobalite(?). The volcanic glass occurs as frothy aggregates, 0.1 to 5 μm in size, which readily collapse into elongate shards and needles (see p. 11). Scanning electron micrographs obtained by A. J. Gude, 3rd (U.S. Geological Survey, Denver, Colorado) (Figures 5 and 6) illustrate the elongate habit of the erionite, with needles 0.5 to 1.5 μm in diameter and up to 50 μm in length being present, associated with rhombs of chabazite 5 to 20 μm in size.

Summary of the Problem

As of the end of January 1978, the available information indicated that zeolite minerals are indeed present in the volcanic tuffs surrounding the mesothelioma villages of Karain and Tuzköy, and that needle-shaped erionite is in all likelihood to be found in the airborne dusts of the village streets and inside of dwellings constructed of the indigenous tuff. The presence or absence of similar assemblages of zeolite minerals in other Cappadocian villages in the same geological environment, but where mesothelioma had not been found, however,

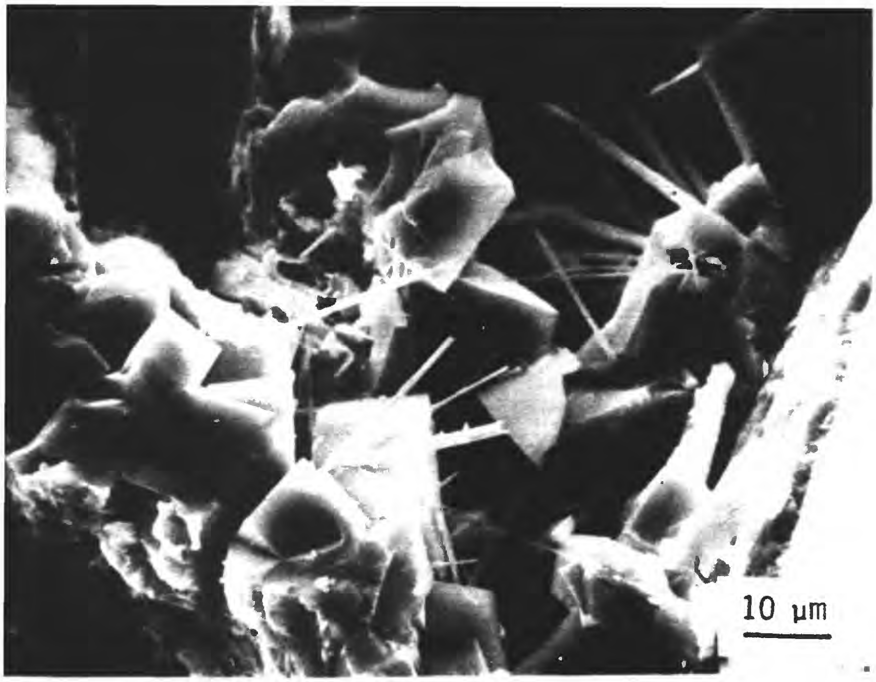

Figure 5. Scanning electron micrograph of erionite and chabazite in Neogene tuff from Tuzköy, Turkey.

Figure 6. Scanning electron micrograph of chabazite rhombs and erionite needles in Neogene tuff from Tuzköy, Turkey. Note the hexagonal cross section of the erionite rod in the upper center of the field.

was still unknown, and apparently was not considered by those engaged in the investigation to be a high priority issue. Despite requests for details, little information could be obtained on whether or not the IUAC team or the Bariş group planned to carry out a more detailed geological analysis of the situation.

Although preliminary in nature, the results of Bariş and others in Turkey and the announcements of Pooley and Wagner cast a shadow across the entire group of zeolite minerals on the basis of the elongate shape of erionite, one of its members. Within one month of the December 1977 S.O.E.H. meeting, this author was questioned by health workers from the United States and Canada as to the location and abundance of zeolite mines and deposits in North America. The questioners were obviously gathering data on which to build a case for the carcinogenicity of zeolites. No distinction was made as to the exact species of zeolite that might be found in any one area -- the entire group was suspect. It became apparent that the future of the established molecular sieve business and the fledgling natural zeolite business could easily become maligned by the premature interpretations that were being presented to the medical community and to the press. The problem of a misinformed press is illustrated in the article published in the May 18, 1978, issue of New Scientist (Appendix 1), where the preliminary and equivocal data discussed above were pieced together to form an uncritical and oversimplified exposition of the problem.

It also became apparent that reliable information on the areal distribution of zeolite minerals in the volcanic tuffs and the coincidence of pleural mesothelioma in peasant villages of Cappadocia was badly needed. The absence of mineralogical or geological researchers familiar with the complexities of occurrence and properties of zeolites from such sedimentary environments meant that the IUAC team would not be able to obtain these data; certainly not to the satisfaction of the engineers and scientists in the zeolite field. The present reconnaissance study was therefore proposed as a means of obtaining first-hand information on the zeolite content of bedrock, building blocks, road dusts, soils, etc. from both mesothelioma and non-mesothelioma villages in the Cappadocia region of central Anatolia, and of providing a small amount of specialized geological input into the overall investigation.

FIELD EXAMINATION OF CAPPADOCIAN TUFFS

In June 1978 a visit was made to Ankara and the Cappadocia region of central Turkey to discuss the overall investigation directly with Professor Bariş at Hacettepe University and to collect samples of lithic materials from mesothelioma and non-mesothelioma villages in the vicinity of Karain and Tuzköy. The author was accompanied by Dr. R. A. Sheppard (U.S. Geological Survey, Denver, Colorado) and locally by Dr. Oguz Arda, a mineralogist with Maden Tetkik ve Arama Enstitüsü (M.T.A.), Turkey's Mineral Research and Exploration Institute. Dr. Arda also accompanied the Elmes-Milne-Thornton team during their October 1977 visit to the area. Financial support of the project was obtained from the National Science Foundation (EAR 7813183), the U.S. Geological Survey (P.O. 24034), and the National Geographic Society.

Discussions in Ankara

A meeting was held on June 5 at Hacettepe University Hospital where Professor Bariş openly presented all of his medical and epidemiological data, both published and unpublished. The discussions were profitable and provided the geologists present with much needed insight into the biological and sociological problems of the situation. Bariş displayed an electron micrograph of a fiber which was embedded in a section of malignant tumor that had been removed from a mesothelioma victim. The fiber had been identified by Pooley (presumably by selected area electron diffraction) as erionite. Bariş used this finding to support his conviction that needle-shaped zeolites in Karain and Tuzköy are the cause of the rampant mesothelioma in the two villages.

Discussions with Professor Guröl Ataman, Vice Rector of Hacettepe University and former chairman of the Department of Geology, were less fruitful. Dr. Ataman indicated that he had carried out a preliminary investigation of the geology of the Karain and Tuzköy areas, after having been alerted to the situation by Bariş, and had identified the zeolites erionite, chabazite, clinoptilolite, and mordenite in the tuffs. He said that no zeolites had been found in the non-mesothelioma villages, but did not present details of his investigation. Although he suggested that a thorough study had already been made of the distribution of zeolites in the region, he provided no data to support this statement.

Dr. Sadrettin Alpan, Director of M.T.A.[2], was extremely cordial and cooperative and provided the party not only with the services of Dr. Arda, but also an M.T.A. vehicle and driver for the visit to Cappadocia. Alpan expressed his desire that detailed geological analysis of the Karain-Tuzköy region be made an integral part of the overall investigation so that unsubstantiated circumstantial evidence is not used to thwart what may become an important industrial mineral commodity in Turkey.

Geological Setting

The Cappadocia region between Karain and Tuzköy (Figure 4) is underlain by about 1000 to 1500 m of interbedded volcanic rocks and lacustrine and fluviatile rocks of Neogene age (Ketin, 1963). The volcanic rocks are latitic,

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[2]The current director of M.T.A. is Dr. Nezihi Canitez.

dacitic, andesitic, and basaltic in composition and consist mainly of flows, air-fall tuffs, and ash-flow tuffs (Brinkmann, 1976). Some of the ash-flow tuffs are moderately welded, but most are only loosely consolidated and consist of varying amounts of pyrogenic quartz, feldspar, and mafic minerals in a matirx of volcanic glass that has partly or completely changed to montmorillonite, cristobalite/tridymite (opal C/T), and, locally, zeolites. Fresh glass, however, in the form of pumice fragments up to several centimeters in size, is common in many of these rocks and is accompanied by quartz and feldspar, finer ash, and alteration products. The interbedded non-volcanoclastic sedimentary rocks are dolomitic carbonate, diatomite, chert, tuffaceous mudstone, and water-laid tuff, some of which have been completely transformed to montmorillonite, zeolites, or in some areas, a mixture of quartz and kaolinite. The "fairy chimney" cones and columns described above are located within tuff units that are as much as 100 m thick. The lithologies of the more erosion-resistant cones and columns and the softer, friable tuff adjacent to them are similar, although the latter rocks contain somewhat less montmorillonite and other alteration products that may act as cementing agents.

The reconnaissance nature of the visit to the area precluded a detailed stratigraphic study, but the following brief description of the rocks may provide a general framework for future study. The oldest unit examined herein designated as Unit C is well exposed in the bottom of Göreme Valley near the village of Avcilar. It consists of 50-60 m of brown to pinkish-brown, non-welded ash-flow tuffs and reworked tuffs. Stratification is common in the reworked portions of the unit, and the ash-flow tuffs show well-developed "fairy chimneys", particularly in the upper part of the unit. Overlying these strata is Unit B which is approximately 100 m thick and which consists of a lower pink and white tuffaceous zone that is succeeded upward by a massive, pink-to-brown, non-welded ash-flow tuff. The lower pink and white zone erodes easily compared to the overlying ash-flow tuff which commonly has well-developed "fairy chimneys" in its upper part. Although the "fairy chimneys" are much more prevalent in certain tuff units than in others, they appear to be present throughout both Unit C and Unit B. Locally, dark-brown, erosion-resistant conglomerates channel into the softer members of the units. The upper (and "fairy-chimney"-rich) portion of Unit B is well exposed in the villages of Karain, Zelve, and Karacaviran (see Figure 4 for locations).

Unit A overlying Unit B is a relatively thick (about 350 m) sequence of thin bedded, white-to-pale-gray, chiefly lacustrine beds. Although Unit A contains a distinctive, brown, non-welded ash-flow tuff in the upper part, it consists largely of carbonate rocks, thin air-fall tuffs, reworked tuffs, tuffaceous mudstones, diatomites, and minor cherts. Unit A is overlain by a gray, welded ash-flow tuff about 30 m thick. This unit is well exposed near the villages of Karain, Karlik, and Yeşilöz and north of Zelve in Göreme Valley. (See also, Figure 13).

Utilization of the Tuff

As discussed above, most of the caves that had been cut into "fairy chimneys" and tuffs of the region are currently uninhabited, serving only as storage bins for fruits and vegetables and as stables for goats and other domestic animals. The soft tuff is used extensively as crude, inexpensive dimension stone in buildings, walls, and fences in almost all of the villages. Commonly, a cellar or ground-level room has been excavated into the tuff and an upper story built on it from the rough-cut blocks of the tuff quarried at the site or from a communal pit at the edge of the village. It is not unusual to find house fronts that have been built onto older caves (Figure 7). In the Tuzköy region, where "fairy chimneys" are absent, blocks of local basalt are used in the

Figure 7. House fronts built onto caves in Ürgüp, Turkey. Note the extensive use of indigenous tuff as dimension stone in construction.

Figure 8. Typical street scene in Tuzköy, Turkey. Note the extensive use of blocks of local tuff in the construction of walls and buildings.

foundations or the first floors of buildings, with upper levels making use of the lighter weight blocks of tuff.

The tuffs crop out extensively in the villages, and unpaved streets and paths rest directly on the soft bedrock. The exteriors of buildings and walls are not evenly faced or covered, and the friable tuff crumbles readily with ordinary use. Interior walls, however, are commonly plastered with a greyish white substance known as "white stucco" which, according to Bariş and others (1976), is obtained from the soil of the surrounding hills. A similar material is employed in the deacidification and filtering of fruit juices in the preparation of "Pekmez", a candy consumed in great quantities by all of the inhabitants. This same soft, white "soil" is used also by the villagers as a talcum powder for young children. Although the mineralogical nature of these materials has not yet been determined, they likely represent soft, light-colored, homogeneous portions of the indigenous tuff. In other parts of Turkey, however, such materials have been found to contain tremolite, a mineral thought by many to be a possible cause of similar lung diseases. Further efforts will be made in May 1979 to obtain samples of such materials.

Sample Collection and Examination

Eighty-one samples of bedrock, quarry products, and local building blocks were collected from 15 towns and villages and 5 field locations within a 25-km radius of Nevşehir. Wherever possible, both bedrock and dimension stone samples were collected from villages, the latter by chipping small fragments from loosely stacked blocks used in walls and dwellings. Care was taken to avoid patches of mortar holding some of the blocks together; however, this was not entirely successful (e.g., samples 26-55-9 from Karain and 26-55-29 from Karaciviran, Table 1). Although the exact location of each sample is not critical in a reconnaissance study of this kind, an attempt was made to record the dwelling number and street address of all sample sites within villages. In addition

TABLE 1. X-ray powder diffraction identification of Turkish tuff samples.

N.B. No.	Town/Village	Locality/Description[2]	Minerals detected[1] Ash	Mont	Qtz	K-spar	Crist	Ill	Cal	Co	Ch	Er	Other
26-55-2	Üçnisar	Pumice bed along road leading to Göreme Valley. Mainly fresh glass.	M	-	-	-	-	-	-	-	-	-	-
-2-1		Sink (68%)	M	-	-	-	-	-	-	-	-	-	-
-2-2		Mids (15%)	M	-	-	-	-	-	-	-	-	-	-
-2-3		Float (26%)	M	-	-	-	-	-	-	-	-	-	-
		(All products are essentially amorphous to x-rays; no reflections of any kind are present in the x-ray powder diffraction pattern.)											
26-55-3	Zelve	Principal pink tuff unit into which most caves are cut. Lightweight, pumiceous unit.	M	s	s	tr	tr	-	-	-	-	-	-
-3-1		Sink (53%)	M	s	s	tr	tr	tr	-	-	-	-	-
-3-2		Mids (30%)	s	M	t?	tr	tr	-	-	-	-	-	
-3-3		Float (16%)	s?	M	tr	tr	tr?	-	-	-	-	-	-
		(A definite concentration of montmorillonite and a depletion of ash, quartz, and feldspar in the finer fractions.)											
26-55-4	Zelve	Dimension stone used in wall at entrance to Zelve city. Lightweight altered tuff.	-	-	M	tr	-	-	-	-	-	-	Kaolinite
		(Probably is not indigenous to the Zelve area; resembles principal building blocks used in major towns of region; probably quarried near Nevşehir.)											
26-55-5	Ürgüp	White pumice in quarry along road between Avanos and Ürgüp. Slight alteration of pumice.	M	-	tr	tr	tr	-	-	-	-	-	-
-5-1		Sink (61%)	M	-	tr	tr	-	-	-	-	-	-	-
-5-2		Mids (22%)	M	-	-	-	-	tr?	-	-	-	-	-
-5-3		Float (17%)	M	-	-	-	-	-	-	-	-	-	-
		(Only minor silicate impurities in an otherwise pure glass.)											
26-55-6	Ürgüp	Banded, lightweight tuff used as dimension stone in buildings in Ürgüp, but quarried near Nevşehir.	-	-	M	-	-	-	-	-	-	-	Kaolinite
		(Principal dimension stone used in most village of region.)											
26-55-7	Karain	"Fairy chimney" tuff immediately above highest structure in village. Fresh pumice in altered, ashy matrix.	M	M	-	tr	tr	tr?	-	-	-	-	-
-7-1		Sink (57%)	M	-	tr	tr	tr	-	-	-	-	-	-
-7-2		Mids (22%)	M	s	-	tr	tr?	s	-	-	-	-	-
-7-3		Float (21%)	-	M	-	tr	-	tr	-	-	-	-	-
		(Definite concentration of montmorillonite and depletion of ash, quartz, and feldspar in finer fractions.)											
26-55-8	Karain	Building block close to locality of 26-55-7, with 1/2" pumice fragments. Contains some fibrous glass.	M	s	tr?	tr	tr	tr	-	-	-	-	-
-8-1		Sink (75%)	M	tr	tr?	tr	tr	-	-	-	-	-	-
-8-2		Mids (25%)	M	s	tr?	-	tr	tr	-	-	-	-	-
-8-3		Float (.2%)	-	M	-	-	-	-	-	-	-	tr?	-
		(Definite concentration of montmorillonite and depletion of ash, quartz, and feldspar in finer fractions.)											
26-55-9	Karain	Building block at address #401; similar to 26-55-8, but less pumice.	-	-	-	M	M	tr	-	-	-	-	Plagioclase
-9-1		Sink (63%)	-	-	-	M	M	tr	-	-	-	-	Plagioclase
-9-2		Mids (21%)	-	-	-	M	M	tr	-	-	-	-	s. Plagioclase?
-9-3		Float (16%)	-	-	-	M	M	-	-	-	-	-	s. Plagioclase? + tr. Gypsum
		(Gypsum? in float product may originate in mortar used in construction.)											
26-55-10	Karain	Building block at address #425. Contains visible phenocrystals of vitreous silicates. Similar to 26-55-9.	-	-	-	M	M	tr	-	-	-	-	Plagioclase
-10-1		Sink (44%)	-	-	-	M	M	s	-	-	-	-	Plagioclase
-10-2		Mids (38%)	-	-	-	M	M	tr	-	-	-	-	s. Plagioclase?
-10-3		Float (18%)	-	-	-	M	M	tr	-	-	-	-	s. Plagioclase?
		(Illite in 25-55-1 is characterized by a relatively sharp reflection at 9.9° 2θ.											
26-55-11	Karain	Building block at address #388. Similar to 26-55-10. Lowest level in village.	-	-	tr	M	M	tr	-	-	-	-	s. Plagioclase?
-11-1		Sink (47%)	-	-	s	M	M	tr	-	-	-	-	s. Plagioclase? + s. Halite
-11-2		Mids (40%)	-	-	-	M	M	s	-	-	-	-	s. Plagioclase?
-11-3		Float (13%)	-	-	-	M	M	-	-	-	-	-	s. Halite
26-55-12	Karain	Bedrock, near address #264C, at lowest level in village. Mass of fresh and devitrified glass.	M	s	-	-	-	-	-	-	-	-	-
-12-1		Sink (63%)	M	-	-	tr	-	-	-	-	-	-	-
-12-2		Mids (21%)	M	tr	-	-	-	tr	-	-	tr??	tr??	-
-12-3		Float (15%)	M	M	-	-	-	tr	-	-	tr??	tr??	-

TABLE 1. X-ray diffraction identification of Turkish tuff samples. (continued)

N.B. No.	Town/Village	Locality/Description[2]	Minerals detected[1] Ash	Mont	Qtz	K-spar	Crist	Ill	Cal	Cn	Ch	Er	Other
26-55-13	Karain	Bedrock, near address #217, at lowest level in village. Gritty tuff, similar to 26-55-12.	M	s	-	tr	tr	-	-	-	-	-	-
-13-1		Sink (75%)	M	tr	-	tr	tr	-	-	-	-	-	-
-13-2		Mids (25%)	M	M	-	tr	tr	tr	-	-	-	-	-
-13-3		Float (.2%)	-	M	-	-	-	-	-	-	-	-	-
		(Montmorillonite is definitely concentrated in finer fractions.)											
26-55-14	Karain	Bedrock near address #200, at lowest level in village. Mixture of fresh and altered glass. Similar to 26-55-12, 13.	M	M	-	tr	-	-	-	-	-	-	-
-14-1		Sink (75%)	M	s	-	tr	-	-	-	-	-	-	-
-14-2		Mids (25%)	M	s	-	tr?	tr?	tr?	-	-	-	-	-
-14-3		Float (.3%)	-	M	-	tr	-	-	-	-	-	-	-
		(Mainly a mixture of ash and montmorillonite.)											
26-55-15	Karain	Building block at address #155. Similar to 26-55-12, 13.	M	s	-	tr	tr?	-	-	-	-	-	-
-15-1		Sink (75%)	M	tr	-	-	tr	tr	-	-	-	-	-
-15-2		Mids (25%)	M	M	-	tr?	tr	tr	-	-	-	-	-
-15-3		Float (.2%)	s	M	-	tr	tr?	-	-	-	-	-	-
		(Definite concentration of montmorillonite in finer fractions.)											
26-55-16	Karain	"Fairy chimney" horizon south of village; pumice fragments 2-5" in size, at top of unit, near fossil locality. Pumice sample.	M	s	-	-	-	tr	-	-	-	-	-
-16-1 J		Sink (42%)	M	tr	-	-	-	-	-	-	-	-	-
-16-2		Mids (37%)	M	s	-	-	-	-	-	-	-	-	-
-16-3		Float (21%)	M	s	-	-	-	-	-	-	-	-	-
		(A pure glass pumice with minor alteration to montmorillonite.)											
*26-55-16-1	Karain	Building block from village library, in center of village. Similar to 26-55-12, but softer.	-	-	-	s	tr	-	-	-	-	M	-
-16-1-1		Sink (48%)	-	-	tr	s	s	-	-	-	-	M	-
-16-1-2		Mids (21%)	-	-	-	tr	tr	-	-	-	-	M	-
-16-1-3		Float (31%)	-	-	-	tr	tr	-	-	-	-	M	-
26-55-17	Karain	Building block, south end of village, at address #539. Similar to 26-55-9.	-	-	s	M	M	tr	-	-	-	-	Plagioclase
-17-1		Sink (51%)	Sample lost										
-17-2		Mids (26%)	-	-	-	M	M	s	-	-	-	-	s. Plagioclase?
-17-3		Float (23%)	-	-	-	M	M	tr	-	-	-	-	s. Plagioclase?
26-55-18	Yeşilöz	Ashy, gray tuff along road north of village.	M	s	tr	tr	tr	-	-	-	-	-	-
-18-1		Sink (25%)	M	tr	s	s	tr	-	-	-	-	-	-
-18-2		Mids (50%)	s	s	tr	tr	tr	-	-	-	-	-	-
-18-3		Float (25%)	s?	s	tr	tr	tr	-	-	-	-	-	-
		(Slight concentration of montmorillonite in fine grained fractions.)											
26-55-19	Yeşilöz	Bedrock near address #100/A. Reddish brown fragments in pink, altered groundmass.	s	s	tr?	s	s	-	-	-	-	-	-
-19-1		Sink (50%)	s	tr	tr?	M	M	-	-	-	-	-	s. Plagioclae
-19-2		Mids (25%)	s	s	tr?	tr	s	-	-	-	-	-	-
-19-3		Float (25%)	-	s	-	tr	tr	-	-	-	-	-	-
26-55-20	Yeşilöz	Pink, gritty tuff; building block at address #388. Similar to 26-55-19	s	-	s	s	M	tr	-	-	-	-	s. Plagioclase
-20-1		Sink (72%)	s	-	tr	s	M	tr	-	-	-	-	s. Plagioclase
-20-2		Mids (19%)	tr	-	tr	s	M	tr	-	-	-	-	-
-20-3		Float (9%)	tr	-	-	s	M	tr	-	-	-	-	s. Plagioclase
*26-55-21	Yeşilöz	Building block near main water supply; White, lightweight, porous tuff with lithic fragments.	tr	s	tr	s	M	-	tr	-	-	s	-
-21-1		Sink (50%)	tr	-	s	M	M	-	tr	-	-	tr	Plagioclase
-21-2		Mids (25%)	s	tr	tr?	s	s	-	tr	-	-	s	s. Plagioclase
-21-3		Sink (25%)	-	s	-	tr	tr	-	s	-	-	s	-
		(Erionite appears in all fractions, but is slightly concentrated in the finest fraction.)											
26-55-22	Karlik	Bedrock above highest level of village. Ashy, gray tuff with lithic fragments.	tr	M	tr	tr	tr?	-	s	-	-	-	-
-22-1		Sink (41)	s	s	tr	tr	tr	-	s	-	-	-	-
-22-2		Mids (18)	tr	s	tr	tr	tr	-	s	-	-	-	-
-22-3		Float (41)	-	M	tr	tr	tr	tr	s	-	-	-	-
26-55-23	Karlik	Building block at address #43. Pink soft tuff.	-	M	tr	s	M	-	-	-	-	-	s. Plagioclase
-23-1		Sink (55%)	-	s	tr	M	M	-	-	-	-	-	Plagioclase
-23-2		Mids (21%)	-	M	-	s	s	-	-	-	-	-	tr. Plagioclase
-23-3		Float (24%)	-	M	-	tr	tr	-	-	-	-	-	-
		(Definite concentration of montmorillonite and depletion of feldspar and cristobaolite in finer fractions.)											

TABLE 1. X-ray diffraction identification of Turkish tuff samples. (continued)

M.B. No.	Town/Village	Locality/Description[2]	Minerals detected[1] Ash	Mont	Qtz	K-spar	Crist	Ill	Cal	Cp	Ch	Er	Other
26-55-24	Karlik	Building block at road level in village. Coarse pumiceous tuff with abundant lithic fragments	-	s	-	M	M	-	tr	-	-	-	s. Plagioclase
-24-1		Sink (63%)	-	tr	-	M	M	-	-	-	-	-	Plagioclase
-24-2		Mids (20%)	-	s	-	s	M	-	-	-	-	-	tr. Plagioclase
-24-3		Float (17%)	-	M	-	s	s	-	-	-	-	-	-
		(Definite concentration of montmorillonite and depletion of feldspar and cristobalite in finer fractions.)											
26-55-25-1	Karacaviran	Bedrock, highest outcrop in village. Tan tuff with pumice fragments.	M	s	-	tr	-	-	-	-	-	-	-
-25-1-1		Sink (51%)	M	s	tr	tr	tr	-	-	-	-	-	-
-25-1-2		Mids (24%)	M	s	-	tr	-	-	-	-	-	-	-
-25-1-3		Float (25%)	-	M	-	tr	-	-	-	-	-	-	-
26-55-26	Karacaviran	Building block, upper level of village. Gray tuff with abundant coarse fragments.	s	M	-	tr	tr	-	-	-	-	-	-
-26-1		Sink (61%)	M	tr	-	tr	tr	-	-	-	-	-	-
-26-2		Mids (24%)	M	s	-	-	-	-	-	-	-	-	-
-26-3		Float (15)	-	M	tr	-	-	-	-	-	-	-	-
		(Ash with montmorillonite alteration; very few crystalline phases otherwise.)											
26-55-27	Karacaviran	Bedrock near address 181A. Tan, gray, gritty tuff, loosely consolidated.	M	-	-	tr	tr	-	-	-	-	-	-
-27-1		Sink (62%)	M	-	-	tr	tr	-	-	-	-	-	-
-27-2		Mids (19%)	M	s	-	tr	-	-	-	-	-	-	-
-27-3		Float (19%)	-	M	-	tr	-	-	-	-	-	-	-
		(Nearly pure ash with minor montmorillonite alteration, and traces of other silicates.)											
26-55-28	Karacaviran	Building block at address 219B. Tan tuff.	M	s	-	tr	tr	-	-	-	-	-	-
-28-1		Sink (59%)	M	-	-	tr	-	-	-	-	-	-	-
-28-2		Mids (23%)	M	tr	-	tr	tr	-	-	-	-	-	-
-28-3		Float (18%)	-	M	-	tr	-	-	-	-	-	-	-
		(Ash partially altered to montmorillonite, with traces of other silicates.)											
26-55-29	Karacaviran	Building block near address 243A. Tan tuff.	M	tr	-	tr	tr?	-	-	-	-	-	-
-29-1		Sink (60%)	M	-	tr	tr	tr	-	-	-	-	-	-
-29-2		Mids (21%)	M	tr	-	tr	-	tr	-	-	-	-	-
-29-3		Float (19%)	-	M	-	tr	-	-	-	-	-	-	tr. Gypsum?
		(Gypsum may be due to mortar used in construction.)											
*26-55-30	Karacaviran	Building block near well by highway. Pinkish tan tuff; more consolidated than most blocks in village.	s	tr	-	s	s	-	-	-	-	M	-
-30-1		Sink (67%)	s	-	-	s	s	-	-	-	-	M	-
-30-2		Mids (17%)	-	tr	-	tr	tr	-	-	-	-	M	-
-30-3		Float (17%)	-	s	-	tr	tr	-	-	-	-	M	-
		(Erionite content decreases in coarse fraction and reaches a maximum in the midling fraction.)											
*26-55-31	Karacaviran	"Fairy chimney" unit east of village. Lowest exposure of "chimney" tuff. Tan, fine grained tuff.	s	s	-	tr	-	-	-	-	-	tr?	-
-31-1		Sink (58%)	s	s	tr	tr	tr	-	-	-	-	-	-
-31-2		Mids (24%)	s	s	-	-	-	s	-	-	-	tr?	-
-31-3		Float (18%)	-	M	-	-	-	tr	-	-	-	tr?	-
		(Identification of erionite is questionable. Illite in midling fraction is probably a well-crystallized mica.)											
26-55-32	Karacaviran	"Fairy chimney" unit east of village. Non-resistant portion of unit, adjacent to a resistant "chimney".	M	s	-	tr	tr	-	-	-	-	-	-
-32-1		Sink (65%)	M	-	tr	tr	tr	-	-	-	-	-	-
-32-2		Mids (20%)	M	tr	-	tr?	-	-	-	-	-	-	-
-32-3		Float (15%)	-	M	-	tr	tr	tr	-	-	-	-	-
		(Mainly ash with minor alteration to montmorillonite and traces of other silicate minerals.)											
*26-55-33	Karacaviran	"Fairy chimney" unit east of village. Resistant "chimney" adjacent to 26-55-32.	M	s	tr	tr	tr	tr	-	-	-	tr?	-
-33-1		Sink (63%)	M	-	tr	tr	tr	-	-	-	-	-	
-33-2		Mids (22%)	M	-	-	tr?	-	tr	-	-	-	-	-
-33-3		Float (15%)	-	M	-	tr	-	tr?	-	-	tr?	tr	-
		(Identification of erionite in float fraction is definite, but that of chabazite is questionable.)											
*26-55-25	Sarinidir	Building blocks being used in upper part of village. Altered tuff with abundant altered lapilli.	-	-	-	-	-	-	-	M	M	-	-
-25-1		Sink (61)	-	-	-	-	-	-	-	M	M	-	-
-25-2		Mids (20%)	-	-	-	-	-	-	-	M	M	-	-
-25-3		Float (19%)	-	-	-	-	-	-	-	M	M	tr	-
		(Clinoptilolite and chabazite are present in about the same ratio in all fractions, with less of each in the float fraction.)											

TABLE 1. X-ray diffraction identification of Turkish tuff samples. (continued)

N.B. No.	Town/Village	Locality/Description[2]	Minerals detected[1] Ash	Mont	Qtz	K-spar	Crist	Ill	Cal	Cp	Ch	Er	Other
*26-55-34	Sarihidir	Section south of river, Gray, gritty tuff, high in section.	tr	-	tr	tr	tr	-	tr	s	-	s	-
-34-1		Sink (57%)	s	-	s	tr	tr	tr	tr	tr	-	tr	-
-34-2		Mids (20%)	-	-	-	tr	tr?	-	tr	s	-	s	-
-34-3		Float (23%)	-	s	-	-	-	tr	tr	s	-	s	-
		(Highest percentage erionite in finest fraction. Clinoptilolite peaks are slightly broad, suggestive of presence of some chabazite and/or mordenite.)											
*26-55-35	Sarihidir	Section south of river. Fine grained, homogeneous, tan tuff.	-	s	-	-	-	-	-	M	-	-	-
-35-1		Sink (46%)	-	s	-	-	-	-	-	M	-	-	-
-35-2		Mids (17%)	-	tr	-	-	-	-	-	M	-	-	-
-35-3		Float (37%)	-	M	-	-	-	-	-	M	-	-	-
		(Clinoptilolite is fairly high-grade and about equal in all fractions, with perhaps somewhat less in finest fraction.)											
*26-55-36	Sarihidir	Section south of river. Coarser tuff than 26-55-35, but with fewer very coarse fragments than 26-55-34.	s	tr	-	-	-	-	-	M	tr?	tr	-
-36-1		Sink (59%)	s	tr	tr	-	-	-	-	M	tr?	tr	-
-36-2		Mids (21%)	tr	tr	-	-	-	-	-	M	tr?	tr	-
-36-3		Float (20%)	-	s	-	-	-	-	-	M	tr?	tr	
		(Most zeolite phases present appear somewhat poorly crystalline, with broad peaks. Erionite is somewhat concentrated in the finest fraction; clinoptilolite in the midling fraction.)											
*26-55-37	Sarihidir	Section south of river; Quarry locality, west of bridge. Gritty, homogeneous tuff, light colored.	s	-	-	tr	tr	-	-	s	s	tr	-
-37-1		Sink (60%)	s	-	-	tr	tr	-	-	s	s	tr	-
-37-2		Mids (20%)	tr	-	-	tr	tr?	-	-	s	s	tr	-
-37-3		Float (20%)	-	s	-	tr	-	-	-	M	s	tr	-
		(Clinoptilolite definitely concentrated in finer fractions, but still not high-grade.)											
*26-55-38	Sarihidir	Section south of river. Quarry Locality. Liesegang rings and accretionary lapilli.	-	M	-	-	tr	-	-	M	-	tr?	-
-38-1		Sink (48%)	-	M	-	-	-	-	-	M	-	tr?	-
-38-2		Mids (17%)	-	s	-	tr	-	tr	-	M	-	-	-
-38-3		Float (35%)	-	M	-	tr	-	tr	-	M	-	-	-
*26-55-39	Sarihidir	Building block at address K-120. Tan, altered tuff with pumice lapilli	s	-	-	s	-	-	-	s	-	tr?	-
-39-1		Sink (60%)	s	-	-	tr	tr	-	-	s	-	tr	-
-39-2		Mids (20%)	s	tr	-	tr	tr	-	-	s	-	tr	-
-39-3		Float (20%)	-	tr	-	tr	-	-	-	s	tr	-	
		(None of these fractions is a high-grade clinoptilolite.)											
*26-55-40	Sarihidir	Building block at address #K-125, Coarse-grained, gritty tuff.	M	-	tr	tr	tr	-	-	tr?	tr	-	-
-40-1		Sink (50%)	M	-	s	s	tr	-	-	tr?	tr	-	Plagioclase
-40-2		Mids (25%)	M	-	tr	tr	tr	-	-	tr	s	tr	-
-40-3		Float (25%)	tr	s?	-	-	-	-	-	tr	tr	tr?	-
		(Chabazite is concentrated in the midling fraction.)											
*26-55-41	Sarihidir	Building block. Coarse-grained, gritty, oxidized tuff.	-	-	s	M	tr	-	-	M	-	-	s. Plagioclase
-41-1		Sink (74%)	-	-	M	M	tr	-	-	M	-	-	Plagioclase
-41-2		Mids (12%)	-	-	tr	tr	-	-	-	M	-	-	-
-41-3		Float (13%)	-	tr	tr	tr	-	-	-	M	-	-	-
		(Clinoptilolite is depleted in the coarse fraction and concentrated in the finer fractions to a high-grade product.)											
*26-55-42	Sarihidir	Building block. Very fine-grained, white, tuff with conchoidal fracture.	-	-	-	tr	M	-	-	M	-	-	-
-42-1		Sink (72%)	-	-	-	tr	M	-	-	M	-	-	-
-42-2		Mids (13%)	-	-	-	tr	M	-	-	M	-	-	-
-42-3		Float (15%)	-	-	-	tr	s	-	-	M	-	-	-
		(All fractions are relatively high-grade clinoptilolite with significant cristobalite/tridymite impurity.)											
26-55-43		Quarry west of Avanos.	-	-	M	-	-	-	-	-	-	-	Kaolinite
26-55-44		Kaolinite quarry west of Avanos	-	-	M	-	-	-	-	-	-	-	Kaolinite
		(Contains less quartz than 26-55-43.)											
26-55-45		Quarry northeast of Nevşehir. Principal building block quarry supplying region.	-	-	M	-	-	-	-	-	-	-	Kaolinite
*26-55-46	Tuzköy	Basement cave in western part of village. Yellow-gray, gritty tuff.	s	-	tr	tr	-	-	-	-	s	-	-
-46-1		Sink (63%)	M	-	tr	tr	-	-	-	-	s	-	-
-46-2		Mids (21%)	tr	tr	tr	tr	-	-	-	-	M	-	-
-46-3		Float (16%)	-	s	tr	-		-	s?	-	s	-	tr Gypsum + tr. Halite?
		(Midling fraction is a high-grade chabazite. Unidentified reflection at 14.6° 2θ in 26-55-46-3).											

TABLE 1. X-ray diffraction identification of Turkish tuff samples. (continued)

N.B. No.	Town/Village	Locality/Description[2]	Minerals detected[1] Ash	Mont	Qtz	K-spar	Crist	Ill	Cal	Cp	Ch	Er	Other
*26-55-47	Tuzköy	Abandoned quarry in village near address #184. Poorly consolidated ashy tuff with abundant needles of pumice.	M	-	s	tr	tr	-	-	-	s	-	-
-47-1		Sink (65%)	M	-	s	s	tr	tr	-	-	tr	-	-
-47-2		Mids (24%)	s	tr	tr	tr	tr	tr	-	-	M	tr?	-
-47-3		Float (11%)	-	M	tr	tr	tr	tr?	-	-	tr	tr	-
		(Chabazite concentrated in midling fraction; erionite concentrated in finest fraction.)											
*26-55-48	Tuzköy	Building block at address #184. Similar to 26-55-46, but with abundant pumice needles.	s	-	s	tr	tr	-	-	-	M	tr?	-
-48-1		Sink (75%)	M	-	s	tr	tr	tr	-	-	M	tr?	-
-48-2		Mids (25%)	s	-	tr	tr?	-	-	-	tr?	M	tr?	-
-48-3		Float (.2%)	-	s	tr	tr	tr	tr	-	-	s	-	-
		(Chabazite is concentrated in the midling fraction to a high-grade product.)											
*26-55-49	Tuzköy	Bedrock at address #89. Yellow-brown, moderately consolidated tuff.	tr?	-	s	-	tr	-	-	-	M	tr?	-
-49-1		Sink (61%)	-	-	s	s	tr	tr	-	-	M	tr	s. Plagioclase
-49-2		Mids (22%)	-	-	s	tr	tr	tr	-	-	M	tr	tr. Plagioclase
-49-3		Float (18%)	-	s	tr	tr	tr	tr	-	-	M	tr	-
*26-55-50	Tuzköy	Building block at address #87. Gritty, loosely consolidated tuff with abundant pumice needles, similar to 26-55-46.	tr	-	tr	tr	tr	-	-	-	M	tr	-
-50-1		Sink (75%)	tr		tr	tr	tr	-	-	-	M	tr	-
-50-2		Mids (25%)	-	-	tr	tr	tr	-	-	tr?	M	tr	-
-50-3		Float (.3%)	-	s	tr	tr	tr	-	-	-	s	tr?	-
		(Chabazite is concentrated in the midling fraction to a high-grade product.)											
*26-55-51	Tuzköy	Building block at address #260. Brown, loosely consolidated tuff.	M	-	tr	tr	tr	tr	-	-	M	-	-
-51-1		Sink (52%)	M	-	s	tr	tr	tr	-	-	tr	-	-
-51-2		Mids (28%)	s	-	tr	tr	-	-	tr?	-	M	-	-
-51-3		Float (20%)	tr	s	tr	tr	tr	-	-	-	M	-	-
		(Midling fraction is high-grade chabazite; much less chabazite in float fraction.)											
*26-55-52	Tuzköy	Building block containing abundant fibrous pumice.	M	-	tr	tr	tr	-	-	-	M	-	+s. Plagioclae
-52-1		Sink (57%)	M	-	tr	tr	tr	tr	-	-	s	-	-
-52-2		Mids (24%)	tr	-	tr	tr	tr	-	-	-	M	tr	-
-52-3		Float (19%)	tr	tr	tr	tr	tr	-	-	-	M	-	-
		(Definite concentration of chabazite in midling fraction. Much less in float fraction.											
26-55-53	Çiftlikköy	Quarry rock at northwest edge of village. Pink, gritty, poorly consolidated tuff with abundant pumice.	M	s	tr	tr	-	-	-	-	-	-	-
-53-1		Sink (59%)	M	tr?	s	M	s	tr	-	-	-	-	Plagioclase
-53-2		Mids (22%)	M	s	tr	tr	tr	tr	-	-	-	-	-
-53-3		Float (20%)	s	s	-	tr	tr	tr	-	-	-	-	-
26-55-54	Çiftlikköy	Building block in village; very similar to 26-55-53.	M	s	s	s	tr	tr?	-	-	-	-	s. Plagioclase
-54-1		Sink (63%)	M	M	M	M	s	s	tr?	-	-	-	s. Plagioclse
-54-2		Mids (22%)	s	M	tr	tr	tr	-	-	-	-	-	tr. Plagioclase
-54-3		Float (15%)	-	M	tr	tr	tr	tr	-	-	-	-	-
		(Montmorillonite definitely concentrated in finer fractions.)											
26-55-55	Kizilköy	Sample from small, old quarry south of village. Pink, poorly consolidated tuff, similar to 26-55-53.	s	s	tr	tr	tr	tr	-	-	-	-	-
-55-1		Sink (62%)	M	tr	tr	tr	tr	tr	-	-	-	-	-
-55-2		Mids (21%)	M	s	tr	tr	tr	tr	-	-	tr?	-	-
-55-3		Float (17%)	M	s	tr	tr	tr	-	-	-	-	-	-
		(Trace of chabazite is probably present in midling fraction, but the phase was not positively identified.)											
26-55-56	Kizilköy	Bedrock in village, containing abundant pumice fragments, up to 2" in size.	M	-	tr	tr?	tr?	-	-	-	-	-	-
-56-1		Sink (67%)	M	-	s	s	tr?	-	-	-	-	-	-
-56-2		Mids (19%)	M	-	tr	tr	tr	-	-	-	-	-	-
-56-3		Float (14%)	s	s	tr	-	tr	-	-	-	-	-	-
26-55-56-4	Kizilköy	Pumice fragments from 26-55-56	M	-	-	-	-	-	-	-	-	-	-
26-55-57	Kizilköy	Building block in village; cream-colored gritty tuff.	s	s	tr	tr	tr	tr	-	-	-	-	tr. Plagioclase
-57-1		Sink (61%)	s	M	s	tr	s	tr	-	-	-	-	tr. Plagioclase
-57-2		Mids (20%)	-	M	tr	tr	tr	tr?	-	-	-	-	-
-57-3		Float (19%)	-	M	tr	tr	tr	-	-	-	-	-	
		(Float fraction is a high-grade montmorillonite with only traces of other silicate minerals.)											

TABLE 1. X-ray diffraction identification of Turkish tuff samples. (continued)

N.B. No.	Town/Village	Locality/Description[2]	Ash	Mont	Qtz	K-spar	Crist	Ill	Cal	Cp	Ch	Er	Other
			Minerals detected[1]										
26-55-58	Kaymakli	Bedrock at entrance to underground city. Lightweight, well indurated tuff with pumice lapilli 1/2" in size	-	-	-	M	M	-	-	-	-	-	s. Plagioclase
-58-1		Sink (63%)	-	-	-	M	M	-	-	-	-	-	s. Plagioclase
-58-2		Mids (23%)	-	-	-	M	M	-	-	-	-	-	s. Plagioclase
-58-3		Float (14%)	-	-	-	M	M	-	-	-	-	-	s. Plagioclase
26-55-59	Taşkinpaşa	"Fairy chimney" unit on west side of highway, south of Ürgüp. Pink tuff with abundant 1/4-1" pumice fragments.	s	s	tr	tr	tr	tr	-	-	-	-	-
-59-1		Sink (64%)	tr	M	tr	tr	tr	-	-	-	-	-	-
-59-2		Mids (21%)	M	M	tr	tr	tr	tr	-	-	tr?	-	-
-59-3		Float (15%)	s	M	tr	tr	tr	tr	-	-	-	-	-
		(Identification of chabazite in midling fraction is questionable.)											
26-55-60		Well-indurated, fine-to-medium grained tuff. White. On east side of highway.	-	M	tr	tr	-	-	-	-	-	-	-
		(High-grade, expanding montmorillonite)											
26-55-61	Ürgüp	Bedrock at address #23 on western edge of town. High in section. Gray, gritty tuff with small pumice fragments.	M	-	tr	tr	tr	-	-	-	-	-	-
-61-1		Sink (63%)	M	-	s	s	tr	tr	-	-	-	-	-
-61-2		Mids (21%)	M	-	tr	tr	tr	s	-	-	-	-	-
-61-3		Float (15%)	M	tr	tr	tr	tr?	s	-	-	-	-	-
26-55-62	Ürgüp	Building block at address #32; same locality as 26-55-61. Poorly consolidated pumice fragments.	M	s	-	-	-	-	-	-	-	-	-
-62-1		Sink (49%)	M	-	tr	tr	-	-	-	-	-	-	-
-62-2		Mids (27%)	M	-	-	-	-	-	-	-	-	-	-
-62-3		Float (23%)	M	tr	-	-	-	-	-	-	-	-	-
26-55-63	Ürgüp	Bedrock at #1 Balci Sokesi; tan, gritty, friable tuff.	M	-	tr	tr	tr	tr	-	-	-	-	tr. Plagioclase
-63-1		Sink (59%)	M	-	tr	tr	tr	tr	-	-	-	-	tr. Plagioclase
-63-2		Mids (22%)	M	-	tr	tr	tr	tr	-	-	-	-	-
-63-3		Float (19%)	s	-	tr	tr	-	tr	-	-	-	-	-
26-55-64	Ürgüp	Building block at address #148, Musaefendi Sokesi; Fe-stained, loosely consolidated pumice fragments.	M	-	-	tr?	-	-	-	-	-	-	-
-64-1		Sink (64%)	M	-	-	tr?	-	-	-	-	-	-	-
-64-2		Mids (21%)	M	-	-	-	-	-	-	-	-	-	-
-64-3		Float (15%)	M	-	-	-	-	-	-	-	-	-	Halite + ?
		(Unknown peaks at 4.67, 4.62, 3.79, 3.74, 3.02, 2.71, 2.66, 2.33, and 2.29 Å in pattern of float fraction)											
26-55-65	Ürgüp	Bedrock from slumped section near center of town. Fe-stained, fine-grained tuff.	M	-	tr	tr	tr	-	-	-	-	-	tr. Plagioclase
-65-1		Sink (52%)	M	-	s	s	tr	-	-	-	-	-	tr. Plagioclase
-65-2		Mids (24%)	M	-	tr	tr	tr	tr	-	-	-	-	-
-65-3		Float (24%)	s	tr	-	-	-	-	-	-	-	-	-
26-55-66	Ürgüp	Banded, lightweight tuff used as dimension stone in buildings in Ürgüp, but quarried near Nevşehir. Similar to 26-55-6.	-	-	M	-	-	-	-	-	-	-	Kaolinite
26-55-67	Ürgüp	Building block at #5 Inhilapşehitler; yellow, loosely consolidated soft tuff.	M	-	-	-	-	-	-	-	-	-	tr. Kaolinite
-67-1		Sink (43%)	M	-	-	-	-	-	-	-	-	-	tr. Kaolinite
-67-2		Mids (34%)	M	-	-	-	-	-	-	-	-	-	tr. Kaolinite?
-67-3		Float (23%)	M	-	-	-	-	-	-	-	-	-	tr. Kaolinite
26-55-68	Ürgüp	Bedrock at #25 Esetaga. Yellow, gritty, pumiceous tuff.	M	-	s	tr	tr	-	-	-	-	-	
-68-1		Sink (60%)	M	s	s	s	tr	tr	-	-	-	-	-
-68-2		Mids (21%)	M	s	-	tr	tr	s	-	-	-	-	-
-68-3		Float (19%)	-	s	-	tr	-	tr	-	-	-	-	-
		(Float fraction is mainly amorphous, with only a small peak for montmorillonite present in the x-ray pattern.)											
26-55-69	Mustafapaşa	Bedrock, soft, altered tuff with some pumice fragments	M	s	s	tr	tr	-	-	-	-	-	tr. Plagioclase
-69-1		Sink (47%)	M	-	s	tr	tr	-	-	-	-	-	tr. Plagioclase
-69-2		Mids (27%)	M	tr	tr	tr	tr	tr	-	-	-	-	-
-69-3		Float (26%)	-	M	tr	tr	-	-	-	-	-	-	-
26-55-70	Mustafapaşa	Building block in upper part of village.	M	tr	tr	s	tr	-	-	-	-	-	-
-70-1		Sink (60%)	M	-	s	s	tr	tr	-	-	-	-	tr. Kaolinite?
-70-2		Mids (20%)	M	tr	tr	tr	tr	tr	-	-	-	-	tr. Kaolinite
-70-3		Float (20%)	tr	M	tr	tr	-	-	-	-	-	-	tr. Kaolinite

TABLE 1. X-ray diffraction identification of Turkish tuff samples.(continued)

N.B. No.	Town/Village	Locality/Description[2]	Minerals detected[1] Ash	Mont	Qtz	K-spar	Crist	Ill	Cal	Cp	Ch	Er	Other
26-55-71	Göreme	Bedrock at roadside by Göreme chapel site. Fairly well consolidated, gray tuff with small pumice fragments.	M	tr	s	s	tr	-	-	-	-	-	tr. Plagioclase
-71-1		Sink (61%)	M	-	s	s	tr	tr	-	-	-	-	s. Plagioclase
-71-2		Mids (20%)	M	-	tr	tr	tr	s	-	-	-	-	-
-71-3		Float (19%)	M	s	tr?	tr	tr	tr	-	-	-	-	-
26-60-1-1[3]	Karain area	Section above village. Capping gray welded tuff with squashed large pumice fragments; a good marker horizon, 30 m thick.	M	-	tr	tr	M	tr	-	-	-	-	-
-1-1-1		Sink (81%)	M	-	tr	s	M	tr	-	-	-	-	-
-1-1-2		Mids (19%)	M	-	tr	tr	M	tr	-	-	-	-	-
-1-1-3		Float (.1%)	s	s	-	s	M	-	tr	-	-	-	-
26-60-1-2[3]	Karain area	Section above village. Opaline limestone in upper part of Unit A, about 60 m below 26-60-1-1.	-	-	-	-	M	-	-	-	-	-	Dolomite
26-60-1-3[3]	Karain area	Section above village. Gray, resistant tuffaceous marker horizon in about middle of Unit A, just beneath carbonates. About 50 m thick. Sample taken about 2 m above base of unit.	s	s	-	s	s	-	-	-	-	-	-
-1-3-1		Sink (58%)	s	s	-	s	M	-	-	-	-	-	
-1-3-2		Mids (21%)	tr?	s	-	tr	s	-	-	-	-	-	-
-1-3-3		Float (21%)	-	s	-	tr	s	-	-	-	-	-	-
26-60-1-4[3]	Karain area	Section above village.Fine grained tuff at base of unit sampled as 26-60-1-3.	M	M	-	tr	M	tr	-	-	-	-	-
26-60-1-5[3]	Karain area	Section above village. White, fine-grained diatomite?	M	-	-	tr	tr	-	-	-	-	-	-
-1-5-1		Sink (42%)	M	-	-	tr	tr	-	-	-	-	-	-
-1-5-2		Mids (21%)	M	-	-	tr	tr	-	-	-	-	-	-
-1-5-3		Float (37%)	M	-	-	tr	tr	-	-	-	-	-	-
26-60-1-6[3]	Karain area	Section above village. White diatomite near base of Unit A; about 2 m thick.	-	M	-	-	-	-	-	-	-	-	-
		(Montmorillonite is poorly crystalline.)											
26-60-1-7[3]	Karain area	Section above village. Brownish, pink tuff at base of Unit A. About 40 m thick; collected at middle of unit.	M	s	tr?	s	M	-	-	-	-	-	s. Plagioclase
-1-7-1		Sink (62%)	M	s	tr?	s	M	-	-	-	-	-	s. Plagioclase
-1-7-2		Mids (20%)	M	s	-	tr	s	-	-	-	-	-	s. Plagioclase
-1-7-3		Float (18%)	-	M	-	tr	tr	-	-	-	-	-	-
26-60-1-8[3]	Karain area	Section above village. Pumice tuff. collected in upper part of Unit B, "Fairy Chimney"horizon.	M	s	-	tr	tr	-	tr	-	-	-	-
-1-8-1		Sink (60%)	M	-	-	s	s	-	-	-	-	-	s. Plagioclase
-1-8-2		Mids (22%)	M	s	-	tr	tr	tr?	-	-	-	-	-
-1-8-3		Float (18%)	s	M	-	tr	tr	-	-	-	-	-	+ ?
		(Unidentified phase in float fraction has a peak at 14.8° 2θ.)											

[1] Minerals detected by X-ray powder diffraction techniques, Cu K_α radiation, Ni-filtered. Normal scanning speed = $2^\circ 2\theta$/min; chart speed = 1"/min. Siemens Diffractometer apparatus, 30 Kv, 40 ma. Xenon-filled proportional counter.

Ash = unaltered volcanic ash or glass, as indicated by the presence of a low-intensity hump between 18 and $30^\circ 2\theta$. Distinction between major and minor quantities of ash is difficult.

Mont = montmorillonite, as indicated by a broad peak in the vicinity of $6^\circ 2\theta$. Distinction between major, minor, and trace quantities of this phase is difficult. Major = relatively strong, sharp peak at $6^\circ 2\theta$.

Qtz = quartz. K-spar = potassium feldspar. Crist. = cristobalite, as indicated by a peak at $22^\circ 2\theta$. Tridymite may also be present in some samples. Ill = illite, or poorly crystalline mica, as indicated by a relatively broad peak at about $8.9^\circ 2\theta$. Cal = calcite. Cp = clinoptilolite. Ch = chabazite. Er = erionite.

M = major phase (>25%). s = minor phase (5-25%). tr = trace phase (<5%, with about 1% the probably detection limit). ? = questionable.

A star in front of the sample number indicates that the sample contains zeolites.

[2] Sink, Mids, and Float refer to fractions of the original sample crushed to -40 mesh and separated on the basis of particle size by ultrasonic scrubbing and water settling, as described in the text. Percentages in parentheses are on a weight basis.

[3] Sample collected by R.A. Sheppard.

to rock samples, 13 wells and water sources in various villages were also sampled. Two, 100-ml samples of water from each well were filtered separately through 1.2 µm-RA Millipore filters, and preserved in sterile plastic envelopes for future examination and particle analysis.[3]

Portions of each sample were gently crushed by hand using a porcelain motar and pestle to pass 40 mesh, and a representative split powdered to -200 mesh (-75 µm) for X-ray powder diffraction analysis. About 5 g of the -40 mesh (-425 µm) material was then disaggregated by ultrasonic scrubbing in a 300-watt Powertron Ultrasonic Bath in about 700 ml of deionized water for 10 min. The slurry was allowed to settle for 1.0 min, and the suspended material was decanted from the coarser sink material. The scrubbing process was repeated on the sink fraction until only a minimum of suspended material was produced. Decantates were combined and allowed to stand for 15 min, after which time the suspended material was again decanted. All products were allowed to evaporate to dryness. Thus, each sample was separated into three fractions on the basis of particle size: (1) a coarse, sink fraction, (2) a fine-grained middling fraction, and (3) an ultrafine-grained float fraction.

Powders of all samples and products were sedimented onto glass slides with deionized water and examined by X-ray powder diffraction techniques using a Siemens F-type diffractometer and Ni-filtered Cu $K\alpha$ radiation. Patterns were recorded from 40 to 2° 2θ at a scanning rate of 2° 2θ/min. Critical samples were also scanned between 10 and 4° 2θ at a rate of $1/4^{\circ}$ 2θ/min and at elevated gain settings in a effort to detect possible weak reflections characteristic of erionite, chabazite, and clinoptilolite. Samples suspected of containing mont-

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[3] Electron microscopic examination of the filters had not been completed when this report was prepared.

morillonite were treated with ethlene glycol to expand the smectite lattice to 17 Å, thereby confirming the identification of this phase.

Scanning electron micrographs were obtained through the cooperation of R. A. Sheppard (U.S. Geological Survey, Denver, Colorado) and K. M. Dentan (Carborundum Company, Niagara Falls, New York) using a Cambridge Steroscan Model S-180 Scanning Electron Microscope and an AMR Model 1000 Scanning Electron Microscope, respectively. Oxygen adsorption capacities of selected erionite-and chabazite-rich samples were obtained by D. W. Breck (Union Carbide Corporation, Tarrytown, New York) at -188°C and 100 torr, after a 12-hour activation at 350°C, and are listed in Table 2.

MINERALOGICAL RESULTS

Tuzköy Area

Tuzköy is located at the northern end of a broad valley, approximately 10 km west of Gülşehir and 3 km south of the Kizilirmak River, in an area of low, rolling hills (Figure 4). The name derives from the presence of a major salt deposit that is being mined about 1 km west of the village (*tuz* = salt; *köy* = village). The area is underlain by a homogeneous, unwelded, ash-flow tuff that is probably stratigraphically equivalent to those in the A Unit exposed in Göreme Valley and at Karain. Basalt flows, 5-10 m thick, cover hills on the eastern side of the valley. Thick exposures of tuff are absent as are "fairy chimney" cones and columns due to the gentle topography of the area. The tuff is exposed extensively in the village where it displays no stratification and is at least 20 m thick. Village streets are generally unsurfaced and rest directly on the soft, crumbly tuff (see Figure 8). Small quarries are scattered throughout the village, and the tuff has been used in the construction of most dwellings, many of which stand on foundations that have been excavated into the bedrock tuff.

Table 2. Oxygen-Adsorption Capacities of Selected Zeolite-rich Samples from the Karain - Tuzköy Area, Central Turkey[1]

Sample No.[2]	Village	Zeolites Present[3]	O_2 Adsorption Capacity (wt.-%) (-188°C, 100 torr)	Zeolite Content[4]
26-55-16-1	Karain	Erionite	7.85	44% Er
26-55-21	Yeşilöz	s. Erionite	0.97	5% Er
26-55-30	Karacaviran	Erionite	4.52	25% Er
26-55-25	Sarihidir	Clinoptilolite + Chabazite	8.30	34% Ch
25-55-46-2	Tuzköy	Chabazite	12.41	56% Ch
26-55-48	Tuzköy	Chabazite + tr. Erionite	6.90	31% Ch
26-55-49	Tuzköy	Chabazite + tr. Erionite	13.54	62% Ch
26-55-50	Tuzköy	Chabazite + tr. Erionite	7.94	36% Ch
26-55-52	Tuzköy	Chabazite + tr. Erionite	6.61	30% Ch

[1] Obtained through the cooperation of D. W. Breck, Union Carbide Corporation, Tarrytown, New York.

[2] See Table 1.

[3] From X-ray powder diffraction analyses. See Table 1. s. = some; tr. = trace.

[4] Pure chabazite adsorbs 22 weight-percent O_2 under these conditions; pure erionite adsorbs 18 weight-percent O_2 under these conditions. Zeolite percentages are based on these values and are only estimates. The O_2 capacity of sample 26-55-21 may be in error, as the X-ray powder diffraction pattern indicates 20-25% erionite.

Bariş (1977) reported 7 cases of pleural mesothelioma between 1971 and August 1977 from the village's population of 2929, along with high incidences of lung cancer and pleural calcification. Except for the absence of "fairy chimneys", Tuzköy is physiographically and sociologically similar to Karain and other peasant villages in the region. It is somewhat less isolated because of the commercial traffic to and from the salt mine.

Seven samples of yellow-gray tuff were collected from bedrock, quarry faces, and building blocks in the village. All are poorly consolidated assemblages of pumice up to several centimeters in size in a fine-grained matrix of pyrogenic quartz and feldspar and altered and unaltered volcanic ash. Many of the pumice fragments contain sheafs of glassy needles and fibers, 0.1 to 0.01 mm in diameter. The pitted nature of these fibers is due most likely to partial dissolution, as is evident in Figure 9. X-ray powder diffraction analyses of the Tuzköy samples indicate the abundance of fresh glass and chabazite, along with minor to trace amounts of montmorillonite, quartz, feldspar, opal C/T, illite and erionite (see Figure 10). Traces of gypsum and halite(?) were detected in one sample. These data confirm those obtained earlier on the small samples of Tuzköy building block received from Pooley (see p. 12). As indicated by the oxygen-adsorption capacities listed in Table 2, some of the Tuzköy samples contain as much as 60% chabazite. Under ordinary circumstances, such material would qualify as a potential ore of this zeolite, although some beneficiation would be required.

The characteristic needle-shape habit of erionite can be seen in Figures 11 and 12, scanning electron micrographs of sample 26-55-50, along with rhombs of chabazite up to 30 µm on an edge. Erionite occurs as individual needles about 0.5 µm in diameter and from 10 to 30 µm in length and as bundles of needles, up to several µm thick. In places, erionite appears to have nucleated in solution cavities in pre-existing chabazite. Very thin needles, a few

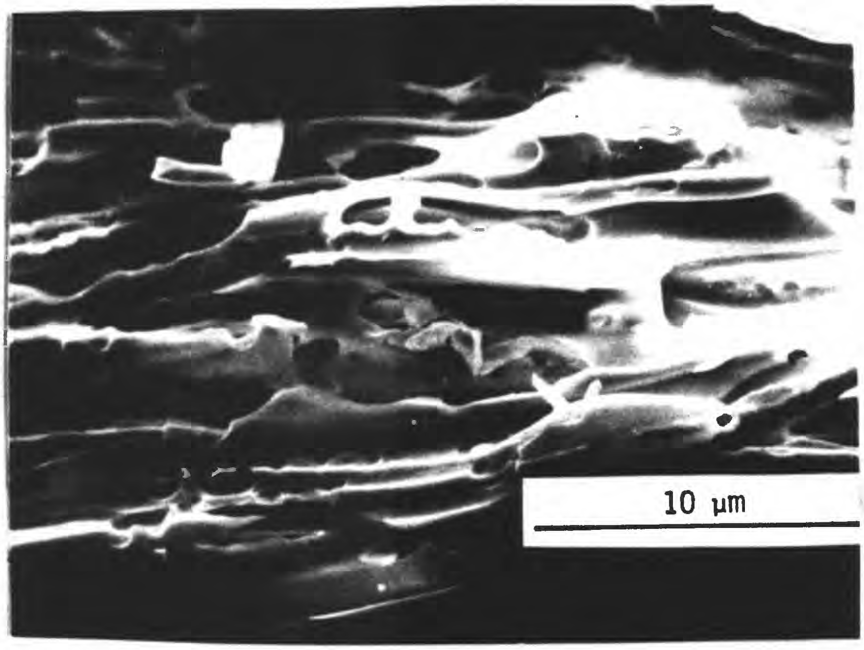
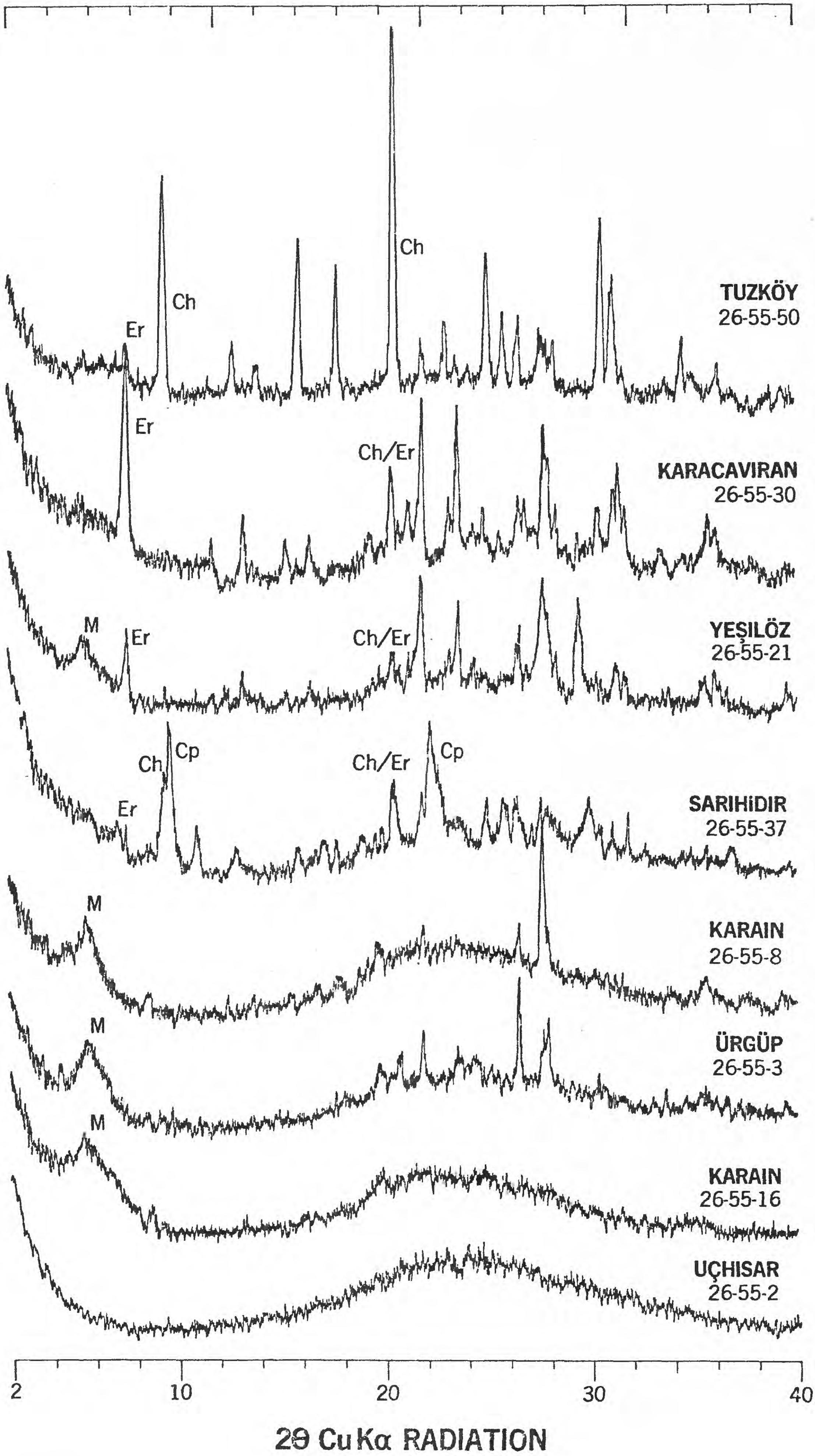


Figure 9. Scanning electron micrograph of "fibrous" glass from Tuzköy, Turkey. Note the pitted nature of the shards.



Ch
Ch
Er
TUZKÖY
26-55-50
Er
Ch/Er
KARACAVIRAN
26-55-30
M
Er
Ch/Er
YEŞILÖZ
26-55-21
Ch
Cp
Ch/Er
Cp
Er
SARIHIDIR
26-55-37
M
KARAIN
26-55-8
M
ÜRGÜP
26-55-3
M
KARAIN
26-55-16
UÇHISAR
26-55-2
2
10
20
30
40
2θ Cu Kα RADIATION

Figure 10. X-ray powder diffraction patterns of representative tuff samples from the Cappadocia region of central Turkey. M = montmorillonite, Er = erionite, Ch = chabazite, Cp = clinoptilolite.

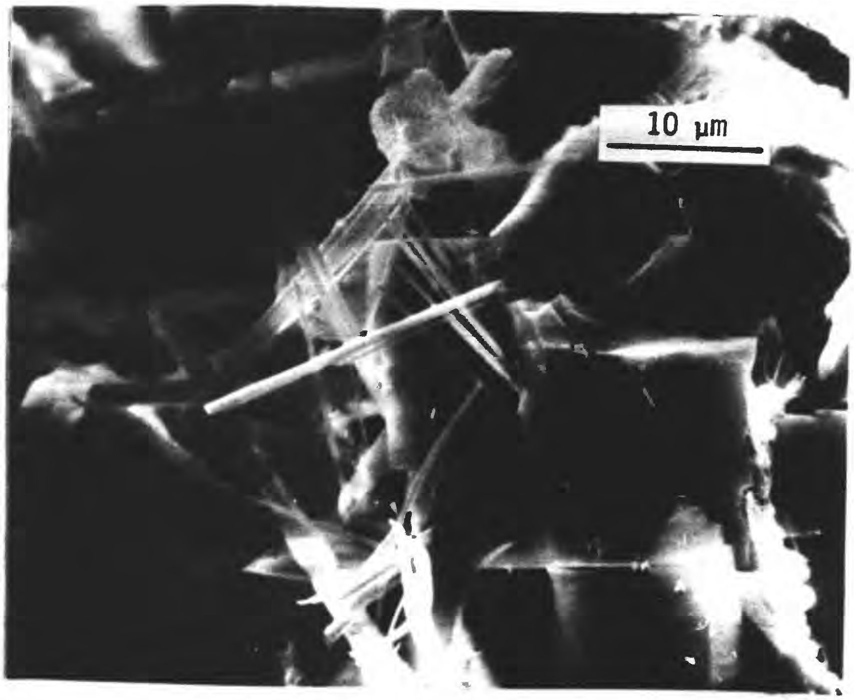


Figure 11. Scanning electron micrograph of ash-flow tuff from Tuzköy, Turkey, showing characteristic needle shape of erionite and rhombs of chabazite. (Sample 26-55-50).

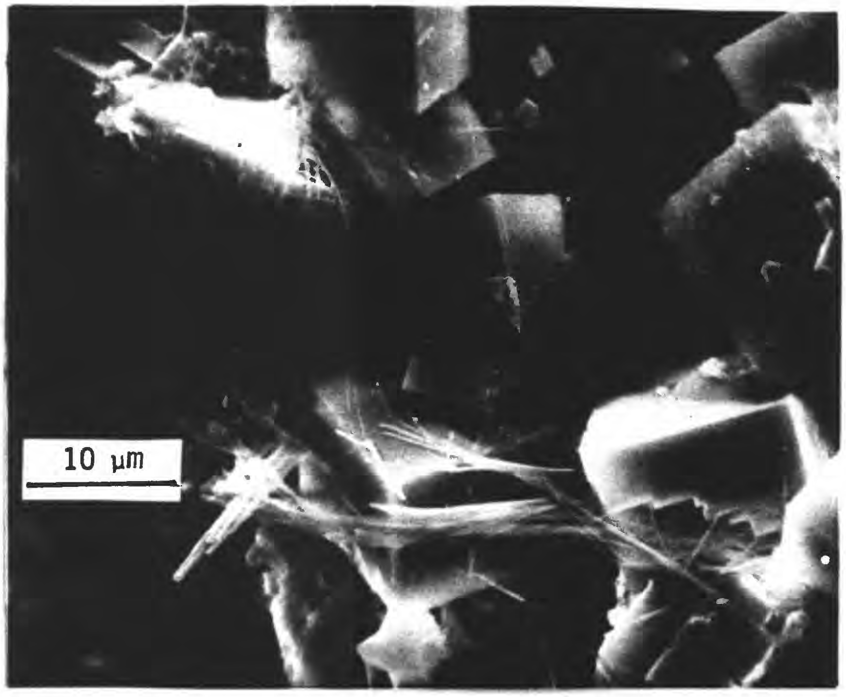


Figure 12. Scanning electron micrograph of ash-flow tuff from Tuzköy, Turkey, showing needles of erionite, rhombs of chabazite, and thin fibers of mordenite(?). Sample 26-55-50.

hundredths of a micrometer in diameter, also can be seen in Figure 12. Although supportive X-ray or electron diffraction data are lacking, this material may be the zeolite mordenite, which commonly occurs as needles and fibers of such dimensions (Mumpton and Ormsby, 1976). Whispy montmorillonite is also visible in Figure 12, as are pitted fragments of volcanic glass. Minor quantities of chabazite and erionite have been found in some samples of the fibrous pumice from Tuzköy, although many samples of the pumice appear to be zeolite-free.

Water classification was somewhat successful in concentrating chabazite in midling and float fractions (see Table 1); however, only minor increase in the erionite content of these products was achieved. Several of the starting samples and float products listed in Table 1 which showed no erionite by standard X-ray powder diffraction were examined by slow-scan diffraction between 10 and 4^{o} 2Θ, the region of the principal zeolite reflections. In no case was it possible to identify zeolite phases by this technique that were not also detectable by standard procedures.

Samples were also collected from what appeared to be the same stratigraphic horizon in Kizilköy and Çiftlikköy, 6 and 10 km south of Tuzköy, in the same valley. Although the life style in these villages appeared to be similar to that in Tuzköy, no mesothelioma has been detected. Both villages make extensive use of indigenous tuff as dimension stone, although basalt blocks are used for foundations and first floors of most dwellings. The bedrock is a poorly consolidated, non-welded, pink, ash-flow tuff, similar in appearance to that examined at Tuzköy, but somewhat less altered. Fresh glass is present in pumice fragments up to several centimeters in size, but the fibrous character of the glass, so prevalent in Tuzköy, is not as well developed.

Six samples from communal quarries, bedrock and building blocks were collected from the two villages and examined by X-ray powder diffraction (see Table 1). The tuff contains abundant unaltered glass, with trace to minor quantities of montmorillonite, quartz, feldspar, opal C/T, and illite. Zeolites were not positively identified in any of the samples examined, although a trace of chabazite may be present in sample 26-55-55. Slow-scan diffraction did not clarify the tentative nature of this identification.

Karain Area

Karain is located against the west wall at the north end of a narrow valley, varying from a kilometer to a few hundred meters wide, about 25 km east of Nevşehir. It is a peasant community, as are Karlik and Yeşilöz, 3 and 5 km to the south, respectively, in the same valley (see Figure 4). Although numerous cases of pleural mesothelioma have been reported in Karain, none have been diagnosed in the other two villages, despite the similarlity of geologic environment, occupations, water supply, and life styles[4]. A well-surfaced gravel road connects the three villages with the paved highway between Nevşehir and Incesu about 1 km north of Karain. A type stratigraphic section of Unit A and the upper part of Unit B are exposed in the west wall of the valley. As shown in Figure 13, the village of Karain is nestled among the "fairy chimneys" in the upper part of Unit B. Karlik and Yeşilöz are stratigraphically above Karain in prominent non-welded, ash-flow tuffs of Unit A. "Fairy chimneys" are not present in these villages. All three villages make extensive use of the indigenous tuff as dimension stone (see Figure 14).

Twelve samples were collected from a 30-m thick section in Karain, repre-

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[4]Although one case of mesothelioma has been reported from Yeşilöz, it is included with those from Karain because the patient was born and raised in Karain until she married and moved to Yeşilöz.

Figure 13. Karain, Turkey. Note the prominent exposures of Unit A overlying the upper part of Unit B at village level. Cultivated fields are in the foreground.

Figure 14. Typical street in Karain near the upper level of the village. Note the cave-pocked "fairy chimney" in the background and the use of indigenous tuff in construction.

senting bedrock and dimension stone from the highest inhabited level of the village to the main thoroughfare level at the bottom of the slope. X-ray powder diffraction identifications of all samples are listed in Table 1. In general, two types of tuffs were encountered: (1) a loosely consolidated, non-welded, altered tuff consisting mainly of fresh glass in the form of pumice fragments several centimeters in size, montmorillonite, and traces of quartz, feldspar, opal C/T, and illite (see Figure 10, 26-55-8 and 26-55-16); and (2) a similar, non-welded gritty tuff consisting of pyrogenic feldspar and cristobalite, with traces of quartz and illite. The partly dissolved nature of the glass in the first type of tuff is illustrated in Figure 15. Little glass was detected in the second type of tuff, although traces of gypsum or halite were identified in some samples. With one major exception, zeolite minerals were not positively identified in either bedrock or building block samples collected from Karain, using either of the two X-ray powder diffraction methods described above.

The one exception is sample 26-55-16-1, a soft, gray, friable tuff collected from a building block in the village library. This sample contains major amounts of erionite (nearly 50%, as estimated from oxygen-adsorption measurements), along with minor quantities of montmorillonite. The exact source of this block is, of course, unknown, and it is possible that it was quarried elsewhere and brought to the site when the relatively new library building was built. Not all of the dimension stone used in the villages of the region is indigenous; some of the blocks used in public buildings and mosques are quarried near Nevşehir and hauled by truck to construction sites. Scanning electron micrographs of rods and needles of erionite in this sample are shown in Figures 16 and 17. In contrast to the individual needles of erionite present in samples from Tuzköy, the Karain erionite occurs in <u>bundles</u> of rods, with aggregate sizes about 5-20 μm in diameter and about 20-80 μm in length. Individual rods are about 0.5 to

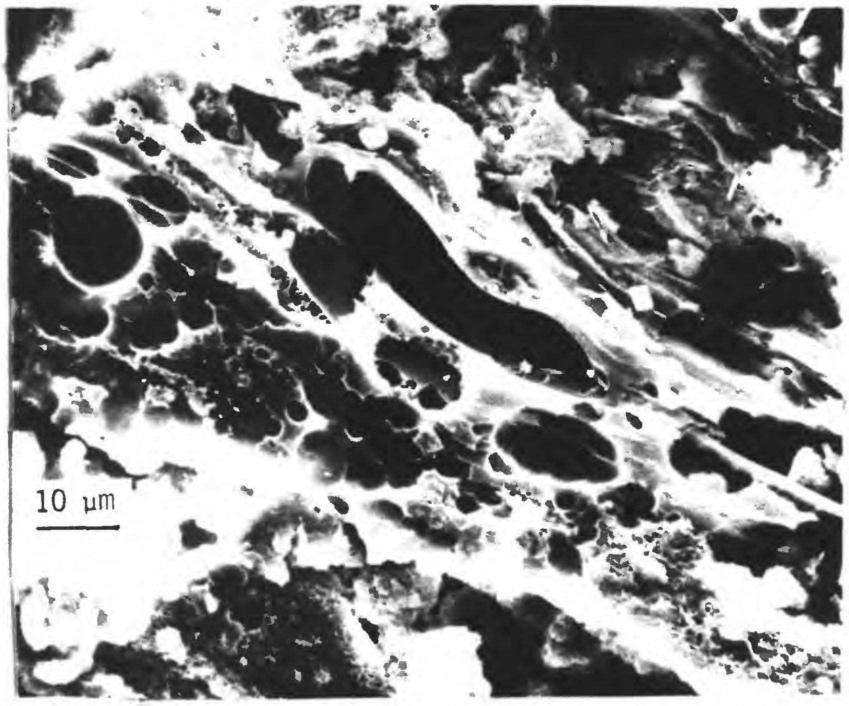

Figure 15. Scanning electron micrograph of pitted glass from Karain tuff. Filmy montmorillonite is also present. (Sample 26-55-8).

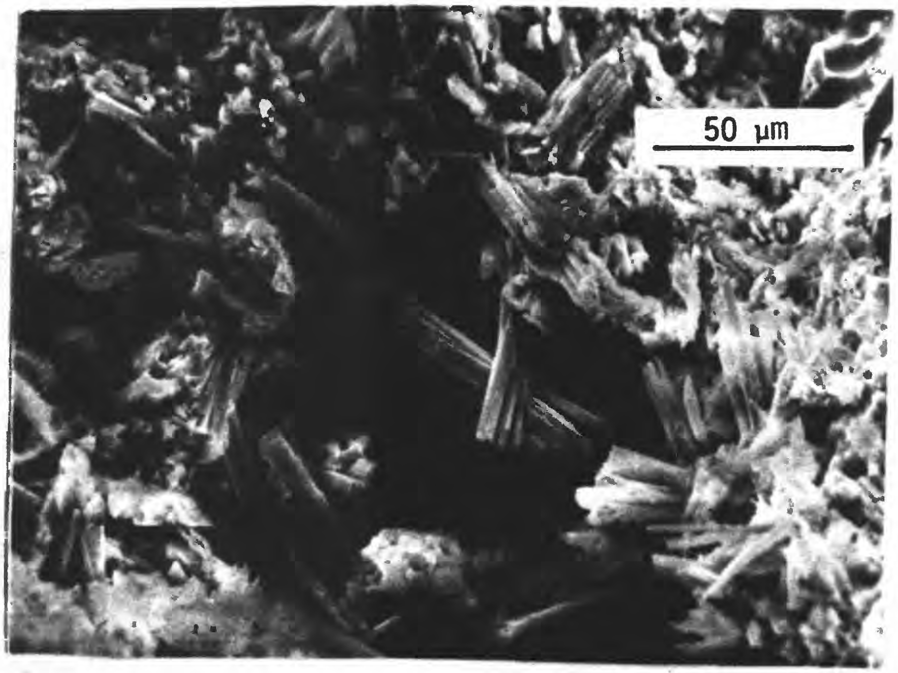

Figure 16. Scanning electron micrograph of erionite rods and needles from Karain tuff. Note the predominence of bundles of erionite. (Sample 26-55-16-1).

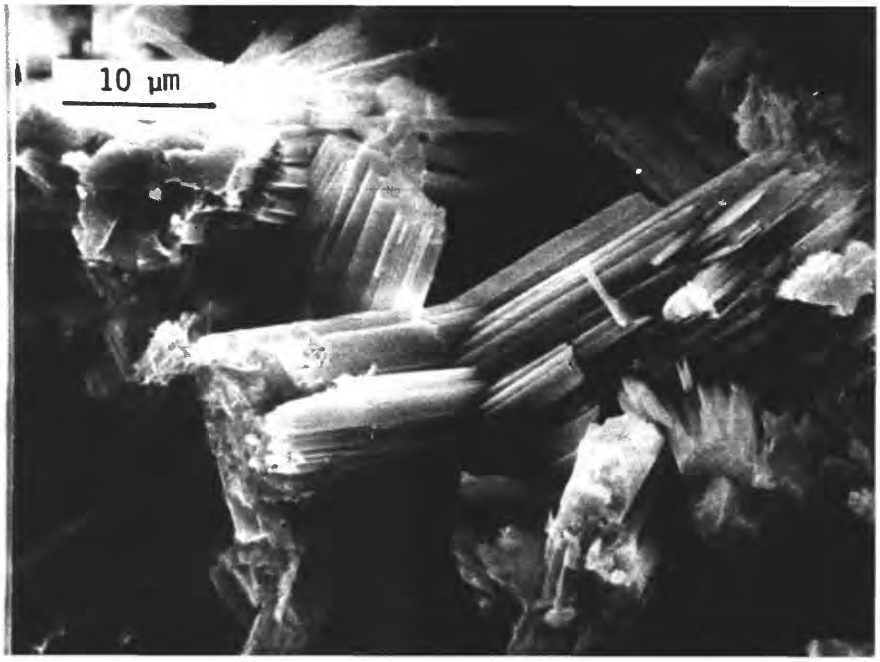

Figure 17. Scanning electron micrograph of rods and needles of erionite. Note the predominence of bundles of erionite. (Sample 26-55-16-1).

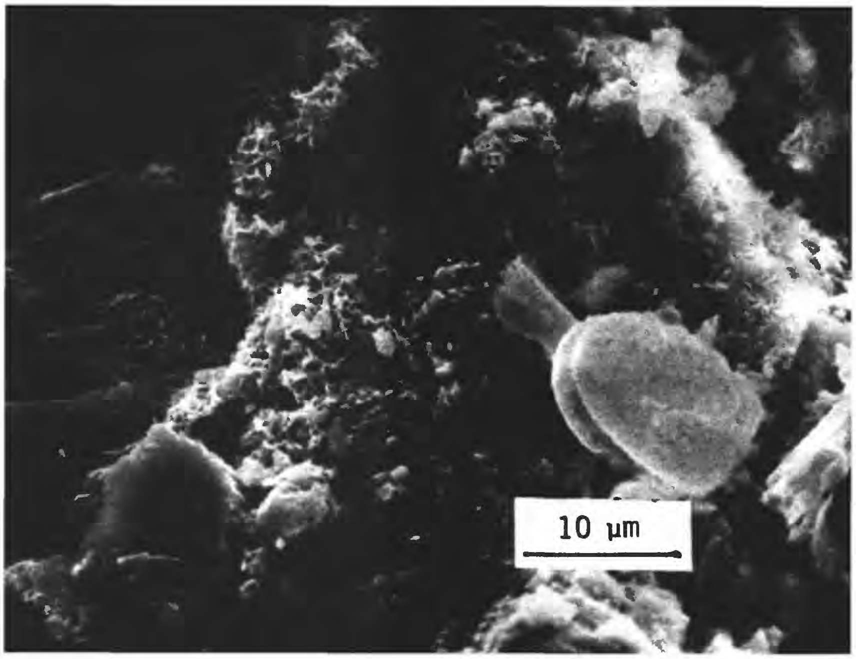

Figure 18. Scanning electron micrograph of massive erionite from Yeşilöz tuff, along with filmy montmorillonite. (Sample 26-55-21).

1.0 μm in diameter. Filmy montmorillonite can also be seen in Figures 16 and 17.

X-ray powder diffraction patterns of the float fractions of two additional samples from Karain (26-55-8-3, 26-55-12-2 and 3) suggest the presence of traces of erionite; however, the low intensity peaks could not unequivocally be distinquished from background, and thus, identification can only be tentative. Since the float fraction of sample 26-55-8 represents only 0.2% of the starting sample, if erionite were present, it would make up less than 0.002% of the rock, assuming a 1% detection limit for the zeolite by powder diffraction techniques. Slow scanning of these samples and fractions was unable to resolve peaks sufficiently for positive identification. Careful transmission or scanning electron microscopy coupled with selected area diffraction will be necessary to identify erionite in these materials.

Three samples of bedrock and building blocks were examined from Karlik. As shown in Table 1, zeolites were not identified in these materials. The Karlik materials are loosely consolidated, non-welded, altered tuffs consisting mainly of montmorillonite, opal C/T, and feldspar, with traces of quartz, volcanic glass, and illite.

Three samples of bedrock and building blocks from Yeşilöz were examined. All are loosely consolidated, non-welded, altered tuffs consisting mainly of feldspar and opal C/T, with minor amounts of montmorillonite, fresh glass, and traces of quartz and illite. Sample 26-55-21, however, contains substantial quantities of erionite (see Figure 10, 25-55-21). Scanning electron micrographs of this material are shown in Figures 18, 19, and 20. The massive character of the erionite is well-displayed in Figure 18, along with its coating of filmy montmorillonite. An enlargement of this field is shown in Figure 19, where the composite nature of the erionite laths and bundles can be seen. Erionite rods and needles are a few tenths of a micrometer in diameter and several micrometers in length. Blades and laths up to several tens of micrometers in length and from 5 to 10 µm wide are also present. As seen in Figure 20, there seems to be a tendency for the erionite laths to break up into short laths, rather than into thin needles.

Karacaviran Area

Karacaviran is located 3 km northwest of Karain on the paved highway between Nevşehir and Incesu (see Figure 4). Most of the buildings in this village are built on a side hill which consists of soft, ashy tuff. Although "fairy chimneys" are not present, the tuff has been excavated for foundations and used as dimension stone in most of the dwellings. Six samples of bedrock and building blocks from several levels of the village were examined. All are loosely consolidated, non-welded, altered tuff consisting mainly of fresh glass and montmorillonite, with traces of feldspar and opal C/T. Zeolites were not detected in five of the six samples examined. The sixth sample (26-55-30) was found to contain major amounts of erionite, in addition to minor quantities of fresh glass, montmorillonite, feldspar, and opal C/T (see Figure 15, 26-55-30). Adsorption analyses suggest that at least 25% erionite is present in this sample. Sample 26-55-30 was collected from a block used in the construction of a village well, close to the highway. It is pinkish tan and somewhat more consolidated than most of the tuff found in the village. It may have been quarried elsewhere.

Scanning electron micrographs of this material are shown in Figures 21, 22 and 23. The characteristic hexagonal outline of individual rods and bundles of rods of erionite is visible in both figures. In this sample also, erionite appears to be tightly packed into thick bundles which cleave into blocky rods, rather than into individual, thin fibers or needles. Some of the thick rods are 10-15 µm wide and 50-60 µm long. Individual needles, however, are only a

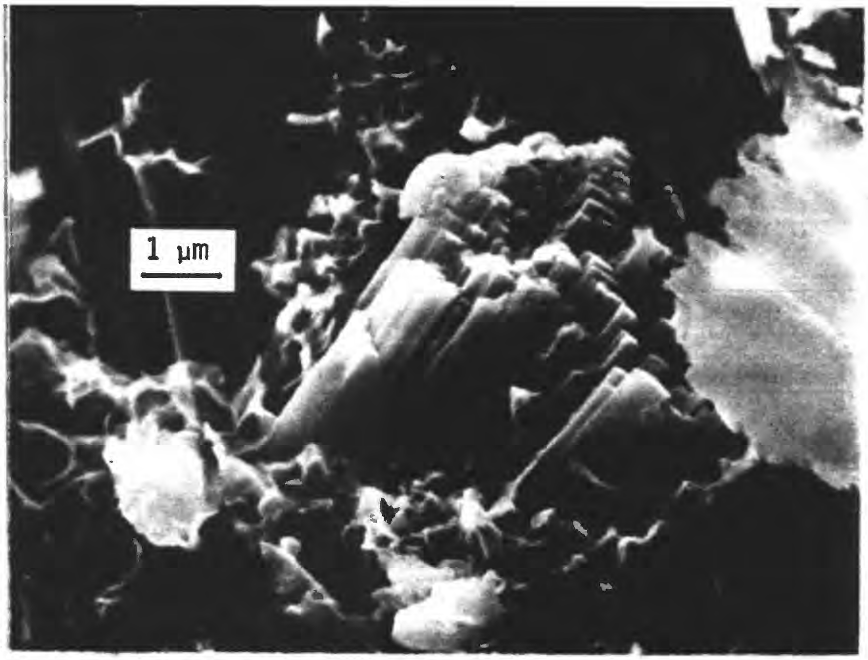

Figure 19. Scanning electron micrograph of erionite in bundles from Yeşilöz tuff. Enlargement of field shown in Figure 18. (Sample 26-55-21).

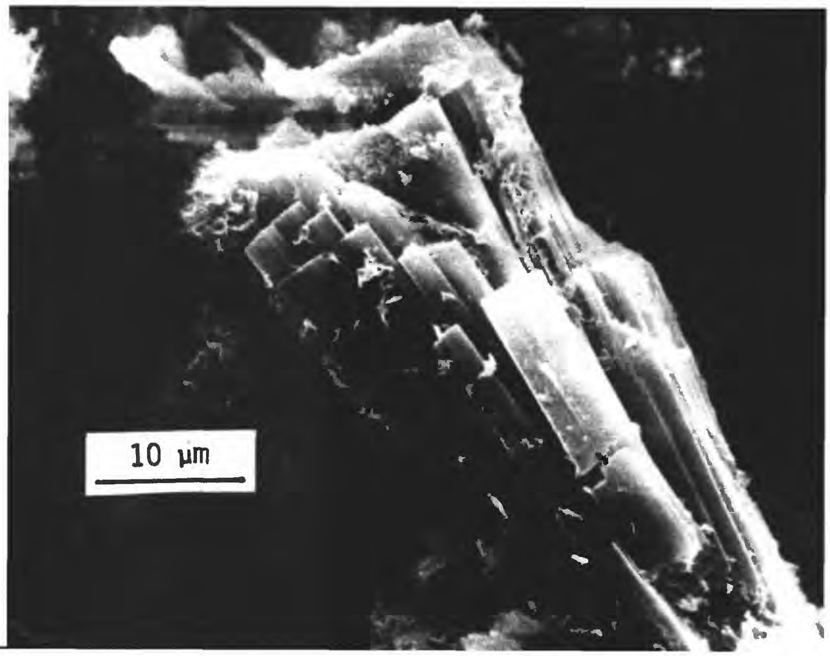

Figure 20. Scanning electron micrograph of erionite in the form of a bundle of laths or rods. Note the tendency to fracture across the laths. (Sample 26-55-21).

Figure 21. Scanning electron micrograph of erionite rods in bundles from Karaciviran tuff. Note the hexagonal cross sections. (Sample 26-55-30).

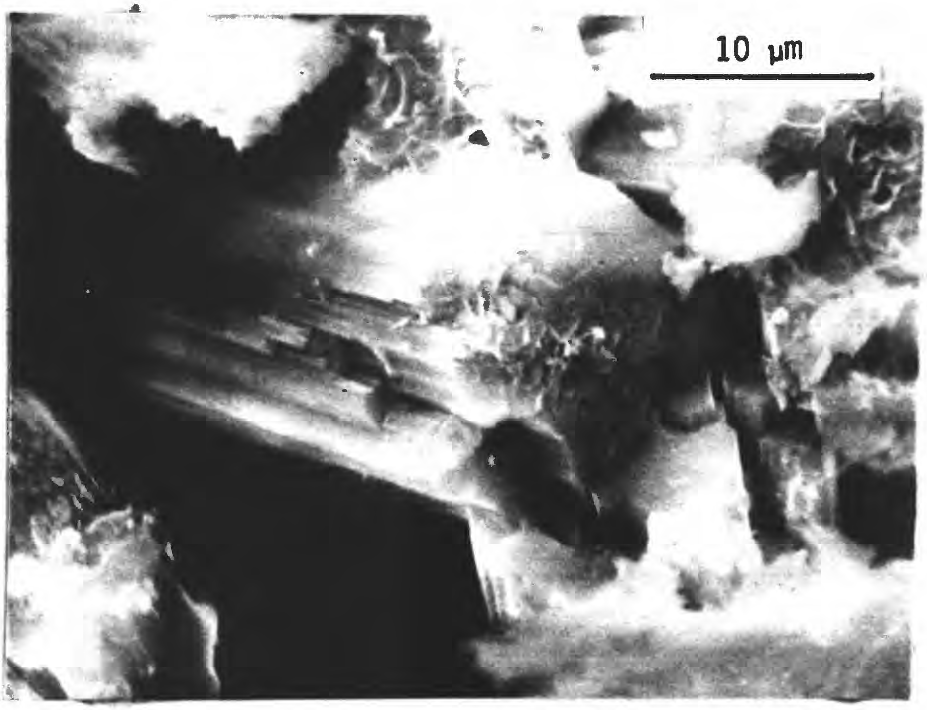

Figure 22. Scanning electorn micrograph of erionite bundle from Karaciviran tuff. Enlargement of field shown in Figure 21. (Sample 26-55-30).

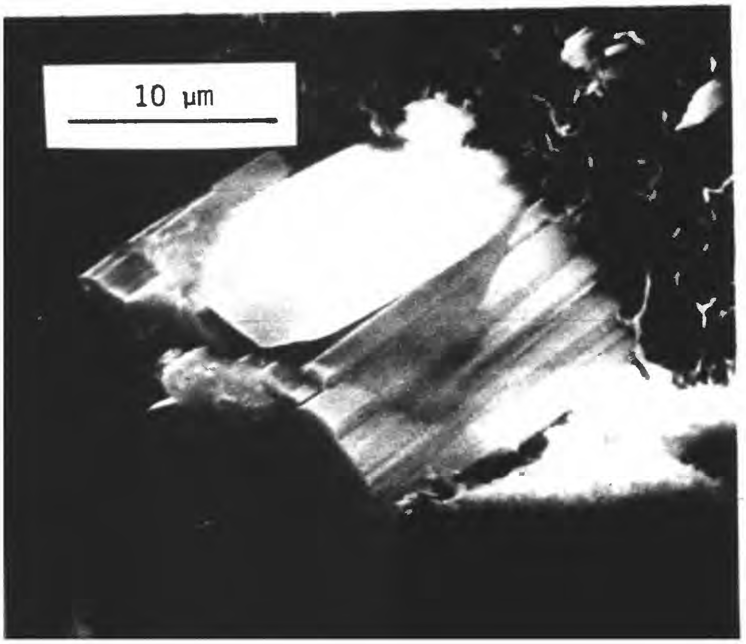

Figure 23. Scanning electron micrograph of bundles of erionite rods displaying prominent hexagonal cross sections. (Sample 26-55-30).

Figure 24. Uninhabited "fairy chimney" area I km east of Karaciviran.

few tenths of a micrometer in diameter. Such morphologies argue against the cleavage of the thick rods into individual needles of more than one micrometer in length.

Three samples were collected from a "fairy chimney" area about 1 km east of the village (Figure 24). Here the cones are pocked with caves, but the area is currently uninhabited. Samples of the somewhat more resistant tuff in a "fairy chimney" cone and of less resistant tuff adjacent to it were examined. As listed in Table 1, the major difference mineralogically appears to be a slightly greater amount of montmorillonite in the "fairy chimney" material, along with what may be a trace of erionite. The slightly greater amount of alteration of the glass may contribute to a higher degree of cementation and thereby account for the persistance of the "fairy chimneys". Much more work is obviously needed before more positive conclusions can be drawn. Questionable traces of erionite were detected by X-ray powder diffraction of two samples of "fairy chimney" material from this locality; however, verifying SEM or TEM studies have not yet been made.

Sarihidir Area

Sarihidir is located approximately 25 km northeast of Nevşehir on the Kizilmak River. Most of the village is on gentle hillsides on the north side of the river; however, numerous dwellings are on the south side, up against steep cliffs of ash-flow tuff. Several quarries are located in the tuff and have provided abundant blocks which have been used extensively for construction in the village. Ten samples of bedrock, dimension stone, and wall blocks were collected from locations on both sides of the river, including two small operating quarries. Identifications are listed in Table 1. With few exceptions, samples from Sarihidir are rich in the zeolite clinoptilolite, with minor to trace amounts of erionite, some of which can be seen with a hand lens. Chabazite was identified in 4 samples, including 26-55-25 which from oxygen-adsorption measurements (Table 2) appears to contain about 34% of this phase.

In general the erionite in tuff samples from Sarihidir appears to be of the "individual needle" type, similar in morphology to that found in Tuzköy, rather than of the "massive rod" type found in Karain, Karaciviran, and Yesilöz. In addition to zeolites, the tuffs contain lesser amounts of fresh and montmorillonite-altered volcanic glass, and trace to minor amounts of quartz, feldspar, cristobalite, and illite. Field observations coupled with X-ray powder diffraction data indicate that some of the tuffs used as dimension stone in this village are high-grade clinoptilolite, of suitable purity and thickness to constitute viable deposits of this material.

During the initial discussions at Hacettepe University Medical School, Bariş indicated that preliminary examination of microfilm X-ray data suggested the possible presence of mesothelioma in Sarihidir, although confirming evidence had not yet been obtained. On the basis of epidemiological and medical studies Bariş (personal communication) recently reported that although there is "significant amount of pleural calcification....we could not find mesothelioma (or) pleural thickening in this village".

Other Areas

In addition to the areas described above, samples of bedrock and building blocks were collected from five other villages, including Zelve, Göreme, Üçhisar, Taşkinpaşa, and Mustafapaşa, and from the city of Ürgüp. One sample was collected from the massive tuff into which the underground city at Kaymakli was dug. In all of these villages, "fairy chimneys" and mounds of easily carved tuff have been used for dwellings and storage pens, and the lifestyles, occupations, and general atmospheres are similar to those in Karain, Tuzköy, and Sarihidir. Ürgüp, on the other hand, is a small city with a population of about 10,000, and extensive use is made here of a durable, white and yellow tuff, quarried near Nevşehir, in the construction of mosques and public buildings. Except for the business district and the tourist hotels, however, most of the private dwellings in the city are housefronts built onto or caves cut into the soft tuff (Figure 7).

X-ray powder diffraction data for samples from the above communities and for size fractions prepared from these samples are listed in Table 1. Zeolite minerals were not identified in any of the samples examined by the X-ray powder diffraction techniques employed. The tuff samples closely resemble those described from other areas of Cappadocia; the seven samples from Ürgüp, for example, consist mainly of volcanic ash with trace to minor quantities of montmorillonite, quartz, feldspar, cristobalite, and illite. In one sample a questionable trace of chabazite was noted (26-55-59-2). Sample 26-55-60, a well-indurated, fine to medium grained white, homogeneous unit between Mustafapaşa and Taşkinpaşa, was identified as a high-grade montmorillonite, readily expandable with ethylene glycol.

DISCUSSION AND CONCLUSIONS

X-ray powder diffraction examination of 81 samples of bedrock and building blocks collected from 15 villages and 5 field locations has shown that most of the thick, volcanic tuffs that blanket the Cappadocia region in the vicinity of Nevşehir, Turkey, are relatively fresh, containing only trace to minor quantities of alteration products. In general, these non-welded, ash-flow tuffs are rich in unaltered pumice fragments, up to several centimeters in size, in a matrix of finer volcanic ash and pyrogenic quartz, feldspar, opal C/T, and micaceous minerals. Trace to minor amounts of montmorillonite are present in most samples, coating particles of pitted glass, and zeolite minerals have been unequivocally identified in tuff samples collected in five villages.

All seven samples collected from the mesothelioma village of Tuzköy are zeolitic, containing minor to major amounts of chabazite and traces (1-2%) of erionite, along with major amounts of fresh pumice. The pumice in bedrock from Tuzköy is somewhat unusual in that it occurs as needles and fibers of glass, some of which are as thin as 0.01 mm in diameter. The needles do not, however, appear to break up into thinner fibers in the so-called respirable size range on pulverization. Erionite occurs as individual needles about 0.5 µm in diameter and from 10 to 30 µm in length, associated with rhombs of chabazite from 3 to 30 µm in size. Very thin needles or fibers, a few hundredths of a micrometer in diameter are also present in some samples and may be the zeolite mordenite, although supporting X-ray or electron diffraction evidence is not available.

Of the 12 samples collected from Karain, the village having the higher incidence of mesothelioma, only one was found unequivocally to contain zeolite minerals. This sample consists of about 50% erionite in the form of bundles of rods or needles having aggregate sizes of 5-20 µm diameter and 20-80 µm length. Individual needles are 0.5 to

1 µm in diameter, but are rarely present. Erionite was also tentatively identified in two ultrafine size fractions prepared from Karain tuff, but without careful electron microscopic examination of these products, positive identification can not be made. One of these products represents only 0.2 weight percent of the starting sample; therefore, if erionite is present in this sample, it must be there in amounts less than 0.002%, assuming a 1% detection limit for X-ray powder diffractometry.

One of three and one of six samples from the non-mesothelioma villages of Yeşilöz and Karaciviran, located 5 km south and 3 km northwest of Karain, respectively, were found to contain substantial amounts of erionite, also as tightly packed bundles of rods or needles. The bundles measure 10-15 µm in diameter and 30-60 µm in length. Individual needles are 0.5 to 1 µm in diameter, but are rarely disaggregated from the bundles. Tentative identification of erionite was also made for two samples from an uninhabited "fairy chimney" area about 1 km east of Karaciviran, but here again careful electron microscopic examination will be needed to verify these identifications. Karain, Karaciviran, and the uninhabitated "fairy chimney" area appear to be in the same stratigraphic tuff unit.

All ten samples collected from the third non-mesothelioma village of Sarihidir are rich in the zeolite clinoptilolite, with varying amounts of chabazite and erionite. The erionite occurs as "individual needles", a habit similar to that of erionite in samples from Tuzköy. Some of these materials may be sufficiently high-grade to warrant commercial exploitation as ores of clinoptilolite, a material useful in pollution-abatement applications and as a dietary supplement in animal feeding (Mumpton, 1978).

Zeolites have not been detected in any of the samples collected from the remaining nine villages in the area using either normal or slow scan X-ray powder diffractometry. Most of these villages are located in the same or similar volcanic tuff units as the above communities, and substantial use is made of indigenous tuff for construction purposes.

Thus, the mineralogical data available at this time indicate that (1) zeolites (and needle-shaped erionite) are present in all samples from one of the two mesothelioma villages (Tuzköy) in the region; (2) zeolites are rare in the other mesothelioma village (Karain), erionite having been detected to date in only 1 of 12 samples; (3) zeolites are likewise rare in two non-mesothelioma villages in close proximity to Karàin (Yeşilöz and Karaciviran), although substantial erionite has been detected in one sample from each village; (4) zeolites, including erionite, are abundant in a third non-mesothelioma village, Sarihidir; and (5) zeolites have not been detected in samples from any of nine other villages in the region in the same geological environment. In so far as a positive correlation between the existence of erionite or other zeolites in the indigenous tuffs of these Turkish villages and the incidence of pleural mesothelioma, the data are equivocal and tend to suggest that no correlation exits.

It is therefore erroneous to state that zeolite minerals (and especially erionite) constitute an environmental health hazard capable of causing malignant disease or that these materials should be considered as "possible" carcinogens. This does not mean, however, that additional data will not be found that link erionite or other zeolites to mesothelioma in this region. A dose-response relationship between exposure to exogenous agents and clinical mesothelioma has never been established, nor has anything resembling a threshold level of exposure been proposed. It may well be that concentrations considerably lower than 1 ppb are sufficient to trigger the development of malignant tumors, but no data are available to support such claims. Inasmuch as X-ray powder diffraction, even under the best of conditions, is incapable of detecting zeolite minerals at levels less than about 1%, it is vital that all samples be examined by careful electron microscopy, utilizing both scanning and transmission techniques and selected area diffraction where possible. Such studies will not only establish the presence or absence of zeolites, but will also provide information of the particle-size distribution and state of aggregation of these materials. These investigations are in progress and will be reported at a later date.

To supplement the reconnaissance data available today, additional samples must be collected from all villages in the Cappadocia region where zeolites have been identified, including both mesothelioma communities and non-mesothelioma communities, as well as from other villages in the region which have not yet been included in the investigation but which are located in areas of similar volcanic tuff. A second visit to the area will therefore be made in May, 1979. Although a few airborne dust samples may also be collected from several villages in the region, systematic air sampling is beyond the scope of this investigation. If zeolite minerals are present in the bedrock and building blocks of a community, there is little question but what such materials will be present in the airborne dust in that community and thus in the lungs of the inhabitants. This is not the question. The question is whether or not all communities in areas where zeolitic tuffs are prevalent are afflicted by pleural mesothelioma and whether or not all mesothelioma communities in this volcanic tuff region are located in zeolite-rich areas. Hopefully such mineralogical investigations will become part of a larger body of knowledge concerning the incidence of this lethal form of cancer in the Cappadocia region, including much needed genetic studies of ingrown population of these small peasant villages.

Although the incidence of mesothelioma in Karain and Tuzköy is well documented, detailed retrospective or prospective analyses of most of the other villages in the region have not been made, and it may be that once the medical histories of these villages are examined, other cases of mesothelioma will be uncovered. If such is the case, common environmental or genetic denominators must be sought. The only ubiquitous mineralogical parameter noted to date is the overwhelming abundance of fresh volcanic glass, much of which occurs as spicules and elongate fragments in all particle-size ranges. The biological reactivity of such material is unknown. Speculation of this kind, however, should not abort continued investigation of the possible relationship between mesothelioma and zeolite distribution in the region.

No one connected with synthetic or natural zeolites wishes to see them used in any way that would endanger the health of the user, and if strong evidence exists that connects any one zeolite mineral with the high incidence mesothelioma in this region, it is imperative that precautionary measures be taken in these villages to halt exposure to such materials. If a positive and significant correlation exists between zeolites and mesothelioma, it is also imperative that steps be taken to minimize or prevent exposure to all individuals in every country who are engaged in zeolite mining, milling, and processing and that the multimillion dollar synthetic molecular sieve and the fledgling natural zeolite businesses use zeolites in such a way as to eliminate exposure danger to the general population.

A corollary caveat is that the geological profession must become seriously involved in such investigations, not only of zeolites and mesothelioma in central Turkey, but of all mineral materials that are being labeled by health and medical workers as possible or suspected health hazards. Only if there is an overwhelming body of reliable geological and mineralogical knowledge about these materials can a proliferation of "bad science" be avoided. The recent rash of speculative and inflammatory statements by overzealous researchers and representatives of regulatory agencies has alarmed the general public and maligned many areas of the mineral industries. As indicated by Comar (1978), preliminary results are often taken at face value; they are misinterpreted and extrapolated far beyond their validity, with the qualifications and uncertainties of the original premises being all-too-often forgotten or discarded completely, especially when the statements are made to the press rather than to a critical scientific audience.

The present investigation will continue with the analysis of additional samples from the Cappadocia region of Turkey and by detailed examination of all samples by scanning and transmission electron microscopy.

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REFERENCES

Ataman, G., 1978, The zeolitic tuffs of Cappadocia and their probable association with certain types of lung cancer and pleural mesothelioma: Comptes Rendus de l'Academie des Sciences, Paris, Ser. D, v. 287, p. 207-210.

Bariş, Y. I., 1975, Pleural mesotheliomas and asbestos pleurisies due to environmenta asbestos exposure in Turkey: An analysis of 120 cases: Hacettepe University Bulletin of Medicine/Surgery, v. 8, p. 167-185.

Bariş, Y. I., Özemsi, M., Kerse, I., Özen, E., Şahin, A., Kolaçan, B., and Ogankulu, M 1975, An outbreak of pleural mesothelioma in the village of Karain/Ürgüp - Anatolia: Kanser, v. 5, p. 1-14.

Bariş, Y. I., Şahin, A. A., Kerse, I., Özen, E., Kolaçan, B., Ogankulu, M., and Göktepeli, A., 1976, An outbreak of pleural mesothelioma in the village of Karain/Ürgüp - Anatolia: Medicine Biologie/Environment, v. 3, p. 5-11.

Brinkmann, Roland, 1976, Geology of Turkey: Stuttgart, Ferdinand Enke Verlag, Ch.15, p. 71-78.

Comar, Cyril, 1978, Bad science and social penalties: Science, v. 200, p. 1225.

Elmes, P. C., 1977, Report on visit to Turkey 11th October - 15th October 1977: Reference PCE/MEW/307A/CF, Medical Research Council Pneumoconiosis Unit, Llandough Hospital, Penarth, Glamorgan, Wales, October 18, 1977, unpublished report, 15 p.

Ketin, Ihsan, 1963, Explanatory text of the geological map of Turkey, Keyseri sheet: Maden Tetkik ve Arama Enstitüsü Vayinlarindan, p. 35-58.

McDonald, J. C. and McDonald, A. D., 1977, Epidemiology mesothelioma from estimated incidence: Preventative Medicine, v. 6, p. 426-446.

McNulty, J. C., 1962, Malignant pleural mesothelioma in asbestos worker: Medical Journal of Australia, v. 2, p. 953-955.

Milne, J., 1977, Mesothelioma in central Turkey: Duty Travel Report, International Union Against Cancer, Geneve, Switzerland, unpublished, 12 p.

Mumpton, F. A. and Ormsby, W. C., 1976, Morphology of zeolites in sedimentary rocks by scanning electron microscopy: Clays and Clay Minerals, v. 24, p. 1-23.

Mumpton, F. A., 1978, Natural zeolites: A new industrial mineral commodity, in Sand, L. B. and Mumpton, F. A., eds., Natural Zeolites: Occurrence, Properties, Use: Elmsford, New York, Pergamon Press, p. 3-27.

Pooley, F. D., 1978, Report of the examination of Turkish samples: Letter Report, University College, Cardiff, Wales, Jan. 3, 1978, unpublished, 5 p.

Ross, Malcolm, 1978, Asbestos health risks to the mining communities of North America: Geological Society of America, Abstracts with Programs, v. 10, p. 481.

Stanton, M. F. and Layard, M., 1978, The carcinogenicity of fibrous minerals: National Bureau of Standards Special Publication 506, p. 143-151.

Wagner, J. C., Berry, G., and Timbrell, V., 1973, Mesothelioma in rats after inoculation with asbestos and other minerals: British Journal of Cancer, v. 28, p. 173-185.

Wagner, J. C., Sleggs, C. A., and Marchand, P., 1960, Diffuse pleural mesothelioma and asbestos exposure in the Northwestern Cape Province: British Journal of Industrial Medicine, v. 17, p. 260-271.

APPENDIX I

PUBLISHED NEWS ARTICLES

ON THE TURKISH ZEOLITE-MESOTHELIOMA PROBLEM

This week
continued

Cancer epidemic raises doubts on mineral fibres

Lawrence McGinty

A remote Turkish village called Karain is about to be enshrined in medical history--because it is the scene of an epidemic of an otherwise very rare tumour called mesothelioma, and because this epidemic throws considerable doubt on the safety of a whole range of man-made mineral fibres suggested as substitutes for asbestos.

In the five years between 1970 and 1974 almost half the people who died in Karain (which in Turkish means "abdominal pain") died from mesothelioma (cancer of the lining of the lung or abdomen). In those years, Karain's population fluctuated between 600 and 800. Twenty-four of the 55 deaths in the village between 1970 and 1974 were attributed to mesothelioma by a team of investigating physicians from Hacettepe University in Ankara lead by Dr Y. Izzettin Baris. In the following two years 16 people died from either mesothelioma or pleurisy. Mesothelioma is so rare that only 100 or so cases are recorded annually in Britain (although other cases may go unrecorded because the disease is difficult to diagnose). For almost 50 per cent of deaths in an area to be caused by mesothelioma is unprecedented and represents an astronomically high incidence rate.

But the outbreak of mesothelioma in Karain is much more than just a medical curiosity. It has enormous implications for the strategies of governments throughout the developed world trying to reduce the toll of diseases caused by asbestos. Mesothelioma was first found to be caused by asbestos in surveys of South African asbestos miners carried out by Dr Chris Wagner. Since then all kinds of asbestos fibre have been found to cause the disease, although it seems likely that blue asbestos (crocidolite) is more potent than other asbestos fibres.

Experiments on rats in the US National Cancer Institute by Mearle Stanton and at the UK Medical Research Council's Pneumoconiosis Unit in Penarth (where Wagner now works) have shown that other silicate fibres (notably glass fibre) can also induce mesothelioma. Crucially, the fibres have to be the "right" size to be successful in causing the tumour—more than 0·2 micrometres in diameter and between 3 and 15 micrometres long. The animal experiments involve embedding fibres in the chest wall of rats, and so extrapolating their results to man has been regarded as, at best, risky. If, however, it could be shown that fibres other than asbestos cause mesothelioma in man, then the theory that size is crucially important in defining which fibres cause mesothelioma might be confirmed.

And, perhaps more important, safety agencies throughout the world who are considering bans on asbestos because of its cancer-causing potential would be faced with a serious problem. Glass fibre is increasingly used and promoted as a "safer" substitute for asbestos. If it is true that silicate fibres other than asbestos also cause mesothelioma (if they are of the right size) this substitution strategy would look much less attractive.

The Karain epidemic certainly seems to suggest that fibres other than asbestos are implicated in human mesotheliomas. Baris and his team carried out an extensive survey of the village for possible carcinogens—and turned up negative results. In a paper in the latest issue of the journal *Thorax* (vol 33, p 181), Baris suggests that "asbestiform" fibres in Karain's drinking water could be responsible for the mesothelioma outbreak.

But more recent research, in conjunction with Dr Fred Pooley from University College, Cardiff—a world expert on the analysis of asbestos fibres—has shown that these fibres are not, in fact, asbestos. Attention has now focused on a group of volcanic silicates called zeolites. Not all zeolites are fibrous, but Pooley has found fibrous zeolites in blocks of volcanic rock that the inhabitants of Karain hew for building blocks and road-making materials. Further, the dimensions of these zeolite fibres are similar to those of amosite and crocidolite—precisely those asbestos fibres known to be most active in causing mesothelioma.

The connection between exposure to zeolite and the astonishing incidence of mesothelioma in Karain is by no means proven. But the connection is striking and is causing quite a stir internationally. Baris and his research group are being now helped by researchers from the MRC unit in Penarth, by Pooley, and by the International Agency for Research on Cancer in Lyon. So crucial is the research that the whole international community of asbestos researchers is anxious to assist Baris—who next month will travel to New York to meet Irving Selikoff of the Mount Sinai Hospital (one of the best known asbestos researchers) and to give a paper on his research to the New York Academy of Sciences.

The consensus among researchers in the area is clear. If the link with zeolite is confirmed it would be the first human evidence that non-asbestos silicate fibres cause mesothelioma.

That, according to Dr Peter Elmes, of the MRC's Penarth unit, would mean "tremendous risks for substitutes for asbestos". IARC is just beginning a study of 12 European glass-fibre factories to assess the hazards of the best-known man-made mineral fibre. But results will not be available for several years. □

NEW ORLEANS
THE TIMES
SUNDAY, JULY 23

Mineral Goes on Cancer Suspect List

WASHINGTON — Researchers have uncovered evidence that a type of mineral found widely throughout the western United States may be linked to a rare form of lung cancer previously believed to be caused only by human exposure to asbestos.

British and Turkish medical experts found recently that at least 10 residents of two small villages in central Turkey had developed mesothelioma, a cancer of the lung lining, which until now had been associated only with asbestos.

A member of the British medical team told a scientific gathering in New York on Friday that the Turkish villagers apparently developed the disease after breathing dust that contained a member of a mineral family known as zeolites.

U.S. medical and geologic experts, who took part in the New York Academy of Sciences symposium last week where the findings were revealed by British lung disease specialist Dr. Peter Elmes, said that the Turkish report was still "very preliminary." But they urged a rapid investigation of potential harmful effects from zeolites in the United States.

The mineral family is found widely in soft rock formations from the Canadian border to southern Arizona in the West. About 40 types of the mineral occur naturally and scientists have synthesized 100 other varieties in what is considered a rapidly growing field of use for the mineral.

Thus far, there has been little scientific investigation into potentially hazardous properties of the fibrous mineral, scientists said. It is still unclear what, if any, potential damage it may have caused to persons living near natural formations of zeolites in the West, they said. But one expert said the latest findings should constitute a "warning flag" to spur government research in the area.

D.E.W. Vaughan, a research manager at the W.R. Grace Co. Washington Research Center in Columbia, Md., said that one form of zeolite with a chemical structure close to asbestos is being tested by the Environmental Protection Agency to clean up municipal sewage waste.

Vaughan, an expert in the mineral, said a type of zeolite called erionite, which has needle-like fibers, may possibly cause the same scarring of lung tissue that asbestos does. The scarring leads to mesothelioma, a usually fatal cancer.

Zeolites with other chemical structures are also widely used in refineries, Vaughan said, to aid in the distillation, or "cracking," of crude oil into gasoline.

Dr. Irving Selikoff, of the Mt. Sinai Medical Center in New York, said his researchers had also tentatively linked zeolites with lung damage similar to that caused by asbestos. Selikoff said he has recently treated two patients -- one a refinery worker — whose lungs were damaged after exposure to zeolites.

"This is simply first observation but it does give us some direction since we have two separate sources," Selikoff said. He said the findings appear to support some earlier research done at the National Cancer Institute showing that all fibrous minerals with asbestos-like composition should be considered potentially dangerous.

Another expert in the mineral said, however, that the evidence linking zeolites with lung cancer in the Turkish villages is still sketchy.

Frederick Mumpton, a professor of mineral science at the state university of New York In Brockport, said in a telephone interview that he visited the two Turkish villages two weeks ago to collect dust and rock samples.

Mumpton said that while the villages — known as Karain and Turzkoy — did have zeolites in their dust samples, other villages that also showed the presence of the mineral did not have any evidence of mesothelioma in their populations.

ENVIRONMENT
7/15/78 Science News
114, No. 3, p41

Janet Raloff reports from the New York Academy of Sciences' International Conference on Health Hazards of Asbestos Exposure

When "asbestos diseases" are not

Mesothelioma, a cancer of membranes lining the chest and abdominal cavity, is extremely rare except among asbestos workers. In fact, whenever a larger than expected incidence of this cancer is found, asbestos is immediately held suspect. But three Turkish researchers from Hacettepe University Medical School in Ankara, reported finding asbestos-free regions in Turkey where asbestos-related diseases — such as mesothelioma, calcified pleural plaques and chronic fibrosing pleuritis — are very common. Mineral fibers of the same general size and shape as asbestos have been found, however, suggesting that it is the size and shape of inhaled fibers, not the mineral itself, that causes the diseases, according to Y. Izzettin Baris, Mustafa Artvinli and A. Altay Sahin.

S. Yazicioglu and colleagues believe that inhalation of asbestos fibers from a popular, white, house stucco is the cause of the diseases. But the Hacettepe study contradicts this. Some asbestos-free towns with high numbers of "asbestos related diseases" also use asbestos-free stucco. And many towns with the same asbestos stucco have widely different proportions of these diseases. (Since most of the afflicted were rural peasant farmers, industrial exposures could be ruled out.)

Karain, an asbestos-free town, exemplifies the problem. In 1974, 11 of its 18 deaths (in a population of 604) were from mesothelioma. While clumps of asbestos had been found in old drinking-water wells, Baris and colleagues concluded (after conferring with British colleagues) that tumors from contaminated water were "highly improbable." Erionite, a form of zeolite, was a much more likely culprit, they said. Not only were its needle-like fibers found in local rock and soil, but also in the lung of at least one man (from another asbestos-free town) with CFP.

In the future, the Hacettepe researchers would like to see regions studied by Yazicioglu examined for erionite. They also suggest implanting fibers of inhalable-size, nonasbestos minerals into animals to confirm the "size and shape" theory.

Environmental Health Letter, July 1, 1978

MESOTHELIOMA FINDINGS IN TURKEY MAY REOPEN QUESTION OF FIBER-RELATED DISEASE:

The unexpected finding of mesothelioma among residents of the villages of Karain and Urgup in Turkey, where zeolite formations are found in homes and caves but where no asbestos is mined, has reopened the entire question of pulmonary diseases related to fibrous minerals. It had been assumed that mesothelioma could occur only in association with asbestos, but the discovery of the condition in association with zeolite, which is a group of minerals closely related to feldspar will, in the words of one government official, "start a whole new ballgame."

Zeolite is used in a variety of consumer products, including water softeners and in treatment of sludge. It is mined rather extensively in southwestern United States and is now cause for new concern, though hardly panic in the light of the findings in Turkey. The data from Turkey was compiled by Dr. Peter Elmes of the Pneumoconiosis Unit, Llandough Hospital, Penarth, Wales, and reported to the symposium sponsored by the New York Academy of Sciences this week.

In Turkey the cases are in a non-mining area and not related to occupation. The cases have occurred in residents of the villages, including youngsters.

Oddly enough, some villages where zeolite is present have not exhibited any cases. At any rate, the source of the zeolite are cave dwellings, where the mineral is found naturally. In addition to living in the caves, some of the villagers use the caves for storage. Zeolite is also used for building.

The main constituent of the zeolite throughout the area is chabazite. In the soil and street dust of the villages where mesothelioma is found, electron microscopy has revealed fine fibers in the chabazite. This was not found in villages where no mesothelioma occurred.

More details were provided in an article in Thorax Journal by a group of investigators from Hacettepe University School of Medicine and Institute of Mineral Research and Exploration in Ankara. They reported that the 575 inhabitants of Karain suffered 11 deaths from pleural mesothelioma in 1975-76 and there were five cases of fibrosing pleurisy. In the previous five years there had been 25 cases of mesothelioma.

Asbestos does not occur in the local soil or rock, nor is it handled in the village, but a few fibers were found in the water, said the investigators, headed by Dr. Y.I. Baris of the medical school. Fibers were also found in the pleural tissue of two of the five cases examined.

Karain is well known to tourists in Turkey because of the picturesque rock dwellings called "fairy chimneys." For a long time, say the investigators, it has been known that the people of Karain die of cancer. The saying goes that "the peasant of Karain falls ill with pain in the chest and belly, the shoulder drops, and he dies."

Mineral Linked to Asbestos-Type Lung Damage

By Bill Richards
Washington Post Staff Writer

Researchers have uncovered evidence that a type of mineral found widely throughout the western United States may be linked to a rare form of lung cancer previously believed to be caused only by human exposure to asbestos.

British and Turkish medical experts found recently that at least 10 residents of two small villages in central Turkey had developed mesothelioma, a cancer of the lung lining, which until now had been associated only with asbestos.

A member of the British medical team told a scientific gathering in New York on Friday that the Turkish villagers apparently developed the disease after breathing dust that contained a member of a mineral family known as zeolites.

U.S. medical and geologic experts, who took part in the New York Academy of Sciences symposium last week where the findings were revealed by British lung disease specialist Dr. Peter Elmes, said yesterday that the Turkish report was still "very preliminary." But they urged a rapid investigation of potential harmful effects from zeolites in the United States.

The mineral family is found widely in soft rock formations from the Canadian border to southern Arizona in the West. About 40 types of the mineral occur naturally and scientists have synthesized 100 other varieties — what is considered a rapidly growing field of use for the mineral.

Thus far, there has been little scientific investigation into potentially hazardous properties of the fibrous mineral, scientists said. It is still unclear what, if any, potential damage it may have caused to persons living near natural formations of zeolites in the West, they said. But one expert said yesterday the latest findings should constitute a "warning flag" to spur government research in the area.

D.E.W. Vaughan, a research manager at the W.R. Grace Co. Washington Research Center in Columbia, Md., said that one form of zeolite with a chemical structure close to asbestos is being tested by the Environmental Protection Agency to clean up municipal sewage waste.

Vaughan, an expert in the mineral, said a type of zeolite called erionite, which has needle-like fibers, may possibly cause the same scarring of lung tissue that asbestos does. The scarring leads to mesothelioma, a usually fatal cancer.

Zeolites with other chemical structures are also widely used in refineries, Vaughan said, to aid in the distil lation, or "cracking," of crude oil into gasoline.

Dr. Irving Selikoff, of the Mt. Sinai Medical Center in New York, said yes terday his researchers had also tenta tively linked zeolites with lung damage similar to that caused by asbestos. Selikoff said he has recently treated two patients—one a refinery worker—whose lungs were damaged after exposure to zeolites.

"This is simply first observation but it does give us some direction since we have two separate sources," Selikoff said. He said the findings appear to support some earlier research done at the National Cancer Institute showing that all fibrous minerals with asbestos-like composition should be considered potentially dangerous.

Another expert in the mineral said yesterday, however, that the evidence linking zeolites with the lung cancer in the Turkish villages is still sketchy.

Frederick Mumpton, a professor of mineral science at the State University of New York in Brockport, said in a telephone interview that he visited the two Turkish villages two weeks ago to collect dust and rock samples.

Mumpton said that while the villages—known as Karain and Tuzkoy—did have zeolites in their dust samples, other villages that also showed the presence of the mineral did not have any evidence of mesothelioma in their populations.

THE JERSEY JOURNAL
JERSEY CITY, N. J.
D 73,151 SUN. 68,613

JUN 28 1978

Mineral may be linked to cancer

Washington Post

WASHINGTON — Researchers have uncovered evidence that a type of mineral found widely thoughout the western United States may be linked to a rare form of lung cancer previously believed to be caused only by human exposure to asbestos.

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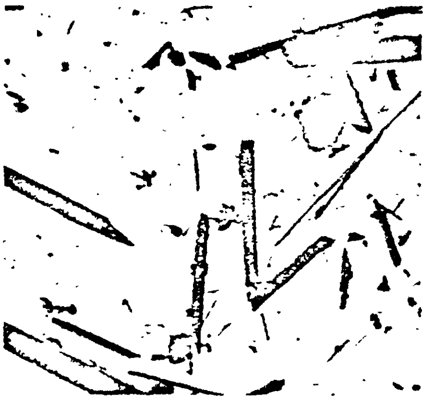
MEDICAL WORLD NEWS/*July 24, 1978*

New mineral linked to mesothelioma cluster in Turkey



Electron micrograph shows zeolite particles, not from Turkish samples.

NEW YORK—Just as Turkish researchers were homing in on a mineral called zeolite—in the absence of asbestos—as the cause of a cluster of 50 mesothelioma cases in two small villages in central Turkey, an American mineralogist has found a chink in the link. Another village with soil rich in the same mineral has no mesothelioma.

The 50-case cluster had raised concern about the potential health hazards of inorganic fibrous materials other than asbestos. In the village of Karain, with 600 inhabitants, 24 of 55 deaths that occurred between 1970 and 1974 have been attributed to mesothelioma, says chest physician **Y. Izzettin Baris** of Hacettepe University in Ankara.

There is little asbestos around Karain or nearby Tuzköy in central Turkey, he told an audience here at the New York Academy of Sciences conference on environmental health hazards. But, he said, scientists from Ankara, Britain, and the U.S. have detected a type of mineral called zeolite in soil and volcanic rock used as building blocks in those villages. The particular form of zeolite (more than 40 are known) found there is called erionite. It has needle-like fibers and is widespread in Nevada, Arizona, Oregon, California, and Wyoming.

A team of scientists from Ankara has been investigating asbestos-related disease in Turkey for several years. They have identified 148 cases of mesothelioma, but the only large cluster is at Karain-Tuzköy. In a preliminary report in the April issue of the British journal *Thorax*, they describe their analysis of the physical and economic structure of the villages, working and living patterns of the inhabitants, and results of physical and x-ray examinations. They also studied rocks, soil, airborne dust, foods, and water.

At first, the Turkish team thought "a few asbestiform fibers" found in the water supply might be the cause of the mesotheliomas and of five cases of fibrous pleuritis also found in Karain. But they couldn't explain why the diseases did not also occur in other villages located in the same valley.

Then, more recent studies by a team at University College in Cardiff, Wales, identified erionite in soil samples sent from Turkey. Dr. **Fred Pooley**, a specialist in inorganic fibers at the Cardiff center, who identified the fibers by electron microscopy, told the academy meeting that he now "would suggest that the word 'asbestos' in connection with mesothelioma be replaced by the phrase 'inorganic fibrous particles.' "

Dr. **Irving J. Selikoff**, director of environmental medicine at New York's Mount Sinai School of Medicine, agrees. The Turkish findings raise concern about the disease potential of all fine inorganic fibers—including glass fiber—being used in place of asbestos, he says. "The significance of Dr. Baris' report is that fine fibers, with a chemistry and structure different from asbestos', can apparently also cause mesothelioma. It is the first time this has been found in people."

Not so fast, says mineralogist **Frederick A. Mumpton**, professor of mineral sciences at the State University of New York College at Brockport. It's much too soon to project the Turkish report into a general view that mesothelioma can be caused by erionite fibers or inorganic fibrous material, he said.

Professor Mumpton recently returned from a two-week trip to that region of Turkey. He visited a dozen villages, including Karain and Tuzköy, collecting soil and rock samples. He found "one of the richest erionite deposits" in one of the other villages but was told by Dr. Baris that that village had no mesothelioma cases.

Dr. **David P. Rall**, director of the National Institute of Environmental Health Sciences in Research Triangle Park, N.C., says his agency, along with the Medical Research Council of Great Britain, has just started animal studies on effects of inhaling glass fibers. ■