# GEOLOGICAL AND MORPHOLOGICAL INVESTIGATIONS OF THE UNDERGROUND CITIES OF CAPPADOCIA USING GIS

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Approval of the Graduate School of Natural and Applied Sciences

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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## ABSTRACT

### GEOLOGICAL AND MORPHOLOGICAL INVESTIGATIONS OF THE UNDERGROUND CITIES OF CAPPADOCIA USING GIS

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The purpose of this study is to investigate the effect of rock types and morphologic classes on the locations of underground cities existing in Cappadocia. To achieve this purpose four databases are created that contain related information of underground cities, present settlements, rock types and morphologic classes.

Four main analyses are carried out using the data created fort the study. These analyses are: 1) Distance analysis to determine the distances between underground cities and present settlements, 2) Density analysis to inspect the areas where the underground cities are concentrated, 3) Distribution analysis to explore the spatial distribution of underground cities within the rock types and morphologic classes, and 4) Neighbourhood analysis to examine whether the underground cities within rock types and morphologic classes are located along or far inside the marginsof the polygons.

The conclusions reached after the analyses are as follows: 1) The mean distance between two underground cities is about 4 km. 2) The mean distance between an underground city and the nearest present settlement is about 700 m. 3) Underground cities are concentrated in Derinkuyu-Nevşehir-Özkonak belt. Present settlements, on the other hand, are concentrated along Aksaray-Ortaköy-Hacıbektaş. 4) For the underground cities, pyroclastic dominant Neogene sequences are preferred whereas all other units are avoided. 5) In terms of morphology, the class defined as "mesa" is strongly preferred for underground cities. 6) Neither lithology nor morphology played a role in the site selection for present settlements.
7) Both for rock types and morphologic classes the underground cities are located along margins of the polygons.

Keywords: underground city, rock type, morphology, Cappadocia, Turkey

# ÖZ

## KAPADOKYA YERALTI ŞEHİRLERİNİN CBS KULLANARAK JEOLOJİK VE MORFOLOJİK İNCELEMELERİ

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Bu çalışmanın amacı, Kapadokya bölgesinde yer alan yer altı şehirlerinin lokasyonlarında kaya türü ve morfoloji etkisini araştırmaktır. Bu amaca ulaşabilmek için yeraltı şehirleri, güncel yerleşimler, kaya türleri ve morfoloji sınıflarına ait birbirleriyle ilişkili dört veri tabanı oluşturulmuştur.

Çalışma için oluşturulan veriyi kullanarak dört ana analiz yürütülmüştür. 1) Yeraltı şehirleri ve güncel yerleşimlerin aralarındaki mesefeleri belirlemek için mesafe analizi ; 2) Yeraltı şehirleri ve güncel yerleşimlerin nerelerde yoğunlaştıklarını araştırmak için yoğunluk analizi; 3)Yeraltı şehirleri ve güncel yerleşimlerinin, kaya türleri ve morfoloji sınıfları içindeki dağılımlarını araştırmak için dağılım analizi ve 4) Yeraltı şehirleri ve güncel yerleşimlerinin, kaya türleri ve morfoloji sınıfları içindeki yerlerini araştırmak için yakınlık analizi.

Analizler sonrası varılan sonuçlar şunlardır: 1) İki yeraltı şehri arasındaki ortalama uzaklık yaklaşık 4 km’dir. 2) Bir yeraltı şehrinin en yakın güncel yerleşime olan ortalama uzaklığı yaklaşık 700 m’dir. 3) Yeraltı şehirleri Derinkuyu-Nevşehir-Özkonak kuşağında yoğunlaşmıştır. Güncel yerleşimler ise Aksaray-Ortaköy-Hacıbektaş hattında yoğunlaşmaktadır. 4) Yeraltı şehirleri için piroklastikçe zengin Neojen yaşlı litolojik istifler tercih edilirken diğer birimlerden kaçınılmıştır. 5) Morfolojik açıdan ise “mesa” olarak tanımlanan sınıf yeraltı şehirleri için çok belirgin olarak tercih edilmiştir. 6) Güncel yerleşimlerin yer seçiminde ne litoloji ne de morfoloji etkin bir rol oynamamıştır. 7) Hem kaya türleri hem de morfolojik sınıflar için yeraltı şehirleri poligonların kenarları boyunca yerleşmiştir.

Anahtar kelimeler: yeraltı şehri, kaya türü, morfoloji, Kapadokya, Türkiye

***To the supreme mountains of Anatolia***

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Before and above all… Thank you God.

I would also like to thank to following people.

To mom and dad… Your patience and common sense always keeps me on the bright side. Without you, what would I do?

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# CHAPTER I

# INTRODUCTION

Once called as Katpatuka by the Assyrians, the land of fine horses (Akat, 1991; Sözen, 1998), Cappadocia has always been an important control point in the history for the settlers and rulers of Anatolia: once an independent kingdom, later became the heart of the Great Hittite Empire, a satrapy for Persians, a state for Romans, a theme for Byzantines etc.

Today the region is popular with its geological, morphological and archaeological features: the volcanoes and their materials, the unique landform caused by this volcanism and the following fluvial activity, the remnants of ancient peoples and of course with the increasing interest on them, the rock settlements both above and below the ground.

## 1.1 Purpose and Scope

The rock settlements of Cappadocia are observed in three types: 1) those carved at the slopes of cliffs (e.g. Zelve, Gümüşler, Mazı), 2) those carved below the surface known as "underground city" (e.g. Derinkuyu, Kaymaklı, Acıgöl) (Figure 1.1) and 3) the integration of these two, which may be called as "mixed type" (e.g. Gelveri, Çanlıkilise, Tatlarin).

Evaluation of site selections for the first two types is different from each other because for the former one, the rocks, in which the settlements are carved, are above the surface whereas for the latter one they are below.

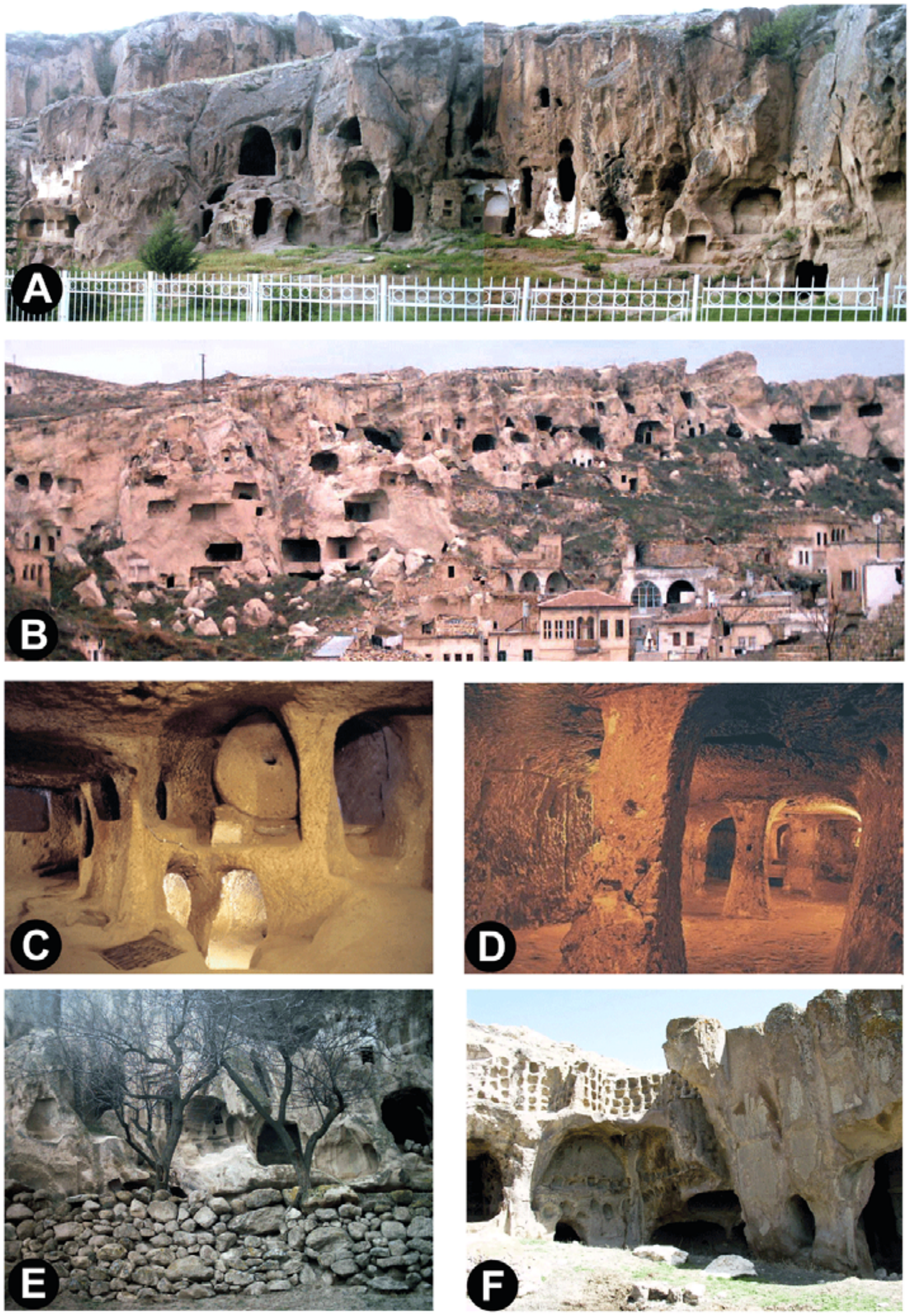

**Figure 1.1** Examples of rock-hewn settlements in Cappadocia
A and B: Gümüşler and Ürgüp (cliff type settlements)
C and D: Kaymaklı and Derinkuyu (underground settlements)
E and F: Gelveri and Çanlikilise (mixed type settlements)

Site of a cliff type settlement is mostly controlled by erosion in the area where a resistant rock unit (mostly ignimbrite) exist as a cap rock and forms a cliff either in a valley or on a flat surface. This settlement is, therefore, built where suitable landform is produced. Evaluation of the site for an underground city, on the other hand, is not easy because there is not a known set of criteria for the site selection of the underground city.

The purpose of this study is to investigate whether the dwellers of the underground cities had considered one or more controlling factor(s) to carve an underground city, particularly rock type or morphology.

There are several other factors that may have played a role in the site selection of an underground city. Examples of these factors can be water resources, traces of the major roads in the region, availability of agricultural fields, scarcity of construction materials (e.g. wood) at the surface etc. These factors, however, are not considered in this study due to lack of the data.

Therefore, the scope of this study is limited with two factors. The first factor is the rock type, which is believed to be the most important one as underground cities are carved within these rocks. Since all the rock types existing in the area will not have the same resistance to carving, it is assumed that, certain rock types had been preferred. The second factor is the morphology of the area around the underground city, which is a reflection of topography that produces a “suitable” landform to settle.

Present settlements are also included in this study and same analyses carried out for the underground cities are processed for them too. The reason for this is to compare the sites of both underground and surface (ancient and present) settlements in order to evaluate the change of trend in site selection from ancient times to present, because it is believed that the habit of dwelling in a particular location has never been interrupted in the course of time: settlings today were also the settlings in the past.

### 1.2 Study Area

It is difficult to define exact boundaries of Cappadocia partly due to its dynamic extend during historical times. Most of the written documents claim that the Cappadocian region, located in the central Anatolia, is bordered by Kızılırmak River in the north, Taurus Mountains in the south, Tuzgölü basin in the west and Kayseri province in the east (Giovannini, 1971; Akat, 1991; Bixio, 1995; Sözen, 1998). It is today included in the provinces of Aksaray, Nevşehir, Niğde, Yozgat, Kırşehir and Kayseri, and covers almost half of the central Anatolia.

Whole Cappadocia, however, is not included in this study due to the lack of data particularly for underground cities in Kayseri and Niğde provinces. For this reason, a rectangular area covered by 1/100.000 scale topographic sheets of K32, K33, L32 and L33 is selected as study area (Figure 1.2). The area includes centres of Aksaray and Nevşehir and some parts of Kırşehir, Kayseri and Niğde.

### 1.3 Previous Studies

Geology of the area which is a part of the Cappadocian Volcanic Province has been investigated throughout the last few decades. Numerous studies are carried out in different geological aspects of the area. These studies are tabulated in Table 1.1. The references are categorised into different subjects; therefore, some references might be repeated in the list. A review of the geology of the area will be given in the next chapter.

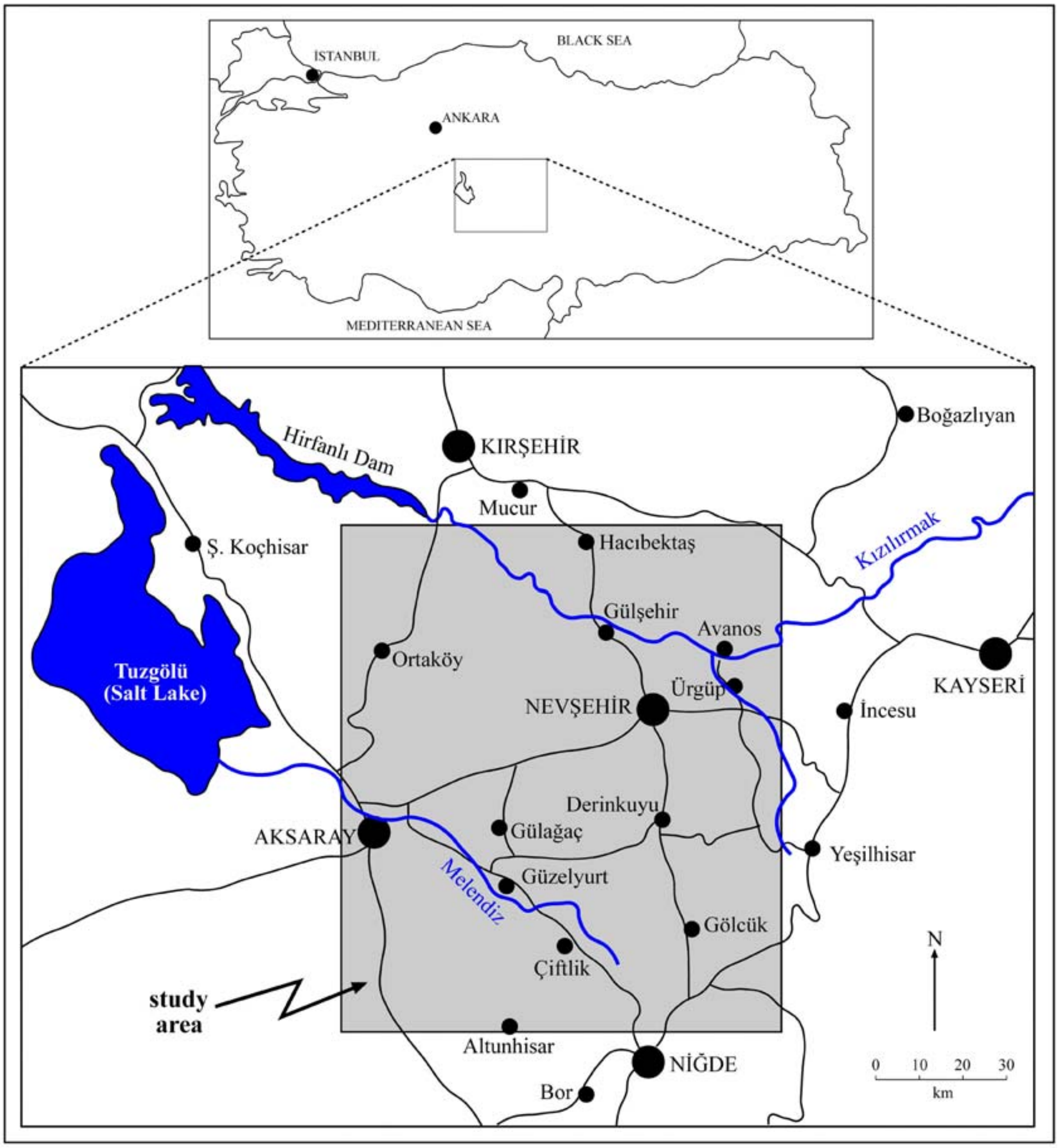

**Figure 1.2** Location map of study area

**Table 1.1** Previous studies categorised according to the purpose of the study

| Purpose | Main Interest | Interest area | Study |
|---|---|---|---|
| **Geology baseline** | Volcanism | Aksaray-Konya | Lahn, 1941 |
| | Volcanism | Central Anatolia | Lahn, 1945 |
| | Volcanism | Central Anatolia | Lahn, 1949 |
| | Volcanism | Nevşehir-Kayseri | Lebküchner, 1957 |
| | Volcanism | Nevşehir-Kayseri | Pisoni, 1961 |
| | Volcanism | İncesu (Kayseri) | Beekman, 1963 |
| | Volcanism | Aksaray-Niğde | Beekman, 1966 |
| | Volcanism | Acigöl | Sassano, 1964 |
| | Volcanism | Nevşehir-Kayseri | Pasquare, 1968 |
| | Palinology | Kırşehir-Nevşehir | Akgün et al., 1995 |
| | Mammalians | Kayseri | Şenyürek, 1953 |
| | Petrography | Acıgöl-Göllüdağ | Batum, 1978a |
| | Stratigraphy | Niğde massif | Göncüoğlu, 1981 |
| | Stratigraphy | Tuzgölü-Haymana | Görür, 1981 |
| | Stratigraphy | Tuzgölü basin | Uygun, 1981 |
| | Stratigraphy | Tuzgölü basin | Uygun et al., 1982 |
| | Stratigraphy | Tuzgölü basin | Atabey et al., 1987 |
| | Stratigraphy | West of Central Anatolia | Göncüoğlu et al., 1992 |
| | Stratigraphy | Kırşehir-Nevşehir | Göncüoğlu et al., 1993 |
| **Regional tectonics** | Orogenesis | Central Anatolia | Beekman, 1966 |
| | Evolution of Cent. An. | Central Anatolia | Westerveld, 1957 |
| | Stratigraphy | Tuzgölü basin | Görür et al., 1984 |
| | Volcanism | CVP | Pasquare et al., 1988 |
| | Neotectonics | CVP | Toprak & Göncüoğlu, 1993a |
| | Neotectonics | Central Anatolia | Dirik & Göncüoğlu, 1996 |
| | Plio-Quaternary basins | CVP | Toprak, 1996 |
| | Vent distribution | CVP | Toprak, 1998 |
| | Geological evolution | Tuzgölü basin | Çemen et al., 1999 |
| **Fault systems** | Tectonics | Ecemiş fault zone | Yetiş and Demirkol, 1984 |
| | Stratigraphy | Ecemiş fault zone | Beyhan, 1994 |
| | Neotectonics | Keçi.-Melendiz fault | Toprak & Göncüoğlu, 1993b |
| | Neotectonics | Tuzgölü fault zone | Leventoğlu, 1994 |
| | Neotectonics | C. Kızılırmak fault | Toprak, 1994 |
| | Slip analysis | Derinkuyu fault | Toprak & Kaymakçı, 1995 |
| | Neotectonics | Ecemiş fault zone | Koçyiğit & Beyhan, 1998 |
| | Neotectonics | Ecemiş fault zone | Koçyiğit & Beyhan, 1999 |
| | Neotectonics | Ecemiş fault zone | Westaway, 1999 |
| | Neotectonics | Ecemiş fault zone | Dirik, 2001 |
| | Neotectonics | Ecemiş fault zone | Jaffey & Robertson, 2001 |
| | Fault systems | Ecemiş fault zone | Toprak & Kaymakçı, 1995 |
| **Geomorphology** | Volcanism | Konya-Ereğli | Sungur, 1970 |
| | District classification | CVP | Andolfato & Zucchi, 1971 |
| | District characters | CVP | Succhiarelli, 1995 |
| | Geomorphology | Sultansazlığı | Erol, 1999 |
| | Volcanic landforms | CVP | Hooper and Sheridan, 1998 |

|  |  |  |  |
|---|---|---|---|
| **Volcanoes, eruptions** | Maar volcanism | Karapınar | Keller, 1974 |
|  | Geology, geochemistry | Erciyes volcano | Baş et al., 1986 |
|  | Geochemistry, age | Central Anatolia | Ercan, 1987 |
|  | Gas emission | Niğde-Konya | Ercan et al., 1987b |
|  | Geology | Hasandağ volcano | Aydar and Gourgaud, 1988 |
|  | Obsidian | Anatolia | Keller & Seifried, 1990 |
|  | Obsidian | Central Anatolia | Ercan et al., 1990b |
|  | Geochemistry | Erciyes volcano | Ayrancı, 1991 |
|  | Tectonics | Western CVP | Göncuoğlu & Toprak, 1992 |
|  | Geochemistry | CVP | Aydar et al., 1995 |
|  | Volcanology | Acıgöl volcanics | Druitt et al., 1995 |
|  | Eruption centers | Misli plain | Schumacher, Mues-Schumacher, 1997 |
|  | Tectonics | CVP | Dhont et al., 1998 |
|  | Evolution | Hasandağ | Deniel et al., 1998 |
|  | Maar volcanism | Narköy maar | Gevrek and Kazancı, 2000 |
| **Geochemistry** | Petrology | Acıgöl-Göllüdağ | Batum, 1978b |
|  | Geochemistry | Nevşehir-Niğde | Ercan et al., 1987a |
|  | Petrology | Hasandağ-Karacadağ | Tokel et al., 1988 |
|  | Geochronology | Hasandağ-Karacadağ | Ercan et al., 1990a |
|  | Geochronology | Hasandağ-Karacadağ | Ercan et al., 1992 |
|  | Geochronology | CVP | Ercan et al., 1994 |
|  | Petrology | Erciyes volcano | Aydar et al., 1994 |
|  | Geochemistry | Erciyes volcano | Kürkçüoğlu, 1994 |
|  | Geochemistry | Erciyes volcano | Kürkçüoğlu et al, 1998 |
| **Chronology** | Geochronology | CVP | Innocenti et al., 1975 |
|  | Geochronology | Central Anatolia | Besang et al., 1977 |
|  | Geochronology | Central Anatolia | Bigazzi et al., 1993 |
|  | Geochronology | CVP | Mues-Sch., Schumacher, 1996 |
| **Tephra** | Depositional setting | CVP | Schumacher et al., 1991 |
|  | Geochemistry | Ürgüp | Temel, 1992 |
|  | Stratigraphy, source | CVP | LePennec et al., 1994 |
|  | Geothermal | Acıgöl | Kazancı et al., 1995 |
|  | Geothermal | Acıgöl | Kazancı & Gevrek, 1996 |
|  | Stratigraphy | CVP | Leuci, 1995 |
|  | Akdağ-Zelve ignimb. | CVP | Schumacher & M-Schumacher, 1997 |
|  | Geochronology | Western CVP | Kuzucuoğlu et al., 1998 |
|  | Geochemistry | Ürgüp | Temel et al., 1998a |
|  | Geochemistry | Konya | Temel et al., 1998b |
| **Geophysics** | Caldera detection | Acıgöl (Nevşehir) | Toksöz & Bilginer, 1980 |
|  | Caldera detection | Acıgöl (Nevşehir) | Yıldırım & Özgür, 1981 |
|  | Caldera detection | Nevşehir | Ekingen, 1982 |
|  | Caldera detection | CVP | Froger et al., 1998 |
| **Paleomagnetism** | Paleomagnetism | Karapınar-Karaman | Gürsoy et al. , 1998 |
|  | Paleomagnetism | Central Anatolia | Platzman et al., 1998 |
|  | Paleomagnetism | Erciyes volcano | Tatar et al., 2000 |
|  | Mag. properties | Central Anatolia | Piper et al. , 2002 |

| | | | |
|---|---|---|---|
| **RS-GIS** | Regional tectonics | CVP | Pasquare et al, 1988 |
| | Remote sensing – GIS | CVP | Güleç et al., 1999 |
| | Remote sensing – GIS | CVP | Arcasoy et al., 2000 |
| | Lineament analysis | CVP | Arcasoy, 2001 |
| | Lineament analysis | CVP | Arcasoy et al, 2004 |
| **Engineering Geology** | Fairy chimneys | Ürgüp-Göreme | Topal & Doyuran, 1995 |
| | Physico-chemistry | Ürgüp-Göreme | Topal & Doyuran, 1996 |
| | Cappadocian tuff | CVP | Topal & Doyuran, 1997 |
| | Deterioriation | Ürgüp-Göreme | Topal & Doyuran, 1998 |
| | Underground cities | CVP | Aydan & Ulusay, 2003 |

## 1.4 Softwares Used in the Study

Though a limited and short duration of the fieldwork and documentary research has been run, the office work is the main body of this thesis. This office work comprises many parts from 1/25000-scaled topographical map readings and detailed literature surveys to use of several computer softwares. Table 1.2 lists these softwares used in this study.

**Table 1.2** Softwares used in the study

| Program Name | Program Type | Using Purpose |
|---|---|---|
| TNTMips 6.2 | Integrated GIS, image processing, CAD, TIN, desktop cartography, and geospatial database management | Vectorizing, attaining attributes, creating outputs for analyses |
| Rockworks 99 | Integrated geological data analysis, management and visualization | Creating histograms |
| Surfer 6 | Contouring, gridding, and Surface Mapping | Creation of density maps |
| Macromedia Freehand 8.0 | Professional print | Various maps and figure production |
| QuickBASIC | Programming | Encoding programs for analysing and linking to other systems |
| MapInfo 7.0 | Integrated GIS, image processing, CAD, TIN, desktop cartography, and geospatial database management | Contouring of rock types map |
| Microsoft Excel 2000 | Creating tables and managing attributes | Organizing data and creating histograms |

## 1.5 Organization of the Thesis

This thesis is organised in seven chapters. The first chapter introduces the reader some basic information about the area.

The second chapter briefly describes geology of the area.

The third chapter contains background information on the underground cities.

The fourth chapter introduces the data used.

The fifth chapter explains the analyses carried out in the thesis. This is the main body of the thesis. For each analysis first the method is explained then the results are illustrated.

The sixth chapter discusses various aspects of the thesis including the weak points with the results obtained and concludes the thesis emphasizing the major outcomes.

References cited and the Appendices are the last sections of the thesis.

# CHAPTER II

# REGIONAL GEOLOGY

This chapter explains general geological characteristics of Cappadocian Volcanic Province (CVP) where the study area is located. The information given in this chapter is based on the literature particularly on the work by Arcasoy (2001). The chapter is divided into four sections as 1) regional setting, 2) stratigraphy, and 3) fault systems existing in the region.

## 2.1 Regional Setting

Cappadocian Volcanic Province (CVP) is one of the Neogene-Quaternary volcanic belts in Turkey extending as a belt in NE-SW direction for a length of 250-300 km situated in Central Anatolia (Figure 2.1). It is surrounded by six major associations, which are:

1) Tuzgölü Basin: A Late Cretaceous fore-arc basin formed along a northeasterly dipping Neotethyan subduction zone (Görür *et al.*, 1984).

2) Sivas Basin: An Eocene to Miocene basin situated between Anatolids and Pontides filled with continental deposits (Cater *et al.*, 1991).

3) Ulukışla Basin: Arc volcanics of Late Cretaceous to Early Tertiary intercalated with flyschoidal sequences being product of a northerly subduction between Anatolides and Taurides (Oktay, 1982).

4) Tauride Belts: A major tectonic belt of Turkey first defined by Ketin (1966) and subdivided into seven tectonic sub-units by Özgül (1976).

5) Niğde Massif: Paleozoic metamorphics overthrust by Late Cretaceous ophiolites and intruded by Upper Cretaceous to Paleocene granitoids (Seymen, 1981, 1984). It is southern part of the "Central Anatolian Crystalline Complex (CACC)" (Göncüoğlu *et al.*, 1992).

6) Kırşehir Massif: Northern part of the CACC (Göncüoğlu *et al.*, 1992). It is lithologically similar to Niğde Massif (Göncüoğlu, 1981, 1986).

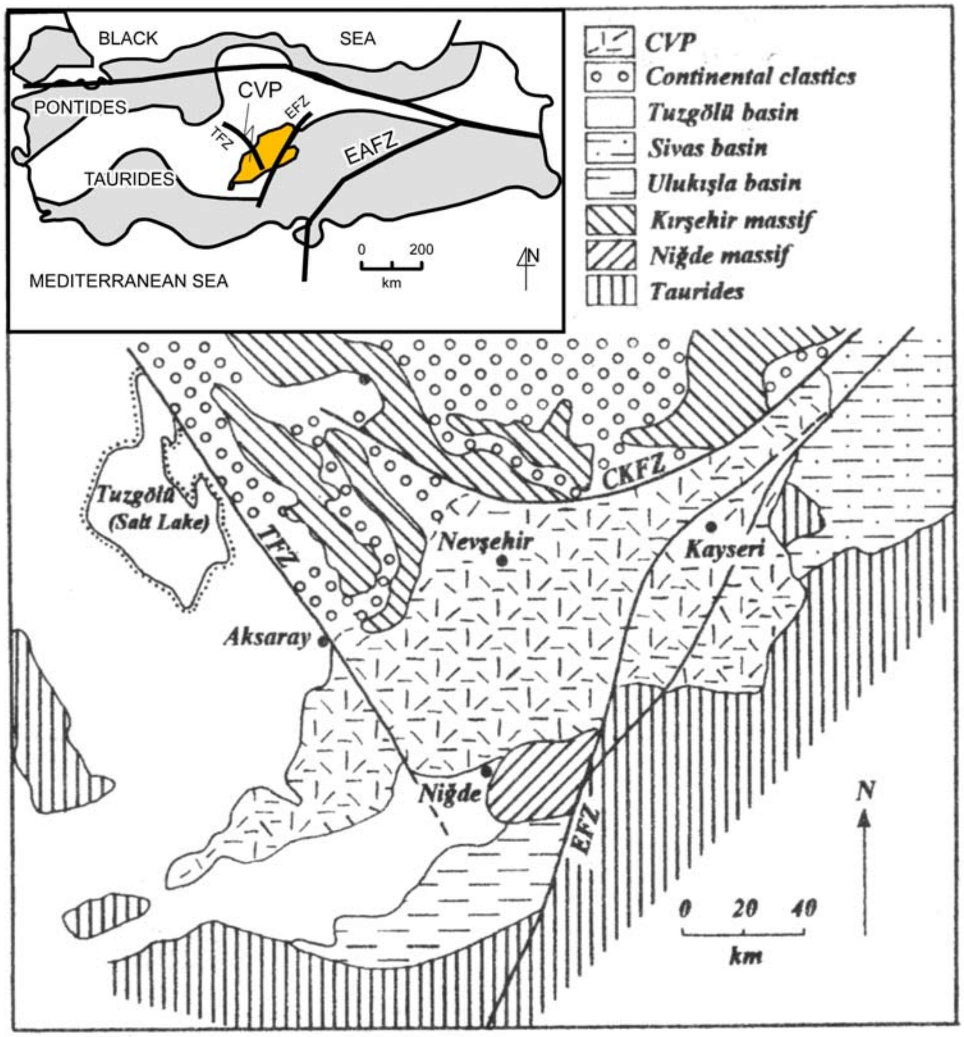

**Figure 2.1** Regional setting of the Cappadocian Volcanic Province (CVP)

## 2.2 The Geological Evolution of CVP

About 100 to 60 million years from now, between the Middle Cretaceous and Cenozoic Era, the conversion between Afro-Arabian plates and Eurasian plate initiated, leading the compression of Anatolian Plate between and advancing a part of the Alpine-Himalayan System, the Taurides. (Bayrak, 1999, Sağdıç, 1987)

The orogenic activity of the Taurides continued during Miocene causing deep fractures in the crystalline mountains in the north. These fractures in the deep caused a weakening of the crust and the generation of a chain of volcanic mountains (some of once primarily granitic, crystalline rocks) at the heart of the central Anatolia. (Stea and Turan, 1993, Andolfato and Zucchi, 1971)

The volcanic activity of mainly Erciyes, Develi, Hasan, Melendiz, Keçiboyunduran and Göllü mountains continued until the Pleistocene times (2,5 million-10 thousand years ago) creating numerous cones and increasing the heights of those principal volcanoes. So, in the Late Pliocene epoch central Anatolia was a region of thick layers of tuffaceous rocks over an area of 10000 square kilometers as a result of masses of eruptive material, molten lava and basalt flows. Altering between silent and explosive phases, these eruptions lasted several hundred thousands of years and continued almost until the beginning of the Quaternary (app. 600000 years ago) followed by an erosional period as a result of the humid climatic conditions of the Holocene age (12000years-recent). (Görmez et al, 2002, Succhiarelli, 1995)

## 2.3 Stratigraphy

Rock units exposed within the CVP are grouped into five types. These are, from bottom to top, Pre-Miocene basement rocks, Mio-Pliocene Ürgüp Formation, Miocene-Quaternary volcanic complexes, Plio-Quaternary continental clastics and Quaternary cinder cone fields (Figure 2.2).

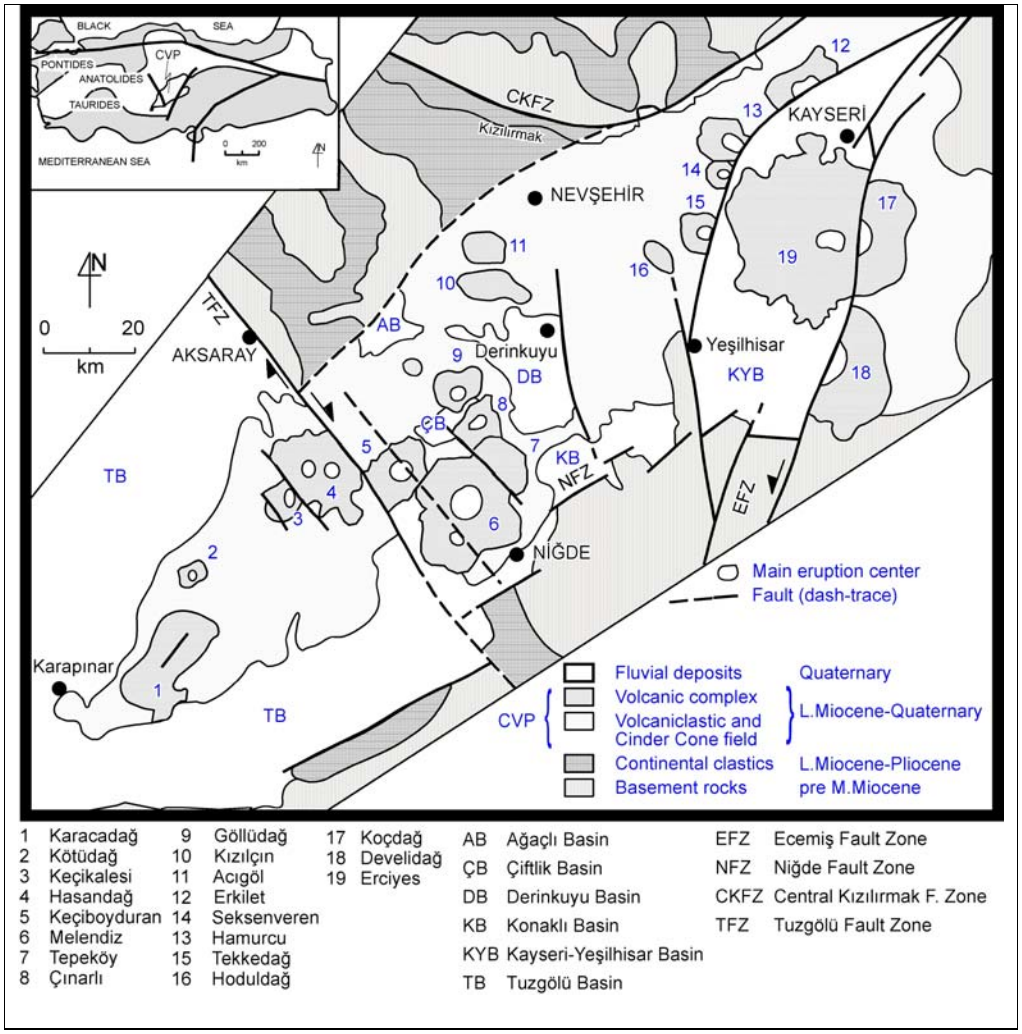

**Figure 2.2** Simplified geological map of the CVP (Numbers refer to the major volcanic complexes.) (Toprak, 1998)

### 2.2.1 Basement Rocks

Basement rocks refer to the sequences that form the base of the CVP. Three basic rock types are crystalline complexes, Cretaceous-Paleocene clastics, and Oligo-Miocene clastics.

**Crystalline complexes:** These rocks belong to the Central Anatolian Crystalline Complex (CACC) divided by CVP into two parts as Kırşehir massif (north) and Niğde massif (south). The CACC is composed of metamorphic rocks overthrust by ophiolitic nappes and are collectively intruded by magmatic rocks. The metamorphic rocks are quartzites, gneisses, schists, and marbles (Seymen, 1981). Radiometric data from Niğde massif suggest that main metamorphic event took place in Late Cretaceous (Göncüoğlu, 1986). Ophiolitic belt is represented by mafic - ultramafic rocks associated with pelagic sediments. Magmatic rocks are exposed as various sizes and consist of granitoids and syenitoids. Rb-Sr dating of granitoids yields ages of 71±1 Ma in the Kırşehir area (Ataman, 1972), 95±11 Ma in the Niğde area (Göncüoğlu, 1986) and 110±14 Ma in the Ağaçören area (Güleç, 1994).

**Cretaceous-Paleocene clastics:** This sequence is observed as cover rocks of the CACC being continuous from Late Cretaceous to Eocene (Görür, 1981). It is a fore-arc basin together with Haymana basin and belongs to the active margin of the Sakarya continent and the Kırşehir block (Görür *et al,.* 1984). Uygun (1981) and Uygun *et al.* (1982) studied the salt potential of the basin and suggested seven phases of evaporitic formation.

**Oligo-Miocene clastics:** These rocks are exposed as three belts around Yeşilhisar, east of Tuzgölü fault zone and south of Central Kızılırmak fault zone. They are composed of unconsolidated to consolidated continental clastics (both fluvial and lacustrine) intercalated with thick evaporites.

### 2.2.2 Ürgüp Formation

Ürgüp formation is the most important unit for this study because most of the underground cities are observed in the vicinity of these rocks. The formation is first named by Pasquaré (1968) and corresponds to Mio-Pliocene volcaniclastic rocks (tephra deposits or ignimbrites) intercalated with the lacustrine-fluvial deposits (Figure 2.3). The formation has a thickness of more than 400 m and extends throughout the CVP.

**Ignimbrites:** Pasquaré (1968) first mapped, named, and measured type sections of the ignimbrites. Innocenti *et al.*, (1975) determined the ages of the major ignimbrites and setup the stratigraphy. Since then, the geochemistry, distribution, emplacement and the source location of these ignimbrites are the major questions to several researches conducted in the area (Besang *et al.*, 1977, Batum, 1978b, Baş *et al.*, 1986, Pasquaré *et al.*, 1988, Schumacher, *et al.*, 1990, Temel, 1992, Le Pennec *et al.*, 1994, Druitt *et al.*, 1995, Mues-Schumacher and Schumacher, 1996, Temel *et al.*, 1998a). Accordingly, the ignimbrite volcanism of CVP occurred between 11 and 1 Ma (Innocenti et al., 1975; Mues-Schumacher and Schumacher, 1996).

Le Pennec *et al.* (1994) attempted to locate the vent for the ignimbrites. They used following criteria to locate the vents: 1. sedimentological characteristics, 2. phenocryst assemblage, 3. pumice vesiculation textures, 4. presence and characteristics of associated plinian fallout, and 5. lithic clast types. The results show that inferred sources concentrate within a limited area between Nevşehir to the north and the Melendiz volcanic complex to the south (Figure 2.4). These vents, however, today are covered by later volcanic eruptions.

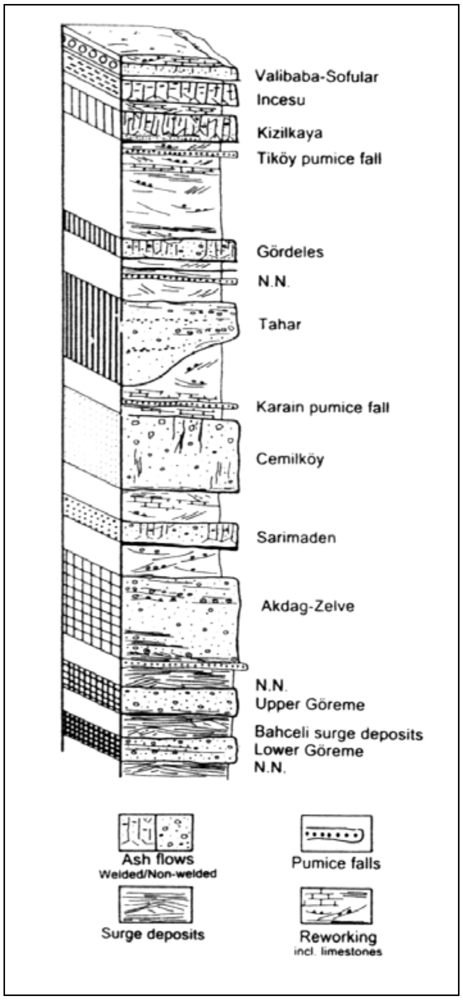

**Figure 2.3** Stratigraphy of the ignimbrites in the area (Mues-Schumacher and Schumacher, 1996) (NN: no-name)

**Sedimentary units:** Sedimentary units within the Ürgüp formation are relatively poorly known compared to the ignimbrites. Pasquaré (1968) and Temel (1992) used the name “Bayramhacılı” and “Çökek” members, respectively, to differentiate these units from the ignimbrites. The units are characterized by volcanic conglomerates and pelitic rocks at the base, by marls and fine-grained slightly tuffaceous sandstones in the middle part and by clay, marls and lacustrine limestones at the top. Six fossil mammal deposits are recognized in different stratigraphic positions of the sequence. Palaeontological data suggest an age between Maeotian (late Late Miocene) and Pontian (Late Miocene-Pliocene) times (Şenyürek, 1953; Pasquaré, 1968). This age is conformable with the radiometric ages of the associated ignimbritic units (Innocenti *et al.*, 1975).

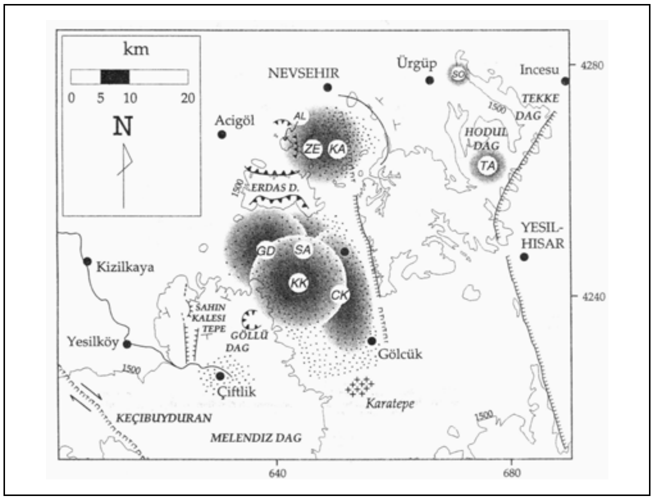

**Figure 2.4** Distribution of the inferred ignimbrite source areas
KK: Kızılkaya, SO: Sofular, GD: Gördeles, TA: Tahar, CK: Cemilköy, SA:Sarımaden, ZE: Zelve, KA: Kavak, AL:Acıgöl Lake (Le Pennec *et al.*, 1994).

### 2.2.3 Volcanic Complexes

Volcanic complexes correspond to the major eruptive centres in the province and form huge topographic masses. Nineteen volcanic complexes are identified within the province (Figure 2.2). Although some of the complexes are studied in detail, most of them are still poorly known. Most of them are polygenetic volcanoes; others are in the form of either a dome or a caldera (Table 2.1). The complexes are aligned in NE-SW direction, more or less, parallel to the long axis of the volcanic belt.

**Table 2.1** General characteristics of the volcanic complexes exposed within the CVP (Ages of non-dated complexes are estimated from their stratigraphic positions.) (1) Innocenti et al., 1975; (2) Besang et al., 1977; (3) Batum, 1978 a; (4) Ercan et al., 1992; (5) Bigazzi et al., 1993; (6) Ercan et al., 1994.

| No | Name | Radiometric age data(Ma) | Age | Form | Size (km) | Dominant lithology |
|---|---|---|---|---|---|---|
| 1 | Karacadağ | | M.L. Miocene | strato volcano | 22*12 | andesite |
| 2 | Kötüdağ | 13 (2) | M.L. Miocene | Dome | 6*4 | andesite |
| 3 | Keçikalesi | 13.7 - 12.4 (2) | M. Miocene | Caldera | 7*7 | basaltic andesite |
| 4 | Hasandağ | 0.78 - 0.277 (4) | Plio-Quat. | strato volcano | 21*12 | basaltic andesite-andesite |
| 5 | Keçiboyduran | | E. Pliocene | strato volcano | 13*10 | andesite-basaltic andesite |
| 6 | Melendiz | 6.5 - 5.1 (2) | E. Pliocene | strato volcano | 23*21 | andesite-basaltic andesite |
| 7 | Tepeköy | | M.L.Miocene | strato volcano | 12*7 ? | andesite, dacite |
| 8 | Çınarlı | | L.Miocene | strato volcano | 9*8 | andesite |
| 9 | Göllüdağ | 1.15 - 0.86 ( 3, 5) | E. Quaternary | Dome | 9*8 | rhyolite, rhyodacite |
| 10 | Kızılçın | 13.7 - 6.5 (3) | M. Miocene | strato volcano | 15*6 ? | andesite, dacite |
| 11 | Acıgöl | 0.4 - 0.019 (3, 5) | L. Quaternary | Caldera | 12*8 | rhyolite |
| 12 | Erkilet | | Mio-Pliocene | strato volcano | 16*6 ? | andesite |
| 13 | Hamurcu | | Mio-Pliocene | strato volcano | 9*8 | andesite |
| 14 | Seksenveren | | Mio-Pliocene | strato volcano | 6*5 | andesite |
| 15 | Tekkedağ | 5.1 (1) | Mio-Pliocene | strato volcano | 7*6 ? | andesite |
| 16 | Hödüldağ | | Mio-Pliocene | ? dome | 5*3 ? | andesite |
| 17 | Koçdağ | | Mio-Pliocene | strato volcano | 24*10? | andesite |
| 18 | Develidağ | | Mio-Pliocene | strato volcano | 27*14? | andesite |
| 19 | Erciyes | 2.59 - 1.43 ( 6) | Plio-Quat. | strato volcano | 39*28 | andesite, rhyo-dacite |

### 2.2.4 Plio-Quaternary Continental Clastics

These continental deposits cover large areas within the Cappadocian Volcanic Province. Some of the volcanic cone clusters are totally located within these deposits. These deposits are exposed within isolated basins developed under the influence of tectonic and volcanic structures existing in the area. Toprak (1996) distinguished six basins and classified them according to their mode of origin. These are, from west to east, Tuzgölü, Çiftlik, Ağaçlı, Derinkuyu, Konaklı and Kayseri-Yeşilhisar basins (Figure 2.2). The basins are all developed within the main depression of the Cappadocian Volcanic Province and are filled with mostly fluvial clastics. The ages of these depressions are assigned relative to the age of the youngest unit of the region. Accordingly, they have an age of Quaternary with minor variations from place to place.

### 2.2.5 Quaternary Cinder Cone Fields

Volcanic cone fields are composed of monogenetic eruptions and associated lava flows. They are scattered in the area being concentrated in certain parts. Most of them are in the form of cinder cones although some exist as rhyolitic or andesitic domes and maars (Pasquare, 1968; Keller, 1974, Batum, 1978a). Cinder cones have a basal diameter of a few tens of meters to 1-1.5 kilometers with a height of a few ten meters to a few hundred meters. They are all associated with basaltic lava flows and are Late Quaternary in age (Ercan *et al.*, 1990b; 1992; 1994; Bigazzi *et al.*, 1993). Rhyolitic domes are common around Quaternary Acıgöl caldera (no: 11 in Figure 2.2) and are characterized with large basal diameters up to 5 km. Andesitic domes are mostly observed in the area between Nevşehir and Yeşilhisar. They range in age from Late Miocene to Quaternary.

Toprak (1998) identified more than 800 cones within the CVP and grouped these cones geographically into 5 clusters. All these cones, however, are re-evaluated and modified by Arcasoy (2001) who classified the cones into three clusters and created a cone database that contains more than 550 cones (Table 2.2).

**Table 2.2** Monogenetic cones of CVP identified by Arcasoy (2001)

| No | Cluster name | Total number | Number used for evaluation |
|---|---|---|---|
| 1 | Hasandağ | 168 | 140 |
| 2 | Acıgöl | 110 | 94 |
| 3 | Erciyes | 210 | 195 |
|  | Others | >60 | --- |
|  | TOTAL | >548 | 429 |

### 2.3 Fault Systems

Two fault systems are recognized within the CVP by Toprak and Göncüoğlu, (1993a) named as: 1) Tuzgölü-Ecemiş fault system trending in NW-SE to NE-SW, and N-S direction; and 2) CVP extensional fault system striking almost parallel to the long axis of the CVP in NE-SW direction. Nature and characteristics of these systems are different in different periods of the history since Miocene.

Activity of these faults is illustrated in Figure 2.5 for three periods, namely, a) pre-mid Miocene, b) Mid-Miocene to early Pliocene, and c) late Pliocene to Quaternary. The second fault system was active for a short period during Mio-Pliocene times while the first system has been activating for a long period and still is active generating earthquakes in the region.

#### 2.3.1 Tuzgölü-Ecemiş Fault System

The Tuzgölü-Ecemiş fault system consists of fault zones that cut CVP almost at right angle across its long axis. Hasandağ fault set, Keçiboyduran-Melendiz fault, Göllüdağ buried fault, Derinkuyu fault, and Ecemiş fault zone are the major faults in this system.

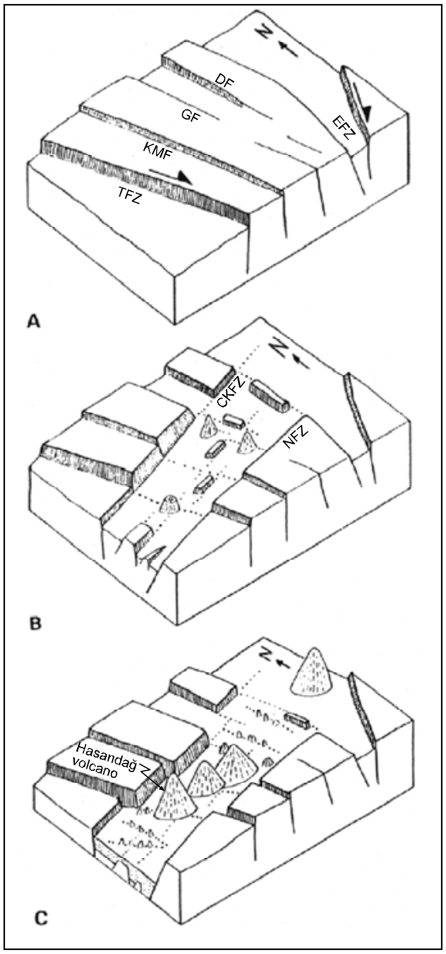

**Figure 2.5** Fault systems acting in the area since Miocene
A) Pre-Mid Miocene, B) 1Mid-Miocene to Eearly Pliocene, C) late Pliocene to Quaternary. (CKFZ: Central Kızılırmak fault zone; DF: Derinkuyu fault; EFZ: Ecemiş fault zone; GF: Göllüdağ fault; KMF: Keçiboyduran-Melendiz fault; NFZ: Niğde fault zone; TFZ: Tuzgölü fault zone)

Hasandağ fault set consists of several parallel/sub-parallel faults striking NW-SE, which constitute the southern extension of the Tuzgölü fault zone. The fault set takes an active role in the location of the Hasandağ composite volcano (Göncüoğlu and Toprak, 1992). It is an active right-lateral strike-slip fault. Several young lava flows (age: 277.000 to 780.000; Ercan *et al.* 1992) are cut and upthrown for 25-90 m by the Hasandağ fault set west of

Keçiboyduran mountain. Numerous monogenetic eruptions occurred along this set (Toprak, 1998; Arcasoy, 2001).

Keçiboyduran-Melendiz fault is located 7-8 km east of the Hasandağ fault set and controls the location of the Keçiboyduran and Melendiz (no: 5 and 6 in Figure 2.2) volcanic complexes. The fault is mostly buried under the lava and ash flows of recent volcanic eruptions (Toprak and Göncüoğlu 1993b).

Göllüdağ fault is a totally buried fault extending in N25W direction in the central part of the CVP, west of Melendiz volcanic complex. The presence of the fault is indicated by the alignment of the major eruption centers, namely Tepeköy, Çınarlı and Göllüdağ complexes (no: 7, 8, 9, in Figure 2.2, respectively). There are several parasitic cones erupted along Göllüdağ fault particularly NW of Derinkuyu basin on the northern margin of this alignment (Toprak and Göncüoğlu, 1993b).

Derinkuyu fault is located in the central part of CVP between Göllüdağ fault and the Ecemiş fault zone. It is well defined by its fault scarp east of Derinkuyu. It strikes approximately N-S and defines the eastern margin of the Quaternary Derinkuyu basin. Slip lineation data measured along fault reveals that the fault is of normal type with the maximum principal stress being almost vertical (Toprak and Kaymakçı, 1995).

Ecemiş fault zone is one of the major tectonic lines of Turkey located to the eastern part of the CVP (Figure 2.2). It is an active left-lateral strike-slip fault and believed to be initiated during post Paleocene-pre Lutetian (Yetiş and Demirkol, 1984) and reactivated during Pliocene (Beyhan, 1994). Erciyes volcano is erected over this fault zone that spatially divides Kayseri-Sultansazlığı depression into two parts.

### 2.3.2 CVP Extensional Fault System

The second fault system in the area trends parallel to the long axis of the CVP. Two major faults of this system, described below, are the Niğde fault to the south and the Central Kızılırmak fault zone to the north of the province. Some smaller faults developed within the volcaniclastic rocks are covered by later volcanic products and therefore are buried (Toprak and Göncüoğlu, 1993a).

The Niğde fault forms the southern margin of the CVP (Figure 2.2). It strikes NE-SW and is cut and displaced into several segments by the Tuzgölü-Ecemiş fault system. The southern block of the fault is up thrown for about 500 m (Toprak and Göncüoğlu, 1993a).

Central Kızılırmak fault zone defines the northern margin of the CVP (Toprak, 1994). The zone is composed of several parallel faults along which widespread travertines are formed. The fault zone cuts the Late Quaternary lava flows and is, therefore, considered to be active. Slip data collected at different localities of the fault zone indicates that the fault is a dip-slip normal fault with minor oblique-slip component. The age of the Central Kızılırmak fault zone is Mio-Pliocene as indicated by its control on the deposition of the Ürgüp formation and continued its activity until recently. The fault, therefore, is contemporaneous with the volcanism of the CVP.

# CHAPTER III

# UNDERGROUND CITIES: A REVIEW

Since the dawn of time, cavities above or below the ground are used as shelter and housing by human beings. Not only natural caves, but also artificial caves, especially man-made underground structures are known all around the world. Other than Turkey, the cradle of cultures, Mediterranean area, has such ancient settlements in Hal Saflieni (Malta), Cyrene (Libya), Maresha (Israel), Petra (Jordan), Bulla Regia and Matnmata (Tunusia), Rome and Matera (Italy) (Bixio, 1995).

## 3.1 Historical Research

In the view of historical records it was Heredotus who for the first time used the name "Cappadocia", which must be the Greek pronunciations of "Katpatuka". The word could have an Assyrian (maybe Persian, Hatti, Luwian or Hittite) meaning as "the land of fine horses" or "the place constantly exposes to sun and which has wide shouldered horses" (Stea and Turan, 1993). This name is at least four centuries older than Christianity.

A few decades after Heredotus, a pupil of Socrates, Xenophon, the Athenian, wrote Anabasis. He took charge with ten thousand Greeks, between 401 and 399 B.C. at the great march from Sardis to Babylon and back to Greece from the coast of Black Sea. In his book is described an underground town. Yet this settlement can be located in the north of the Van Lake, not in Cappadocia. Anyway, this may prove that the underground dwelling was already a fact in Asia Minor at the end of the 5th century B.C. (Stea and Turan, 1993, Bixio, 1995, Lloyd, 1989)

In Geographica, which was written by Strabon of Amasya, the region was said to have a fire-worshipping cult after the Hittites and is said to have Greek belief systems later. So it can be assumed that the migration to the region and taking refuge in the isolated landscape always continued because of hostile encounters and persecutions. (Stea and Turan, 1993, Giovannini, 1971)

Paul Lucas, who was commissioned in 1704 and later in 1714 by the French King Louis XIV to travel to the oriental countries, was the first occidental traveler to Cappadocia in the modern times. He was astonished by the panorama of Avanos and Ürgüp. After he returned home from his first journey, with the help of his imagination he made an irrational approach to the region, claiming that the fairy chimneys look like "monks with hoods" and the rocks on the fairy chimneys look like busts of "Mother Mary holding Baby Jesus". He thought that these interesting rock-cut houses were the ones of the Christian monks. Even in his famous engraving, it is obvious that the tops of the fairy chimneys were demonstrated, in an exaggerated way, like the busts of people (Fig. 3.1). On his second journey through the region, he characterized the Fairy Chimneys as the ancient cemetery of a vanished city or maybe Caesarea.

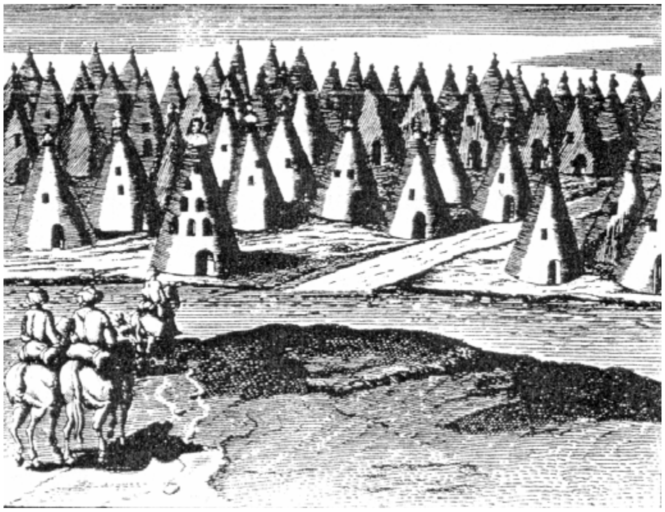

**Figure 3.1** An engraving of Paul Lucas, 1714

About a hundred fifty years after Lucas in 1833 and 1837, the French voyager and well-known architect Charles Textier who was assigned by the French government with the task of conducting research in Anatolia, visited the region and provided a more realistic description of Ürgüp and Göreme. He publishing the results of his travels and research in Anatolia in a six-volume work titled 'Description de l'Asie Mineur', which included engravings and plans. (Fig. 3.2)

**Figure 3.2** A lithography of Charles Textier, 1862

Other European voyagers like Ainsworth, Hamilton, Ramsay and Sterrett also visited the region especially during the late 19th century, in the period when scientific studies about nature and the history of the region began to be carried out, but they were unable to disguise their astonishments and couldn't help to express that they were bewildered in their notes upon they encountered in this land of Dantesque strangeness.

Sterrett (1919) stated that, at the scale of a settlement like Derinkuyu or Kaymaklı to accommodate 3000 people, not less than 30000 cubic meters, need to be excavated and removed and it takes one person about 30 days to carve only 100 cubic meters if approximately 3 cubic meters are carved per day. This was a very progressive, beneficial and important study and statement not only for that day but also for today.

Priest G. de Jerphanion's work which was published between the years 1925-42 was the first extensive art-historical study that was carried out to examine the rock churches, monasteries and the wall frescoes on their interior walls and ceilings in a systematic manner.

Martin Urban (1973) who did the earliest detailed research in the region between 1960 and 1970 dated the underground settlements back to the 7th-8th centuries B.C., the period of Phrygians after his investigations on the millstones of the underground cities.

Huo (1986) claims that, except for lighting and ventilation, the microclimate of the burrowed settlements, with their comparatively stable air temperature and humidity quite favorable to temperature regulation and metabolic processes of the human body makes them suitable as living environments.

Stea and Turan (1993) investigated two volcanic regions with similar geological, morphological and archaeological features. The regions are Cappadocian region of Turkey and the Pajarito plateau of northern Mexico. In both regions erosion and other natural processes gradually perforated the geological formations left by the ancient volcanic eruptions. In both locations, but at different geological ages, various groups of people also created homes within these perforations.

Bixio and Castellani (1995) presented a classification of the underground structures as follows:

1. Natural cavities
2. Artificial cavities
    - Cliff settlements (fig. 3.3): cone villages, cliff wall villages, rocky churches, rocky castle villages, and rocky tombs rocky pigeon lofts
    - Underground structures (fig. 3.4): towns, redoubts and hydraulic tunnels

Bixio (1995) made the first list of the places where there exist underground structures, without typological distinctions connected to their possible original destinations.

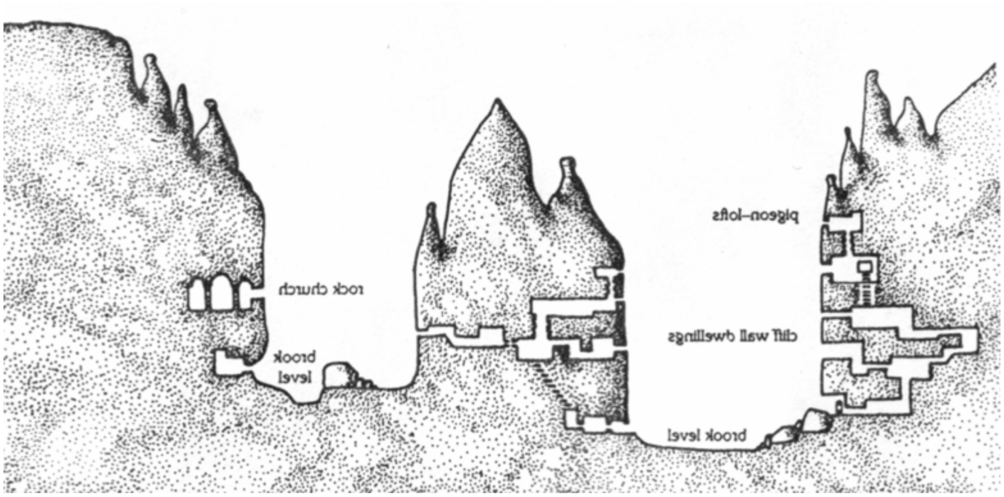

**Figure 3.3** Schematic section of cliff settlements (Giovannini, 1971)

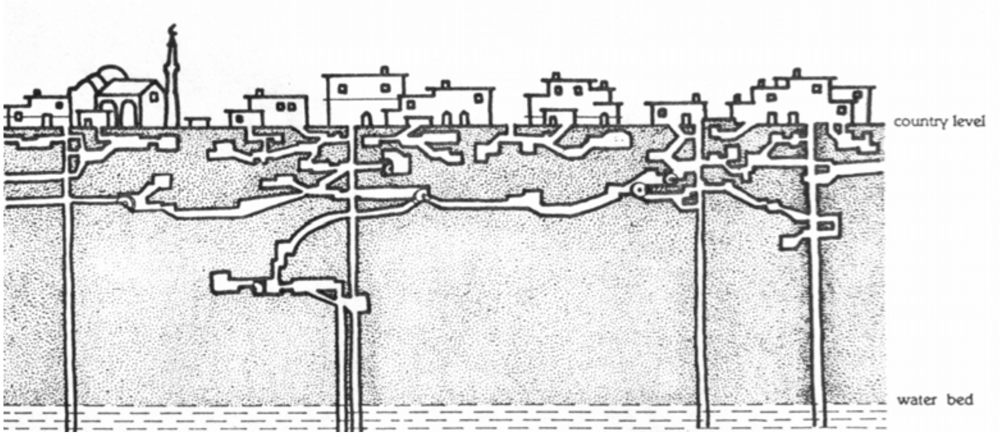

**Figure 3.4** Schematic section of underground structures (Urban, 1973)

### 3.2 Dating Underground Cities

While the historical sources concerning the past of Cappadocia are rather abundant, there is very few information useful to date these structures (Bixio, 1995). As it is certain that metal tools were used to carve these inner rock and underground structures and also it is known that metals have been use in Anatolia since the 3rd millennium B.C., these underground cities cannot be dated to earlier times. But still it is very difficult to determine, with 100% precision, when those living spaces are excavated. There are many hypotheses concerning the period during which, these structures have been excavated: the first could be Hittite or Phrygian. There are remains of Stone Age settlements, which have been found like Kaneş on the site of the Hittite town Kültepe (Kayseri). A similar property of all underground settlements in the region is the existence of a Hittite monument usually about 300-500 m in the vicinity.

With the existence of concrete evidences, the scientists are absolutely sure that the greatest development in the underground settling culture was between the 6th and the 16th century A.D., which means the time of Christianity. But Kostof (1972) says that, "there is no reason to disbelieve that the practice was more ancient." In the light of all information about the settling history in the region, to date the underground settlements as early as the same time as the first civilizations in the region, which is Prehistoric period, is not inaccurate. To hollow out the soft tuffaceous material, using simple tools would not be very difficult for the people of the Prehistoric period. Finally some indirect proof could arise from the studies made on the erosion phenomena, which modified the morphology of the underground drainage channels, so strongly that it is possible to date them before the Byzantine period.

### 3.3 Reasons for Underground Settling

Rock carving has been a major habit for place making in Cappadocia for the long time range of human settling. It has also been a way of life, the fundamental of their unique culture for the inhabitants of this quite unusual landscape (Figure 3.4. and 3.5).

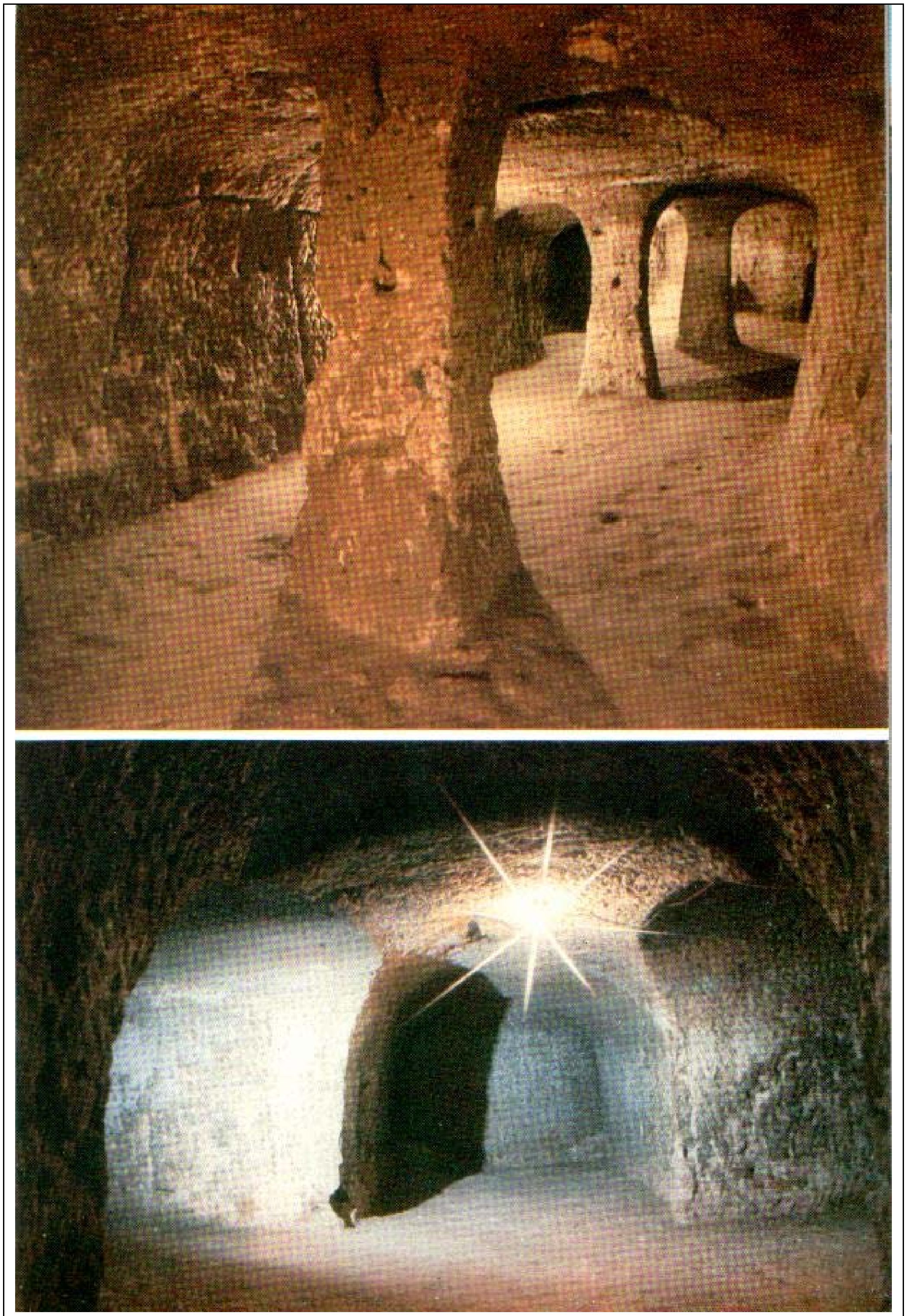

**Figure 3.5** Two views from Derinkuyu underground city

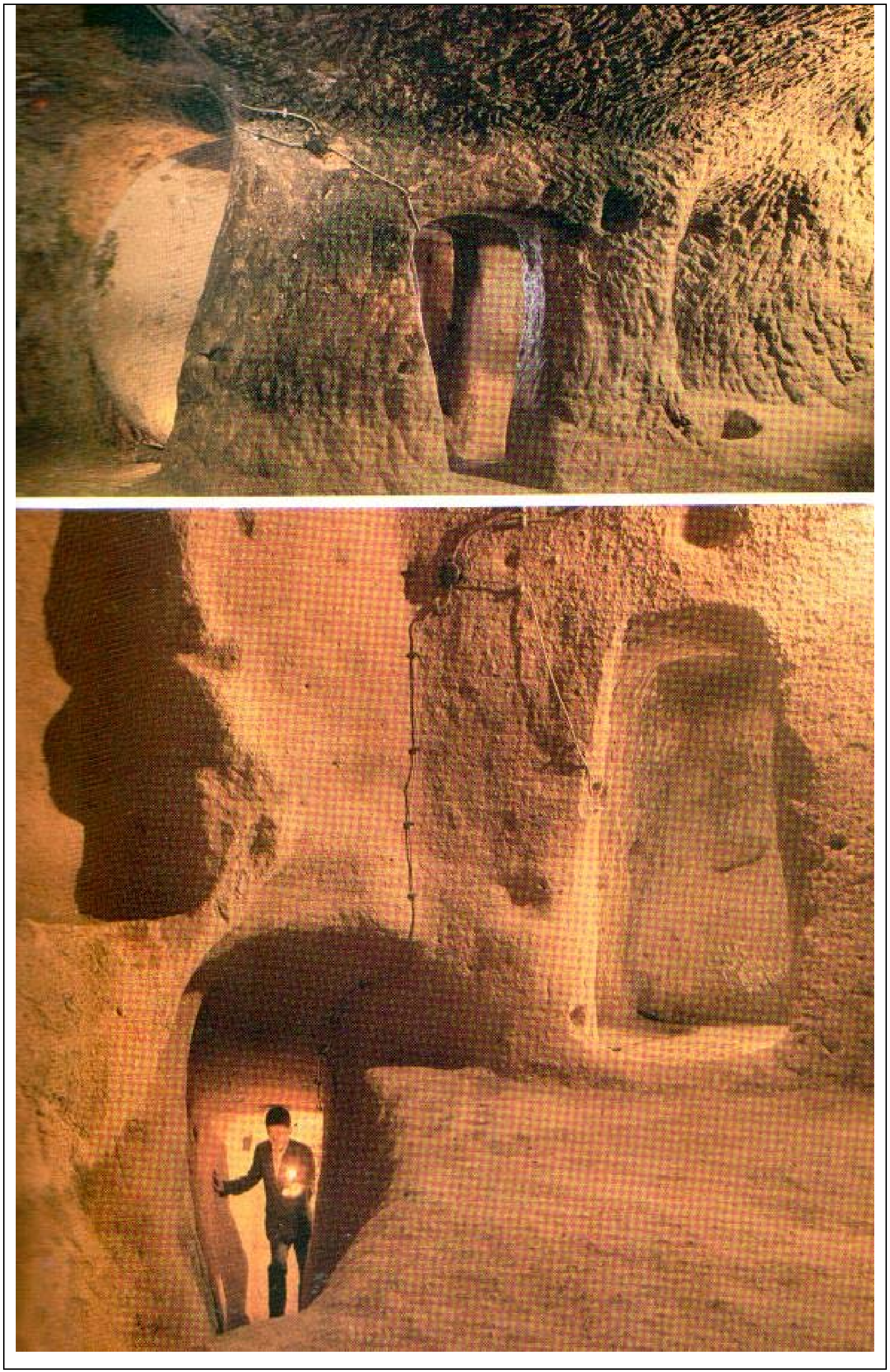

**Figure 3.6** Two views from Özlüce underground city

But what was the reason for the inhabitants to choose to dwell in Earth. In 1888, J.R.S. Sterrett was surprised by the way of living in the ancient and said in his book "The Epichraphical Journey in Asia Minor" that:

***"There is no earthly reason why they should live there as the country is safe and land abundant…"***

Erguvanlı and Yüzer (1977) categorized the environmental and anthropological factors for the settling in Cappadocian underground cities into six groups:

1. Severe daily and seasonal changes of temperature in the region,
2. Thermal isolation properties of the rock units covering the region,
3. Self-supporting behavior and construction opportunities of rocks,
4. Easily carved, particularly soft tuffs,
5. Defensive advantage and safety against enemy attacks for hiding and camouflage,
6. Superior resistance and protection against natural disasters such as earthquake and/or volcanic eruptions.

It looks evident that the main reason was defense for carving rocks under the ground. Cappadocia, which is lying at the foot of the Taurus chain, always served as a first halting place for incomers traveling from the southeast; and the natural roots to the north and east brought it into contact with the peoples of the Black Sea and Caucasus, Eastern Anatolia and the Iranian plateau (Giovannini, 1971). The area was also defenseless to the west, because of the wide plain around Tuzgölü. So the region was never a quite land and was always a strategic crossroad.

In addition to the need to camouflage and conceal the living environment as a defensive tool against attacks by other groups of armed men as well as animals, there are also environmental reasons for cliff dwellings, caverns and grottoes hewn out of soft rock. The soft, volcanic material provide a habitat that is climatically very advantageous compared to other structures built above the ground, because of the high, natural thermoregulation of the Earth, in a region which is hot and dry during summer; cold and precipitated in winter. A relatively constant and comfortable temperature, about 12 to 15 degrees Celsius, prevails throughout the year (Stea and Turan, 1993).

In the absence or shortage of other building materials such as timber, which is necessary to built above the surface, carving as opposed to building saves labor. This is a definite natural adaptation, which also allows an intense land use and conserves nature in a region where efficient agriculture is available in limited areas (Stea and Turan, 1993).

An underground settlement spread out over several square kilometers, reaching deeper than fifty meters and accommodating a few thousand people, poses problems in terms of air and water supply. There are evidences for hydrological planning in ancient Cappadocia, for example in the valleys of Meskendir and Kılıçlar. There are underground collectors, which are under-passing, these valleys. They were used to capture the floods in rainy days (also clearing the field from water streams and making them available for farming) in a region (Bixio, 1995).

Carefully excavated deep air shafts reach to the lowest levels from the surface. Some of the underground spaces are immediately adjacent to these shafts, almost spiraling around them; some are connected to the shafts with galleries.  Because of a very low water table, the wells supply water at lower depths.  (Stea and Turan, 1993)

### 3.4 General Features of an Underground City

An entrance to a typical underground city such as Kaymaklı or Derinkuyu, well concealed on the surface, leads down steps to a modest chamber five meters below the surface. A gently descending tunnel starts at the other end of the chamber; approximately five meters down the tunnel is the first "security check point" with a room like cavity on one side containing a round stone slab (about 1.5 m in diameter and 50 cm in thickness), very similar to a millstone, that can be rolled across the tunnel to block the passage from inside. This blocking is repeated about every ten m along the tunnel in the first fifty to sixty m of a typical burrow. As the tunnel descends deeper and as the tributary tunnels branching from the main one from a network of passages, use of this blocking device decreases in frequency. (Stea and Turan, 1993)

Branching tunnels go in all directions, with either descending ramps or steps, covering an area of several square kilometers. At some of the junctions of the underground streets, or tunnels, are relatively larger spaces or squares occurring at intervals of anywhere from twenty to fifty m. Between the squares along the underground cities are the individual living spaces, divided with walls, columns, and irregular arches, providing privacy for families and rooms for storage. Winding down and descending further underground, the streets on the either side connect not only living spaces but also such religious public spaces as chapels, churches, cemeteries, baptismal pools, wine cellars and grape pressing chambers. Spaces serving religious functions however are encountered only after a certain depth is reached, at which the inhabitants must have felt secure: larger churches are generally hewed out at lower depths, reaching 85 m in the case of Derinkuyu. (Stea and Turan, 1993)

The oldest floors of the underground cities are generally the ground floors. They were usually used as stables, due to the fact that it was difficult to the animals to access to the lower floors. On the lower part of the stable walls were un-evenly hollowed out pits in which to put fodder for the animals and holes to tie them up. (Gülyaz and Yenipınar, 2003)

There are communication holes, not bigger than 10-15 cm in diameter on the floors and the ceilings of the rooms between the various levels. Using these holes, underground city inhabitants did not have to walk through the long and tiring tunnels, they also could take defense precautions easily and quickly during times of war. (Gülyaz and Yenipınar, 2003)

Inside the underground cities, usually connected with the lowest floor of the system, are the shafts used for ventilation and also communication. These shafts were also used as wells. Some of these wells did not have access at the ground level, to prevent the enemy from poisoning the water supply. (Stea and Turan, 1993)

In spite of the labor and hardship involved in removing tens of thousands of cubic meters of earth, this type of troglodytic settlement was not meant to be permanent. Such settlements were inhabited during periods of danger, for short duration of times and for longer periods at others, perhaps lasting several months. (Stea and Turan, 1993)

Although some researchers claim that the underground settlements were connected to each other with tunnels, no conclusive evidence to support this idea has been found so far. (Gülyaz and Yenipınar, 2003)

# CHAPTER IV

# DATA USED IN THE STUDY

This chapter deals with the data collected, refined and recreated for the analyses. Four sets of data are used in this study. They are as follows:

- Underground Cities
- Present Settlements
- Rock Types
- Morphological Classes

## 4.1 Underground Cities

Underground cities constitute the main data of the study as far as the scope of the thesis is considered. Since there is not a database that contains underground cities of the Cappadocian area, an attempt is made to create this database. During the compilation of the data, various written documents and oral information provided from Nevşehir and Aksaray museums are used. Several field trips are organized to the area to check the locations of some of these cities.

The main source for the creation of this data is the list of the underground cities of Cappadocia made by the Italian Speleology Society (SSI, 1995). This list contains 175 underground cities, which are located in the provinces of Aksaray (46), Kayseri (22), Kırşehir (5), Nevşehir (60), Niğde (35), Yozgat (4) and unknown (3).

The second and relatively limited data are obtained from a study made in the Nevşehir province by a Turkish geology company (SIAL, 1992). The report prepared by the company consists of geological information (stratigraphy, tectonism, earthquake risk, geomorphology and volcanism) of the region for 25 underground cities. Exact locations of the cities are illustrated on 1/25.000 scale topographic maps. The report also includes the plans and archaeological information of some underground cities.

The third data source is "Rock Cities and Underground Cities Of Cappadocia"; a book including a map of 22 underground cities and information about 10 of them (Gülyaz and Yenipınar, 2003). Another article by Gülyaz (1995) published in Atlas magazine indicates the locations of 19 underground cities and can be considered as the complementary data of the book.

The last data source is a book published in Turkish (Yörükoğlu et al., 1990) that gives the detailed plans of 19 underground cities in different provinces of the region and includes a list of 121 cities without a description of the location.

During the compilation of the database following rules are applied:

- At some localities two or more underground cities are reported at the same settlement. These are interpreted as different entrances to the city as indicated by some sources. Therefore, only one underground city is assigned to this settlement.
- If the exact location of the underground city is not known, centre of the present settlement is considered to be the site of the city.
- All the underground cities are plotted on 1/25.000 scale topographic maps and their UTM coordinates are read from the map.

- Sizes of the underground cities are not considered in this study. Therefore, each city is represented by one point (pixel). The main reasons for this are: 1) there is not enough data for their sizes because some of the cities are not even visited, 2) even in the cities open to public, some sections in the cities are closed for safety reasons, 3) there is a difficulty in calculating the size of the city whether to base on the volume of carved space or the capacity of the inhabitants hold by this city.

Total number of underground cities within the area is 127 (Figure 4.1). The database for these cities is given in Appendix A that includes following columns:

- Name of underground city,
- Alternative name of the city identified in the literature,
- Name of the province that the underground city belongs to,
- Two columns for UTM easting and northing, respectively
- Two columns indicating the rock types and morphological classes of the cities that will be explained later in this chapter.
- One column indicating whether the underground city is visited or previously known or only bibliographical information could be obtained about it.
- One column indicating whether there is a present settlement in close vicinity to the underground city.

69 cities are either visited or their locations are identified during the field studies. Locations of other 58 cities, on the other hand, are estimated from previous works. Distribution of the cities among the present administrative divisions is shown in Table 4.1.

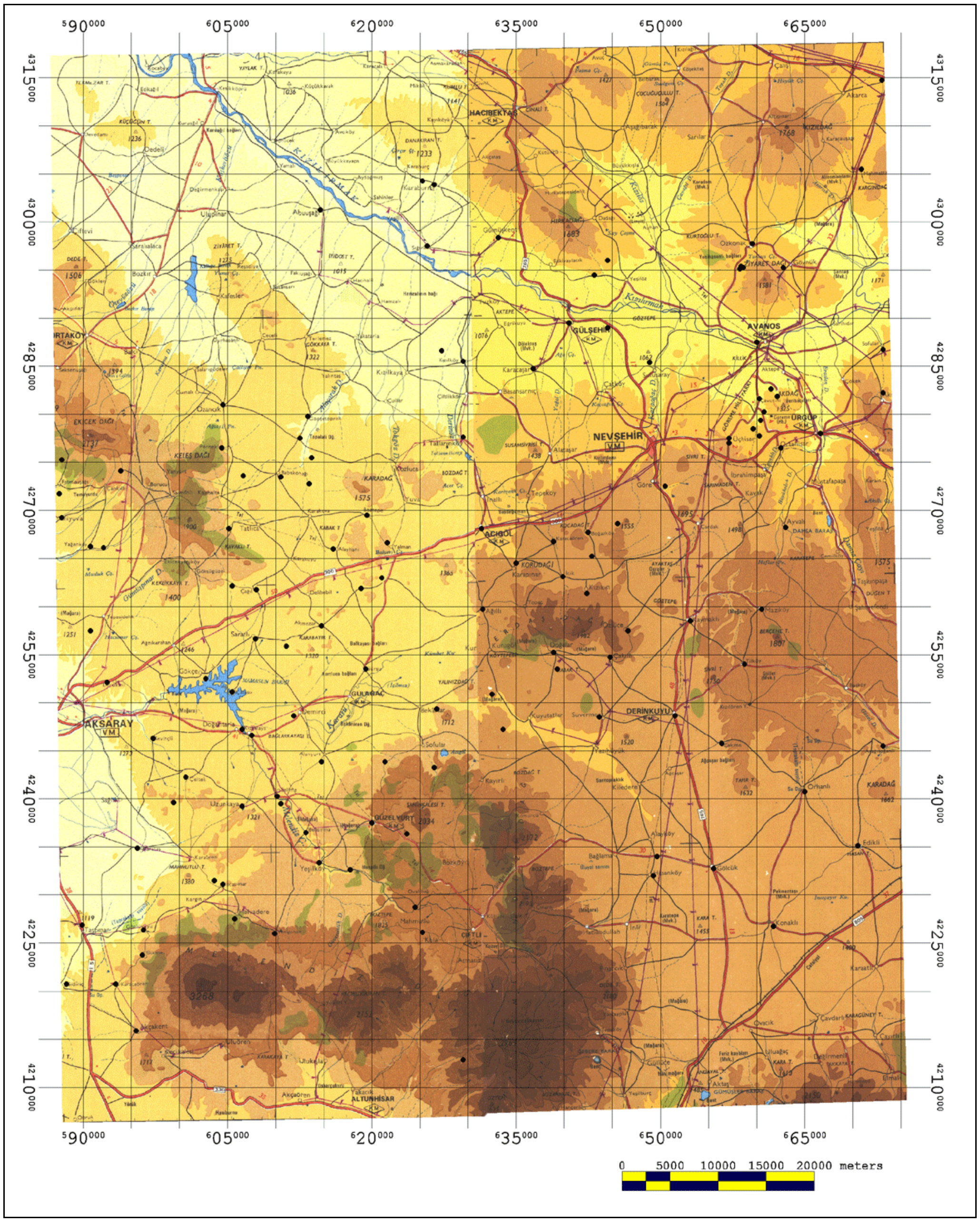

**Figure 4.1** Underground cities (black circles) identified in the study area

**Table 4.1** Distribution of underground cities and present settlements in the area

| Province | District | Frequency | |
|---|---|---|---|
| | | Underground city | Present settlement |
| Aksaray | Aksaray | 32 | 67 |
| | Ağaçören | - | 1 |
| | Gülağaç | 11 | 16 |
| | Güzelyurt | 9 | 13 |
| | Ortaköy | 1 | 26 |
| Nevşehir | Nevşehir | 13 | 20 |
| | Acıgöl | 6 | 14 |
| | Avanos | 11 | 19 |
| | Derinkuyu | 10 | 10 |
| | Gülşehir | 13 | 39 |
| | Hacıbektaş | 2 | 33 |
| | Ürgüp | 6 | 22 |
| Niğde | Niğde | 7 | 36 |
| | Altunhisar | - | 12 |
| | Çiftlik | 5 | 23 |
| Kırşehir | Kırşehir | - | 8 |
| | Mucur | - | 19 |
| Konya | Emirgazi | - | 1 |
| Kayseri | Kocasinan | | 1 |
| | Yeşilhisar | | 4 |
| **TOTAL** | | **127** | **384** |

## 4.2 Present Settlements

Present settlements (Figure 4.2) are compiled from 1/100.000-scaled topographic maps that belong to the period of 1963 to 1968. Coordinates of the settlements are read from 1/25.000-scaled maps for a better accuracy. Following rules are adopted during the compilation of Present settlement data:

- As long as it is known that, all settlements are initially located in a small area (at a specific point) and are grown later due to several factors, all the villages, towns and cities in the study area are considered as one type of settlement and no distinction is made between them in term of their population, size etc. Therefore, during the measurements a special attempt is made to determine the coordinates of these initial locations.

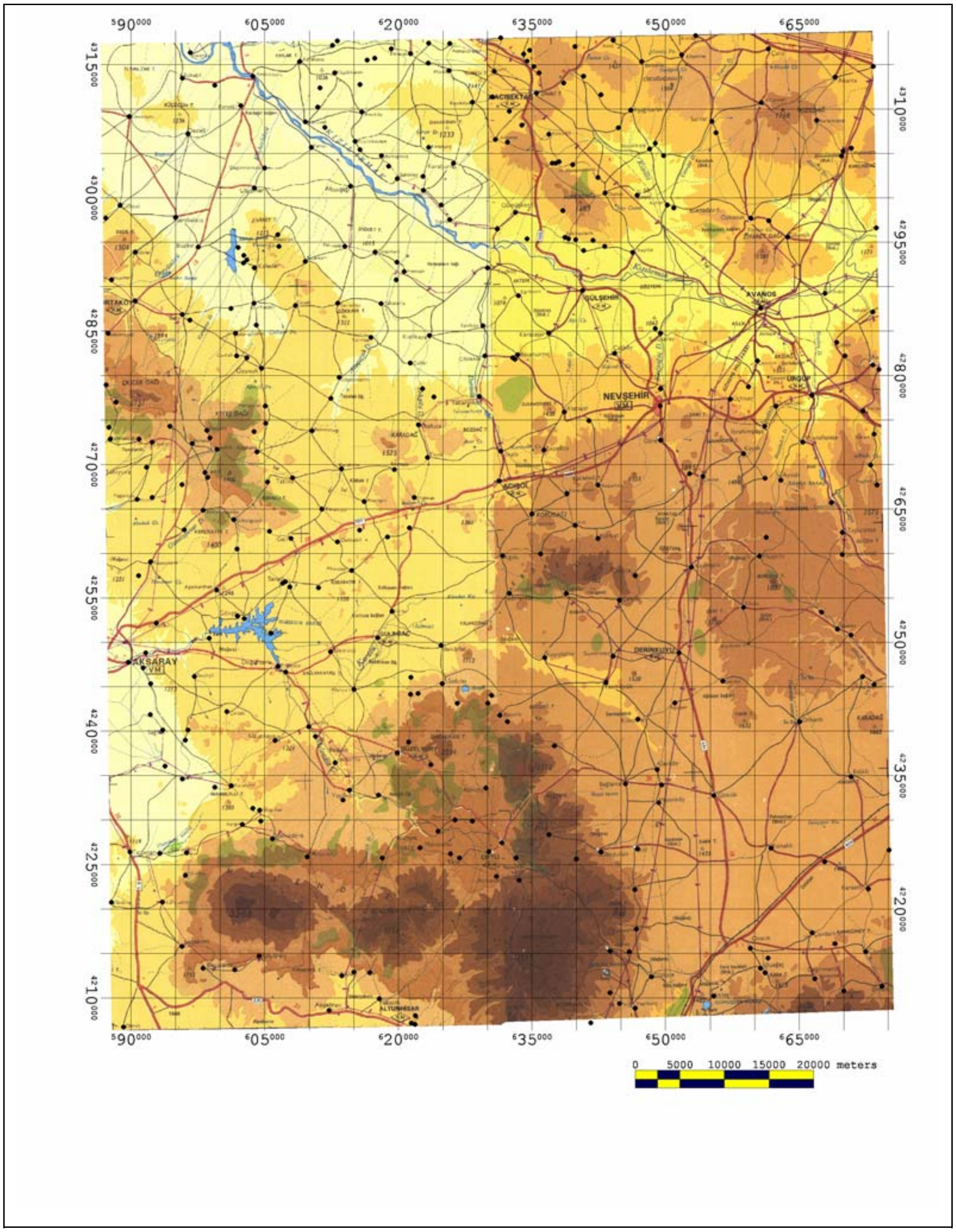

**Figure 4.2** Present settlements (black circles) identified in the study area

- Administrative divisions of the settlements such as "village" or "mahalle" are not considered. Therefore "mahalle" type settlements are also included in the database.
- Recent small settlements such as farms or a groups of houses located around a petrol station are not considered.
- Highland settlements such as "yayla" are not included in the database since these settlements are not permanently used.

A total of 384 present settlements are identified in the study are (Figure 4.2). The database for these settlements is given in Appendix B, which has a similar format to that of underground cities. Distribution of the cities among the present administrative divisions is shown in Table 4.1.

### 4.3 Rock Types

Rock types are compiled from 1/500.000 scale geological maps of General Directorate of Mineral Research and Exploration (MTA) (Figure 4.3). This map is re-classified to produce a "rock type map" of the area to be used in processes. This map should not be considered as a geological map because geological features and structures other then the rocks are discarded in the map. For this reason the map is called "rock type map". This classification is mostly based on the lithological characteristics and the age of the units. Information provided by the previous works (explained in the first two chapters) is also taken into consideration.

Number of rock types in the resultant map is eight. Basic topological information on these rock types is given in Table 4.2. Distribution of the rocks is illustrated in Figure 4.4. A short description of the rock units is as follows:

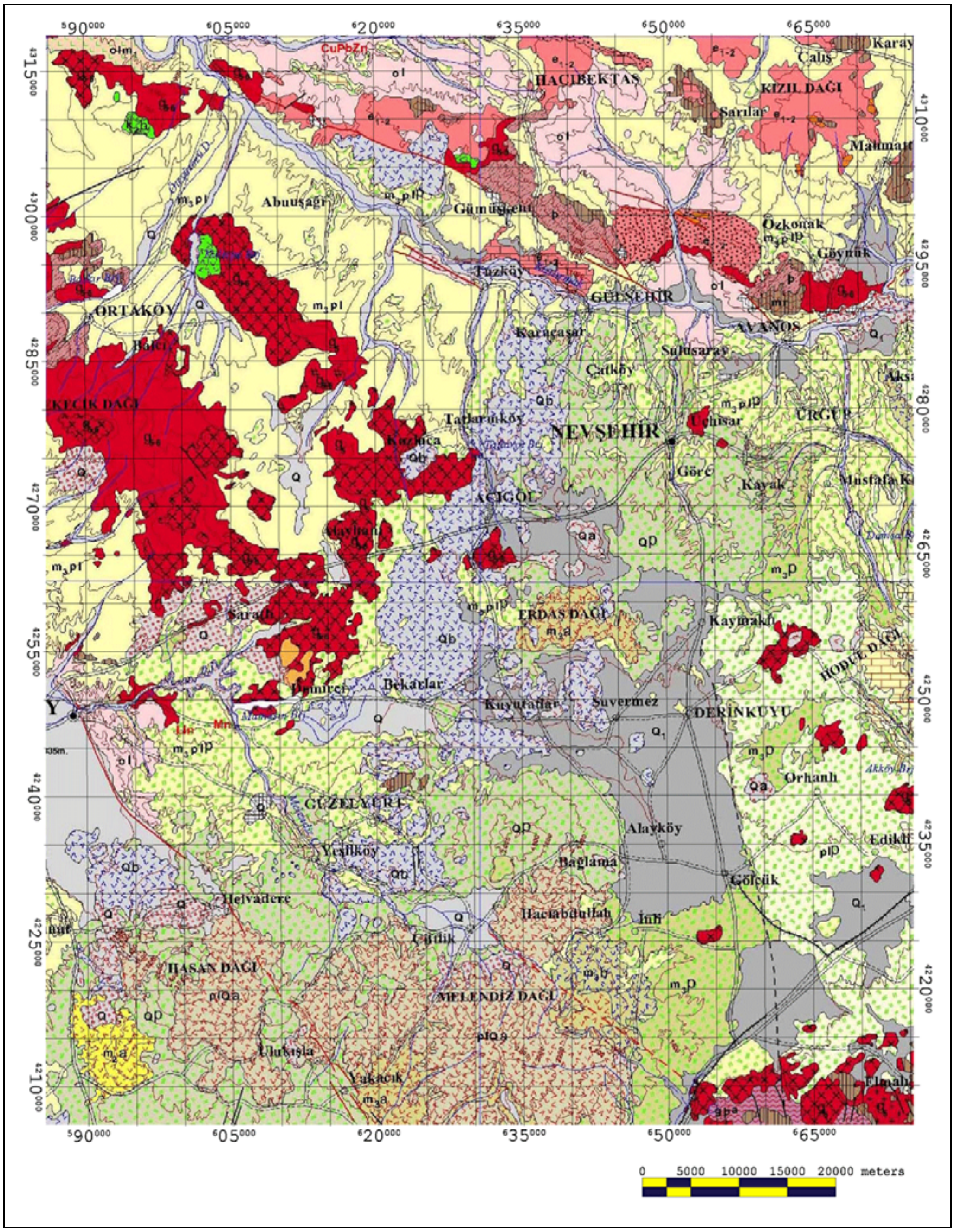

**Figure 4.3** Geological map of the area at 1/500.000 scale compiled by General Directorate of Mineral Research and Exploration (This map is re-classified to prepare a "rock type map" for this study.)

**Table 4.2** Basic topological information of the rock types used in the study

| | Number of Polygons | Min Polygon Area (km2) | Max Polygon Area (km2) | Total Area (km$^2$) | % of the area |
|---|---|---|---|---|---|
| **Quaternary Alluvium** | 32 | 0,41 | 429,83 | 1559,2 | 16,1 |
| **Quaternary Basalt** | 44 | 0,07 | 352,84 | 711,2 | 7,3 |
| **Neogene Andesite** | 25 | 0,19 | 544,38 | 842,9 | 8,7 |
| **Neo1 (Pyroclastics)** | 18 | 0,31 | 1245,1 | 2078 | 21,4 |
| **Neo2 (Pyro dominant)** | 77 | 0,17 | 166,76 | 889,7 | 9,2 |
| **Neo3 (Sed dominant)** | 34 | 0,2 | 897,96 | 1634,8 | 16,9 |
| **Oligocene Clastics** | 14 | 0,41 | 151,83 | 448,6 | 4,6 |
| **Basement Rocks** | 63 | 0,91 | 251,63 | 1530 | 15,8 |
| **Total** | 307 | | | 9694,4 | 100.0 |

**Alluvium:** Alluvium refers to unconsolidated material deposited in river channels. They are Quaternary in age and are still being deposited. They cover 16.1 % of the area and are mostly observed along Kızılırmak and Melendiz river and their tributaries.

**Basalt:** Basaltic rocks are formed by recent volcanic eruptions of Quaternary age. (Ercan, 1987; Ercan et al., 1990, 1992, 1994) and are exposed as thin layers in the area. They are usually observed at low elevations in the vicinity of cinder cones. Although there are 44 polygons of basaltic rocks in the area, almost all of them are observed in a belt extending N-S direction. They cover 7.3 % of the area.

**Andesite:** Andesites are the older lava flows of Neogene volcanic activity. The oldest dated andesitic volcanism is around Keçikalesi village (SW of study area) with an age of 13 million years and the youngest is about 5.4 million years at Melendiz mountain (north of Niğde) (Besang et al., 1977). Andesites are, in general, are observed at major volcanic eruption centers such as Hasandağ, Keçiboyduran, Melendiz and Kızılçın volcanoes. They cover approximately 8.7 % of the area.

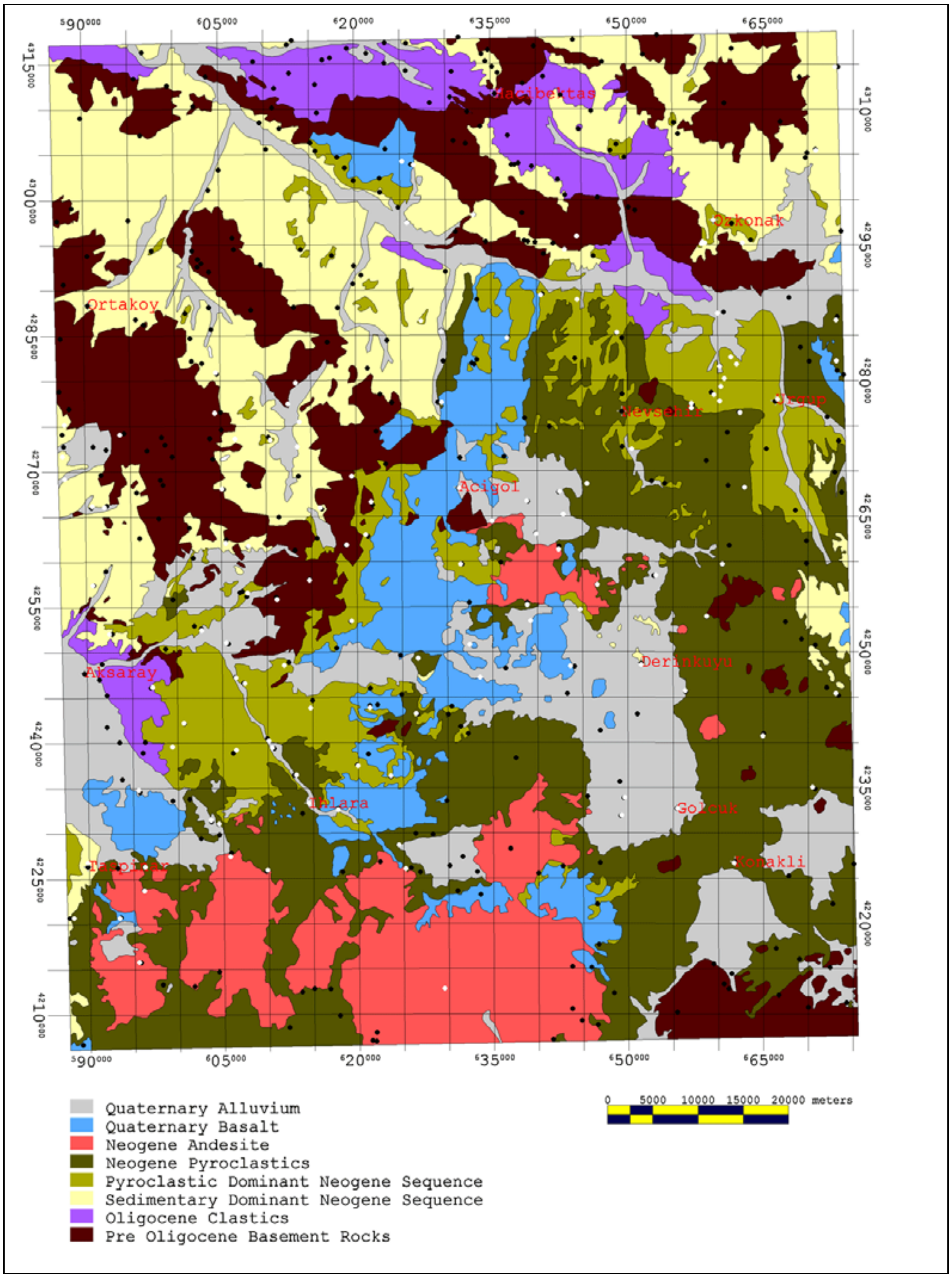

**Figure 4.4** Rock types map of the area used in the study (Black circles are underground cities and white circles are present settlements.)

**Neogene sequences (Neo1, Neo2 and Neo3):** Neogene sequences are one of the most commonly observed rock units in the area. They are named as Ürgüp formation around Nevşehir and Kızılırmak towards the western part of the area (Pasquare, 1968; Göncüoğlu et al, 1993). The age of formation is almost the same over the whole area (13-4 million years, Innocenti et al, 1975; Besang et al., 1977, Schumacher, Mues-Schumacher, and Schumacher, 1996). However, they differ in volcanic (pyroclastic) and sedimentary content in different parts of the area. This difference is due to local variations in the depositional environments, from lacustrine to fluvial which at the same time receives volcanic products erupting from vents in the vicinity. Although it is difficult to draw a sharp boundary to indicate these differences, an attempt is made to divide this sequence laterally into three units based on the pyroclastic content. Pyroclastic content is compiled from literature given in the first two chapters.

**Neo1 (Pyroclastics):** Neogene pyroclastic rocks are characterized by successive tuff (ignimbrite) layers with almost no sedimentary intercalation. They are commonly observed around Hasandağ-Melendiz volcanic complexes and around Derinkuyu-Kaymaklı depressions. They cover 21.4 % of the area.

**Neo2 (Pyroclastic dominant):** Pyroclastic dominant Neogene sequences are composed of both tuff and sedimentary layers. Large outcrops are exposed east of Aksaray and around Nevşehir. Total area covered by this sequence is 9.2 %.

**Neo3 (Sedimentary dominant):** Sedimentary dominant Neogene sequences are composed dominantly of lacustrine to fluvial sedimentary rocks with minor volcanic intercalations. Typical outcrops are located within the Kızılırmak drainage basin. They cover an area of 16.9 %.

**Oligocene clastics:** Oligocene clastic rocks are composed of two distinct outcrops one east of Aksaray, other north of Kızılırmak river (Göncüoğlu et al, 1993; Akgün et al., 1995). The sequence around Aksaray is composed of unconsolidated, massive clastic rocks (mostly conglomerates) whereas the second sequence is composed of well-bedded conglomerate-sandstone-siltstone alternation. Area covered by this rock type is 4.6 %.

**Basement rocks:** Basement rocks comprise all rock units younger than Oligocene in age. Although there are a variety of rocks in this group, they are not subdivided in order not to complicate the map. Dominant rock types are metamorphic rocks, intrusive bodies, ophiolitic rocks and their cover rocks. Large outcrops of basement rocks are exposed in the northern half of the area in belts extending in NW-SE direction. They cover an area of 15.8 %.

### 4.4 Morphological Classes

Morphological classes refer to the types of landscape existing in the area. These landscapes are manually drawn from Digital Elevation Model (DEM) of the area (Figure 4.5) obtained from SRTM. SRTM (Shuttle Radar Topography Mission) is an international project pioneered by NGA (National Geospatial-Intelligence Agency) and NASA. SRTM has 90 m pixel resolution and 16 m vertical accuracy.

Morphological classes used in this study are digitized using elevation and slope maps prepared from the DEM. Type and name of morphological classes are identified after visual interpretation of these maps. Total number of classes is eight (Figures 4.6 and 4.7). A short description of each class is as follows:

**Figure 4.5** Digital Elevation Model (DEM) of the area obtained from SRTM data (This DEM is used to prepare morphological classes.)

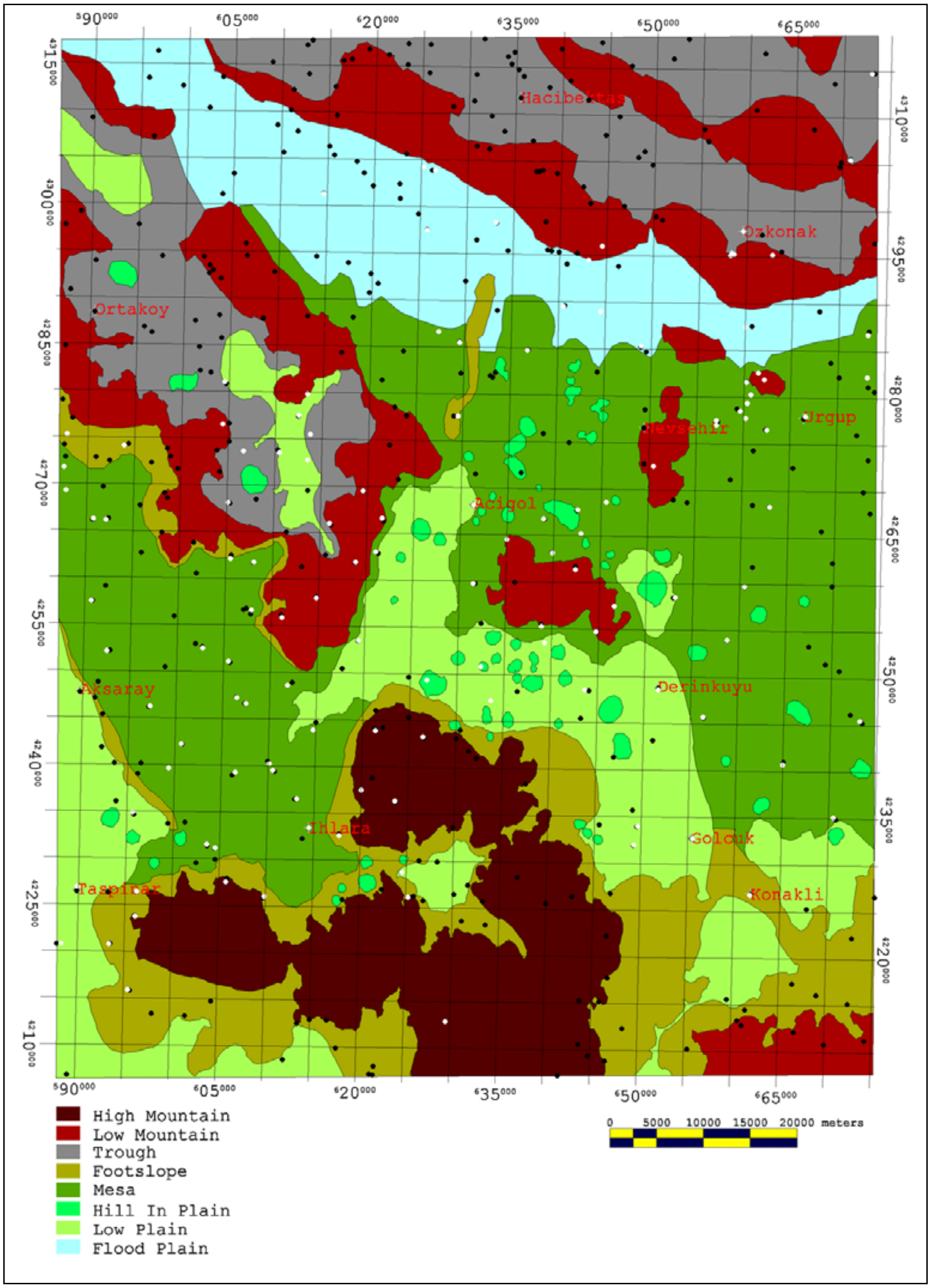

**Figure 4.6** Morphological classes map of the area used in the study (Black circles are underground cities and white circles are present settlements.)

**Table 4.3** Basic statistics of the morphological classes identified in the study area

| | Number of Polygons | Max Area (km2) | MinArea (km2) | Total area (km2) | % of area |
|---|---|---|---|---|---|
| **Flood Plain** | 1 | 891,54 | 891,54 | 891,5 | 9,19 |
| **Low Plain** | 8 | 619,83 | 30,67 | 1371,3 | 14,14 |
| **Hill in Plain** | 66 | 6,52 | 0,34 | 143,5 | 1,48 |
| **Footslope** | 4 | 928,47 | 21,52 | 1066,5 | 10,99 |
| **Mesa** | 1 | 2625,2 | 2625,2 | 2625,2 | 27,06 |
| **Trough** | 3 | 501,04 | 207,74 | 1207,6 | 12,44 |
| **Low Mountain** | 9 | 601,49 | 7,55 | 1461,8 | 15,07 |
| **High Mountain** | 1 | 934,01 | 934,01 | 934 | 9,63 |
| **Total** | 93 | | | 9701,4 | 100,00 |

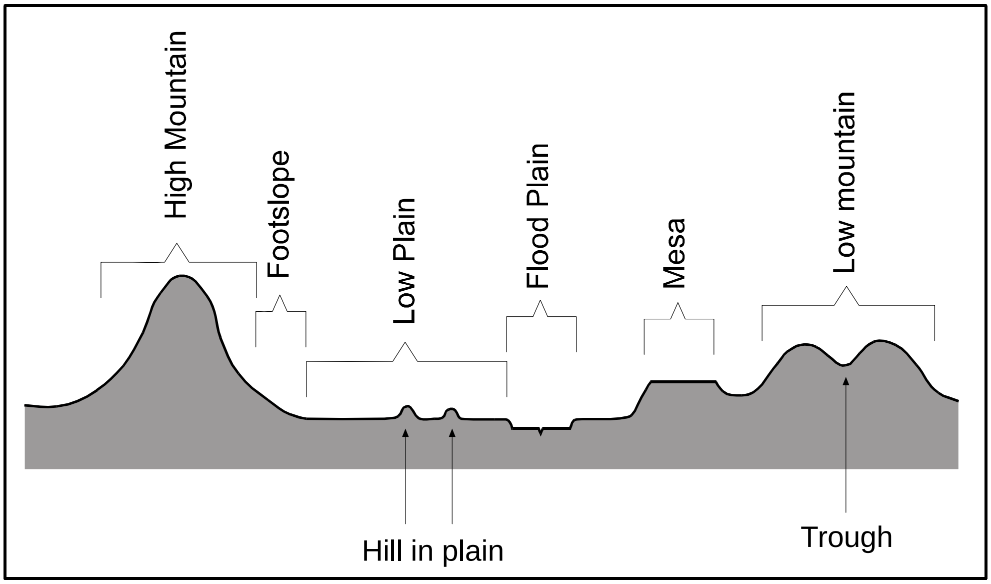

**Figure 4.7** An imaginary profile showing morphological classes (without scale)

**Flood plain:** Flood plain refers to the wide alluvial plains formed along major streams. Within the study area this landscape is observed along the Kızılırmak river valley. This valley is characterized by a flat surface filled by alluvium. It is exposed as a belt in almost E-W direction with a maximum width of 15 km. It covers 9.19 % of the area.

**Low plain:** Low plain is represented by flat areas observed at low altitudes. Geologically, most of them correspond to recent basins (depressions) filled by alluvium (Toprak, 1996). Examples are Tuzgölü, Derinkuyu and Çiftlik basins. They have high potential for agricultural activities. They cover 14.14 % of the area.

**Hill in plain:** This landform is characterized by circular to elliptical hills located at low altitudes. Size of the hills is relative small with an average diameter of 1-2 km. A total of 66 hills are determined in the area forming the most populated landform (Table 4.2). The percentage over the whole area, on the other hand, is the smallest with 1.48 %. Geologically, most of the hills are the monogenetic volcanic eruption centres (basaltic or andesitic) which are frequently observed in the area (Toprak, 1988; Arcasoy, 2001; Arcasoy et al, 2004)

**Footslope:** Footslope landform is the transitional area between high mountains and other classes particularly the low plains. Geologically they are represented by large scale alluvial to talus type deposits. They are geographically confined mostly around major volcanic complexes south of the area. They cover an area of 10.99 %.

**Mesa:** The term mesa refers to a broad, flat-topped hill bounded by cliffs and capped with resistant rock layer. In the study area, this landform is well developed within Neogene sequences because of two reasons: 1)

These sequences are horizontal and can produce flat surfaces; 2) Tuff (ignimbrite) layers in the sequence are relatively resistant to erosion and can be good capping rocks. Mesa landform is the most commonly observed class in the area with 27.06 %.

**Trough:** Troughs are elongated low areas (depressions) formed in mountainous regions. Geologically they may correspond to graben filled with young rock units. Troughs in the area are developed within "low mountain" class mostly located in the northern parts as parallel belts extending in NW-SE direction. They cover 12.44 % of the area.

**Low mountain:** This class is represented by relatively high mountainous regions with gentle slopes. Geologically most of this class corresponds to basement rocks of Kırşehir and Niğde massifs. The area covered by this class is 15.07 %.

**High mountain:** High mountain class includes steep and high regions of the area. Most of the recent major eruption centers (Hasandağ, Keçiboyduran, Melendiz, Göllüdağ etc) are included in this class. This class covers 9.63 % of the area.

# CHAPTER V

# ANALYSES AND INTERPRETATION

This chapter explains the analyses carried out to investigate location of underground cities and other parameters. Four analyses are as follows:

- Distances between underground cities and present settlements
- Density analysis of underground cities and present settlements
- Distribution analysis of underground cities and present settlements within different rock units and morphological classes
- Prediction of unexplored underground cities

## 5.1 Distance Analysis

Distance analysis aims to evaluate the distances between underground cities and present settlements. To do this, the coordinates of them are used. A program is written in BASIC language to calculate the distances for each set of data (App. C1). The program inputs the X and Y coordinates of each record and finds the nearest (minimum distance) underground city or present settlement. This program is executed three times to find the distances: 1) between two underground cities; 2) between two present settlements, and 3) between an underground city and the nearest present settlement.

The results of the analyses are summarized in Table 5.1 for three outputs. Distribution of these results in histograms are illustrated Figure 5.1.

**Table 5.1** Basic statistics for the distances for underground cities (UC) and present settlements (PS)

| | Number | Minimum distance (m) | Maximum distance (m) | Mean (m) |
|---|---|---|---|---|
| UC to UC | 127 | 280 | 13915 | 3905 |
| PS to PS | 384 | 292 | 11120 | 2679 |
| UC to PS | 127 | 0 | 9029 | 717 |

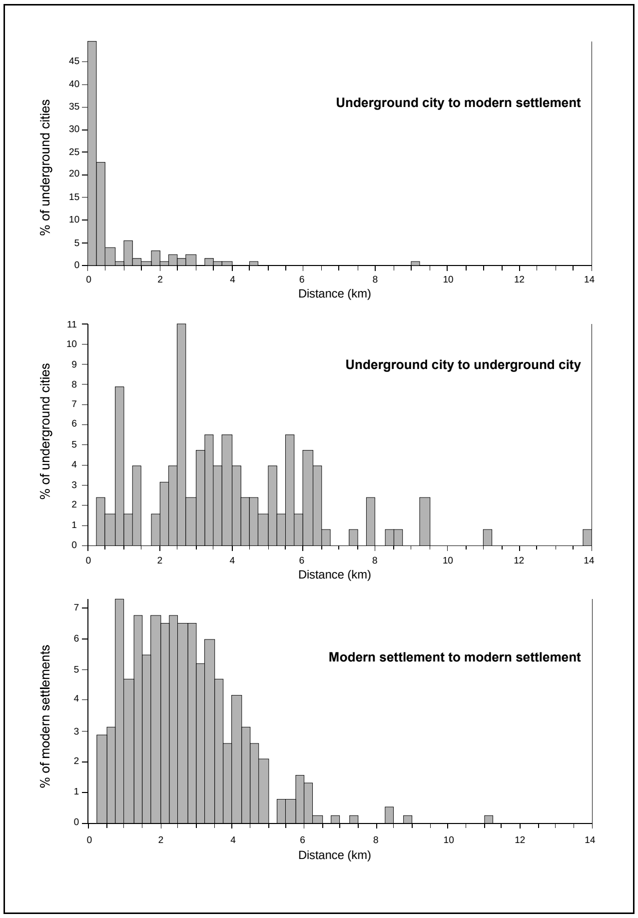

**Figure 5.1** Histograms showing the distances between two underground cities, two present settlements and an underground city and a present settlement (Bin width is 250 m.)

Accordingly, the mean distance between an underground city and present settlement is 717 m, between two underground cities is 3905 m, and between two present settlements is 2679 m.

The mean distance between an underground city and the closest present settlement is 717 m. This suggests that most of the underground cities are in the close vicinities of present settlements. As seen in the histogram, about 50% of the underground cities are at distances of 0 to 250 m (moderate) and more than 70% are at distances of 0 to 500 m. The largest distance is 9029m. This value drops to 4626m for the second largest distance.

The mean distances of two underground cities and two present settlements, on the other hand, cannot be compared with each other since the frequencies of them are different. There are 127 underground cities and 384 present settlements in the study area. Since the frequency of the present settlements is almost three times than that of underground cities, a larger distance for the underground cities should be expected. For this reason, the distances are tested by generating two sets of mean distances using two methods.

The first method is generating random coordinates for the locations of underground cities and present settlements. A program in BASIC language is written that uses "randomize" command to produce random coordinates within the study area (127 random coordinates for underground cities and 384 random coordinates for present settlements). The program is executed ten times for the underground cities and ten times for the present settlements. The mean distances are calculated using the BASIC program mentioned above. Results of the computations are given in Table 5.2. Accordingly, the average values are 4335m for the mean distances between the underground cities and 2443m for those of the present settlements.

The second method is based on a theoretical consideration assuming that the underground cities and present settlements are uniformly distributed in the study area. The total area covered in the study is approximately 9700 km$^2$. Therefore the size of unit area per one underground city 76.4 km$^2$ and per one present settlement is 25.3 km$^2$ (Figure 5.2). The distances between two underground cities and two present settlements should be 8.74km and 5.03km respectively if they are located exactly at the centers of their polygons.

**Table 5.2** Distances provided by random generation of site location

| **Run No** | **Mean distances between underground cities (m)** | **Mean distances between present settlements (m)** |
|---|---|---|
| 1 | 4483 | 2467 |
| 2 | 4421 | 2377 |
| 3 | 4630 | 2430 |
| 4 | 4370 | 2504 |
| 5 | 4853 | 2407 |
| 6 | 3821 | 2460 |
| 7 | 4070 | 2403 |
| 8 | 4241 | 2414 |
| 9 | 4154 | 2498 |
| 10 | 4303 | 2467 |
| **Average** | **4335** | **2443** |

Results of the mean distances calculated in three ways are given in Table 5.3. Distances for the real averages and empirical ones do not differ too much. On the other hand, the averages of the real data and theoretical values are considerably different.

These values are used to find indexes those will compare the distances between underground cities and present settlements. These indexes are simply the divisions of a) empirical averages by the real ones and b) theoretical averages by the real ones. Accordingly, the indexes for underground cities and present settlements are:

a) 4335/3905 = **1,110** (uc)

2443/2679 = **0,912** (ps)

1,110/0,912 = **1,217…1,2**

b) 8740 /3905 = **2.238** (uc)

5026 /2679 = **1.876** (ps)

2.238/1.876 = **1,193…1,2**

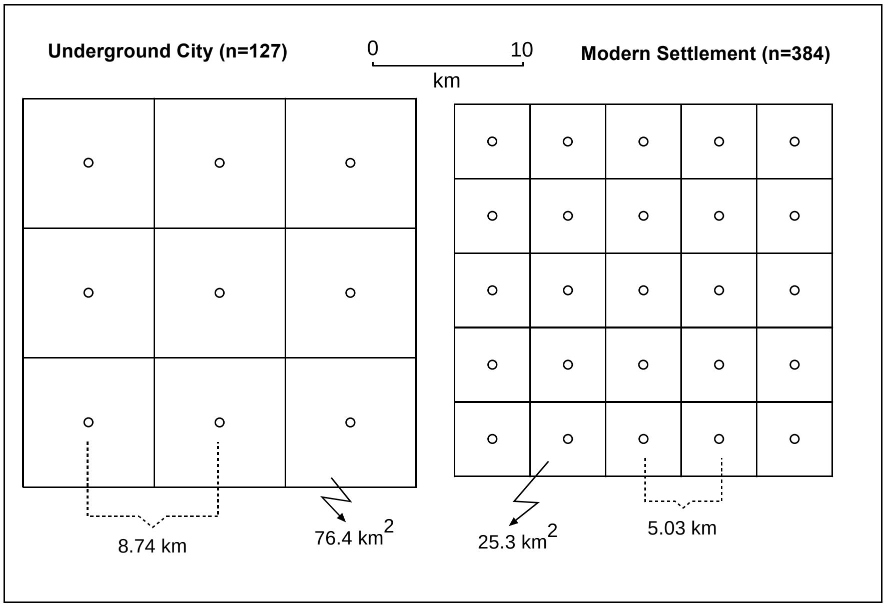

**Figure 5.2** Theoretical distances between underground cities and present settlements assuming a uniform distribution over the area

These two values mean that whether the underground cities and present settlements have a random or uniform distribution in the area the distance between two underground cities is about 20% larger than that of the present settlements.

**Table 5.3** Comparison of the mean distances computed by three methods

| Method | Underground cities | Present settlements |
|---|---|---|
| Real average computed from the database | 3905m | 2679m |
| Empirical average computed by generating random coordinates | 4335m | 2443m |
| Theoretical average assuming uniform distribution | 8740m | 5026m |

### 5.2 Density Analysis

The main purpose of the density analysis is to investigate where the cities and settlements are concentrated. The procedure of this analysis is illustrated in Figure 5.3. The numbers of underground cities and present settlements are counted within a circular area whose search radius is 5km and grid spacing (shift amount) is 1km. This number is assigned to the grid that corresponds to the center of circle.

A BASIC program is written to count the number for each grid and to move the circle from left to right for all columns and top to bottom for all rows (App. C2). The process produces a grid system with 93 columns and 105 rows. Therefore, the area covered for each grid cell is about 50km$^2$ (49.35km$^2$).

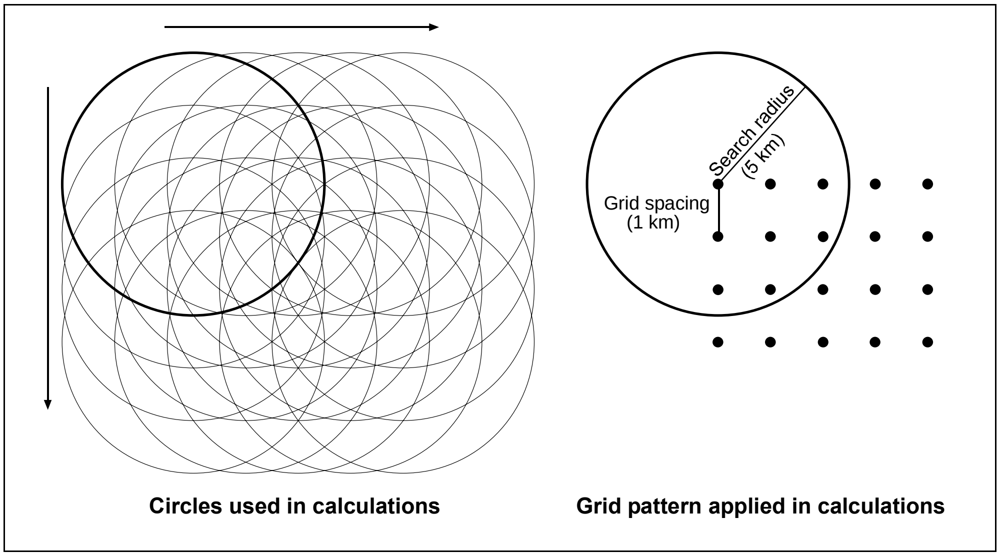

**Figure 5.3** Principle of the density analysis carried out in the study

Frequencies of the underground cities and present settlements for different concentrations of 9765 pixels are shown in Table 5.4. Density maps of cities and settlements are given in Figure 5.4. Density patterns are quite different in both maps mostly due to difference in the frequencies of the underground cities and present settlements.

**Table 5.4** Frequencies of the density analysis of underground cities and present settlements for different percentages

| | Freq. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Underground city** | % | | 1.0 | 1.8 | 2.4 | 3.1 | 3.9 | 4.7 | 5.5 | 6.3 | 7.1 | 7.8 | 8.6 | |
| | n | 4527 | 2569 | 2230 | 255 | 104 | 28 | 30 | 12 | 9 | 1 | 1 | 1 | 9765 |
| **Present settlement** | % | | 0.3 | 0.5 | 0.7 | 1.0 | 1.3 | 1.5 | 1.8 | 2.1 | 2.3 | 2.6 | 2.9 | |
| | n | 2578 | 6197 | 961 | 29 | - | - | - | - | - | - | - | - | 9765 |

Maximum concentration of the underground cities per unit area is about 11 (8.6% of 127 underground cities) around east of Nevşehir. This amount suddenly drops to 6 (4.7%) in other places such as near Özkonak; southwest, east and west of Acıgöl; east of Aksaray; and southeast of Taşpınar. 7096 pixels in the area which corresponds to 72.6% of the whole study area has a frequency less then 2 (1.8 %). These areas are mostly located in the northwestern and southeastern parts of the study area.

Maximum concentration of the present settlements per unit area is about 11 (2.9 % of 34 present settlements) around Hacıbektaş and north of Aksaray. This maximum value is relative small compared to that the underground cities due to the almost three times larger frequency of the present settlement in the area. 8775 pixels in the area (89.8 % of the whole area) have a frequency less than 2 (0.5 %).

Although two maps in Figure 5.4 give an idea on the densities and spatial distribution of underground cities and present settlements in the area, it is difficult to compare the areas preferred by any of these two kinds of sites. So, the area is divided into the following four regions.

1. Low underground city, low present settlement frequencies
2. Low underground city, high present settlement frequencies
3. High underground city, low present settlement frequencies
4. High underground city, high present settlement frequencies

Two cases with different “high” and “low” frequencies are considered here. Percentages of the underground cities and present settlements given in Table 5.4 are used as thresholds during the classification. The first case assumes that the percentage of underground cities is greater than 3, and of the present settlements, greater than 1. In the second case, the percentage of underground cities is assumed to be greater than 1, and of the present settlements, greater than 0.

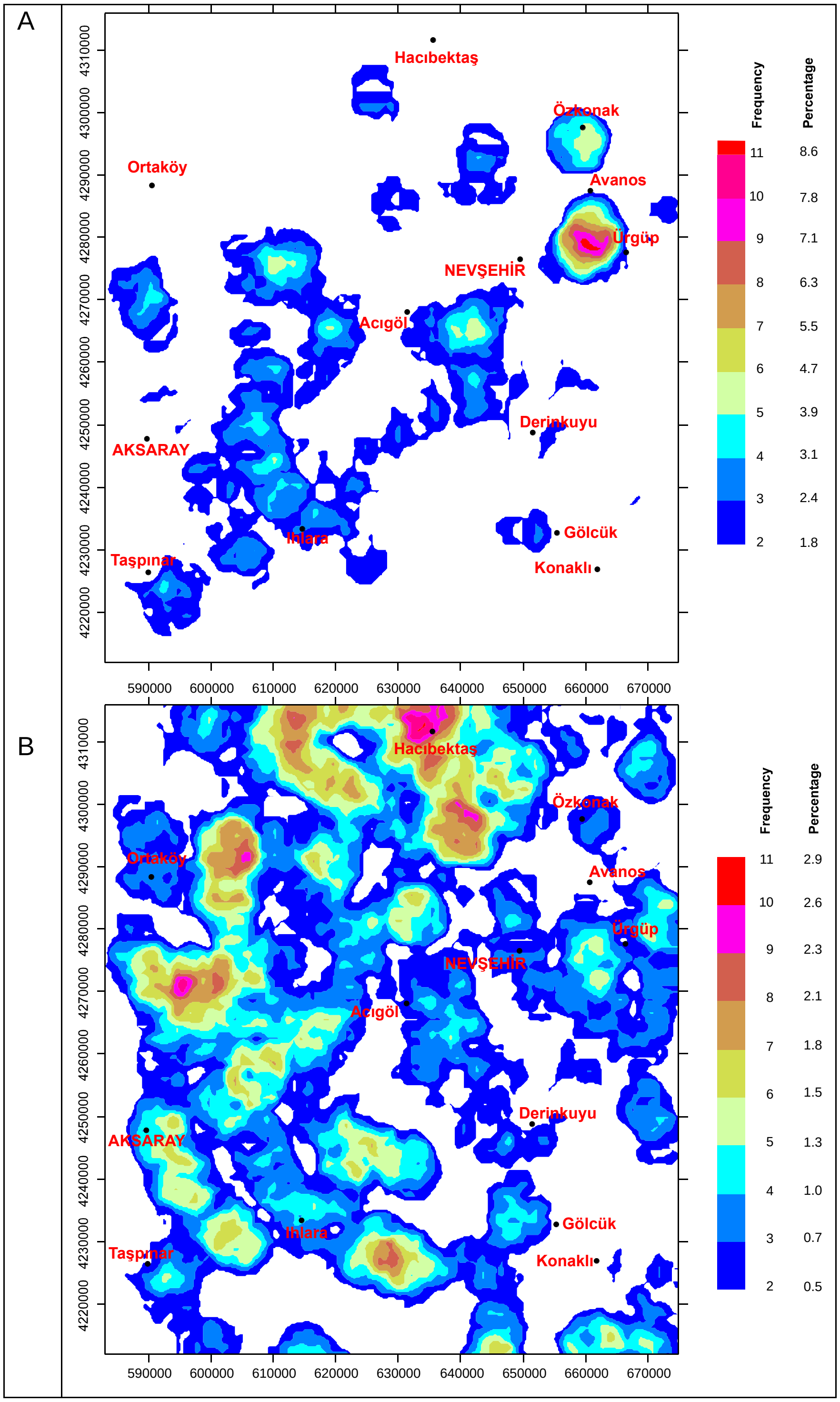

**Figure 5.4** Density maps of underground cities (A) and present settlements (B)

A BASIC program is written that inputs one pixel for each 1km$^2$ area (App. C3). Each of these pixels is classified into one of the four regions mentioned above and two maps based on these regions are generated. Basic statistics of the data used are given in Table 5.5.

Two maps prepared from this analysis are shown in Figure 5.5. Green color in the maps indicates the regions with high underground city and low present settlement percentages. Blue color, on the other hand, shows low underground city and high present settlement percentages. White and red colors display the areas where the percentages of both underground cities and present settlements are either low or high, respectively.

**Table 5.5** Classification of the area into four distinct regions for two cases (Numbers in the columns are frequencies if this condition is true. UC: underground city, PS: present settlement)

| | **Underground cities** | **Present settlements** | **CASE-1 % of UC>3 % of PS>1** | **CASE-2 % of UC>1 % of PS>0** | **Color on Map** |
|---|---|---|---|---|---|
| **Region1** | no | no | 8602 | 2402 | White |
| **Region2** | no | yes | 979 | 4694 | Blue |
| **Region3** | yes | no | 173 | 176 | Green |
| **Region4** | yes | yes | 11 | 2493 | Red |
| **Total** | | | 9765 | 9765 | |

The main focus in these maps is on the distribution of green and blue colored pixels. Accordingly, a few small regions are determined for underground cities, which are not preferred by present settlements. The most emphasized green regions are between Nevşehir, Ürgüp and Özkonak; and between Derinkuyu and Acıgöl; Blue regions, on the other hand, are highly clustered in the area and cover a larger portion compared to underground cities. Distribution of blue colored regions forms a belt that resembles a ring around the green areas. The whole blue areas seem to be the western half of ring that surrounds the underground cities. From this pattern it can be deduced that the location of sites moved from central parts, which are suitable for underground cities towards the periphery in almost all directions.

White areas indicate the areas that are not preferred by underground cities or present settlements. Most of these areas (particularly those in the central and southern parts) correspond to high mountain regions, which are not suitable for the location of a site.

### 5.3 Distribution Analysis

In this analysis the spatial distribution of the underground cities and the present settlements within the rock types and the morphological classes are investigated. The emphasis is given to the relationships between:

1. Underground cities (uc)/present settlements (ps) and morphological classes
2. uc/ps and rock types
3. Morphological classes and rock types

#### 5.3.1 Distribution in Morphological Classes

Frequencies and percentages of the morphological data used in the study are given in Table 5.6. First two columns indicate the areas and percentages of the areas of the morphological classes. Next four columns show frequencies and percentages of the underground cities (uc) and the present settlements (ps). The last two columns are differences obtained by subtracting the percentages of uc/ps from the percentages of the study area.

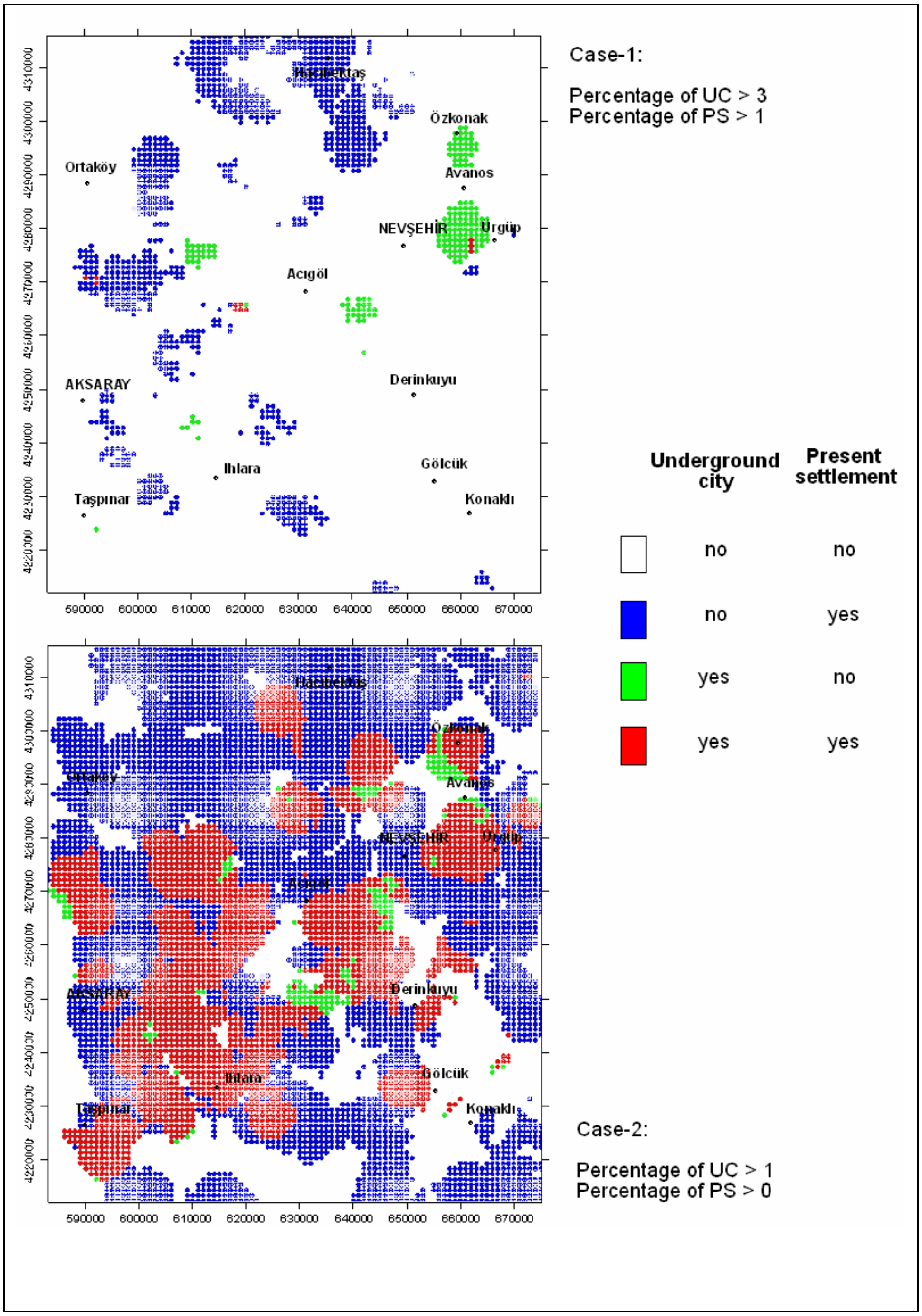

**Figure 5.5** Classification of the area with respect to percentages of the underground city and the present settlements for two cases

Histograms prepared from this table are illustrated in Figure 5.6. Among the morphological classes, the mesa landform is the most dominant class with a percentage of 27.1 (Figure 5.6-A). Hill in plain landform, on the other hand, is the least dominant class with the percentage of 1.5. Other six classes have almost similar percentages ranging between 9 and 15.

Percentages of the underground cites and the present settlements are given in Figure 5.6-B. Underground cities located within the mesa class have the maximum value with 42.45 %, followed by low mountains (15.8 %) and low plains (15.7 %). All other classes have percentages less than 10. There is no underground city located within "hill in plain" class.

**Table 5.6** Frequencies and percentages of the study area, the underground city (UC) and the present settlement (PS) for morphological classes.

| **Morphological Class** | **Study area** | | **UC** | | **PS** | | **UC minus study area** | **PS minus study area** |
|---|---|---|---|---|---|---|---|---|
| | **($km^2$)** | **(%)** | **(#)** | % | **(#)** | % | | |
| Flood Plain | 891,5 | 9,2 | 10 | 7,9 | 41 | 10,7 | -1,32 | 1,49 |
| Hill in plain | 143,5 | 1,5 | 0 | 0,0 | 1 | 0,3 | -1,48 | -1,22 |
| Footslope | 1066,5 | 11,0 | 10 | 7,9 | 50 | 13,0 | -3,12 | 2,03 |
| Low plains | 1371,3 | 14,1 | 20 | 15,7 | 38 | 9,9 | 1,61 | -4,24 |
| Mesa | 2625,2 | 27,1 | 54 | 42,5 | 94 | 24,5 | 15,46 | -2,58 |
| Low mountain | 1461,8 | 15,1 | 20 | 15,8 | 75 | 19,5 | 0,68 | 4,46 |
| Troughs | 1207,6 | 12,4 | 6 | 4,7 | 62 | 16,1 | -7,72 | 3,70 |
| High Mountain | 934 | 9,6 | 7 | 5,5 | 23 | 6,0 | -4,12 | -3,64 |
| **TOTAL** | 9701,4 | 100,0 | 127 | 100,0 | 384 | 100,0 | | |

Distribution of the present settlement is quite different than that of the underground cities. Although mesa landform is again the most populated class, its percentage is relatively low (24.5) followed by low mountain (19.5), trough (16.1) and footslope (13.0). Other classes have percentages equal or less than 10.

The percentages of uc and the ps are subtracted from the percentages of the areas of the morphological classes to investigate the relationship between the area of the class and the frequency of uc or ps. If this value is positive then the percentage of uc or ps is greater than the percentage of area for this class, which implies that this class is favoured as a suitable place to settle. Otherwise, if the value is negative that means although the nature has provided this landform it is not preferred by the settlers and therefore avoided. The resultant histograms are shown in Figure 5.6-C in different colors for underground cities and present settlements.

Following observations can be made on the relationship between morphological classes and uc/ps percentages based on the histogram in Figure 5.6-C.

- For the underground cities, mesa landform is the most distinctive class with a score of +15.46. Therefore, this landform is the most favoured class for an underground city. Trough landform, on the other hand, is the most avoided class as indicated by the value of -7.72. All other classes have values ranging between -4.12 to +1.61, which do not suggest a strong relationship. However, among these classes only low plain and low mountain classes have positive values indicating a slight preference for these classes, while all others (high mountain, footslope, hill in plain and flood plain) are avoided as indicated by their negative values.
- For the present settlements, there is not strong evidence on the preference of the morphological classes. The maximum and minimum values range between -4.24 and +4.46. Two most preferred classes are low mountains and troughs where two most avoided classes are high mountains and low plains.

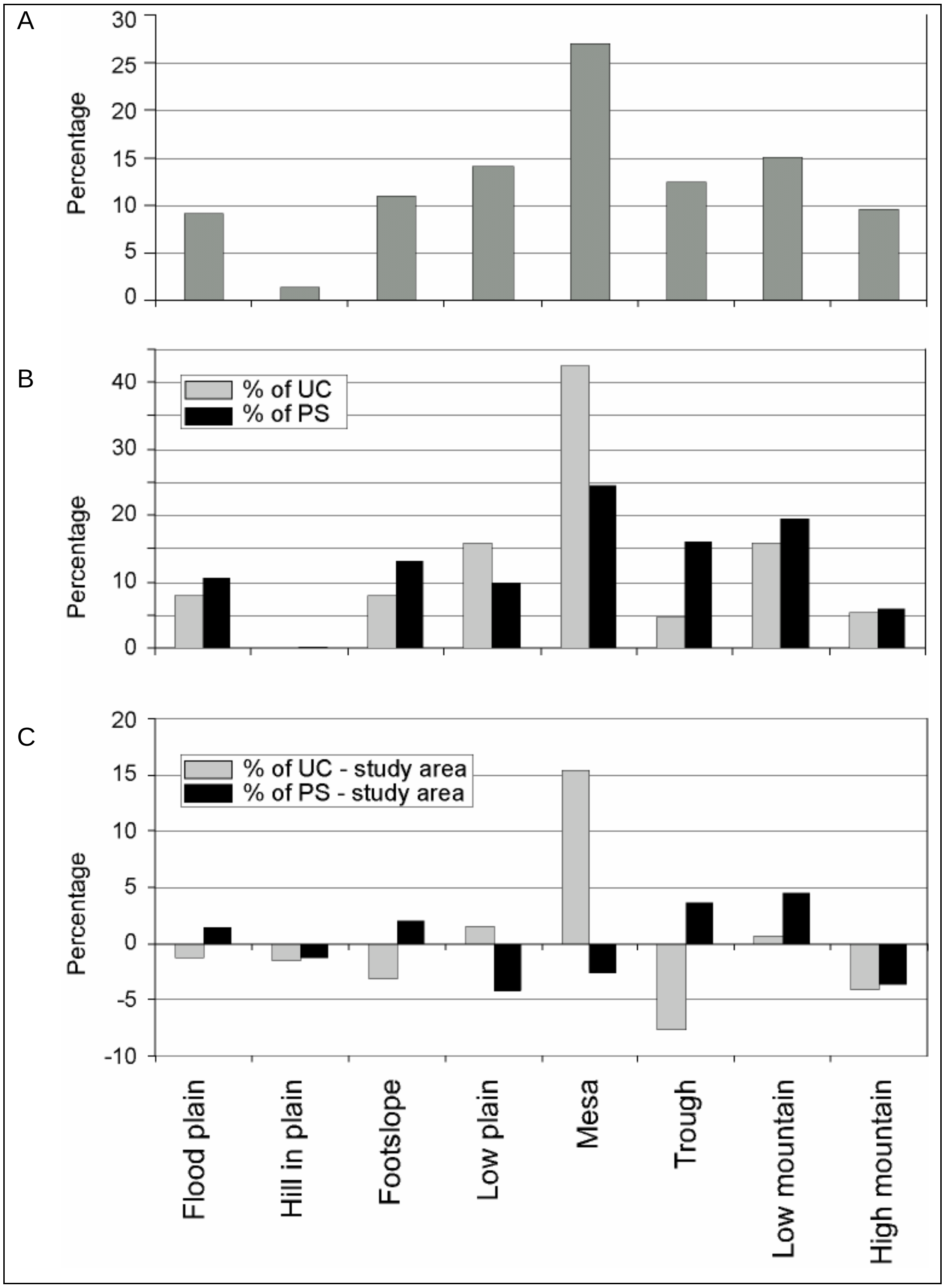

**Figure 5.6** Histograms prepared from data shown in Table 5.6

A. Histogram of the morphological classes in the study area
B. Histogram of the underground cities and present settlements
C. Histogram of the differences

- Comparison of values for the underground cities and the modern settlements implies that the favour to the morphological classes is greatly different for the underground cities from that of the present settlements. Only positive value for both is low mountain class with different values (0.68 for uc and 4.46 for ps). Hill in plain and high mountain classes are commonly avoided classes with almost similar values. All other classes have opposite values suggesting that the use of landforms is highly different for the underground cities and the present settlements. Two contrasting examples are mesa (maximum positive for uc and negative for ps) and trough (maximum negative for uc and positive for ps)

### 5.3.2 Distribution in Rock Types

Frequency and percentages of rock type classes are given in Table 5.7. First two columns indicate area and percentage of the rock type classes. Next four columns show frequencies and percentages of underground cities and present settlements. Last two columns are differences found by subtracting percentages of cities/settlements from that of study area. Histograms prepared from this table are illustrated in Figure 5.7.

Four classes of the rock types (alluvium, Neo1, Neo3 and basement) have percentages greater than 15 and four classes (Basalt, Andesite, Neo2 and Oligocene) less than 10 (Figure 5.7-A). The most dominant class is Neo1 (Neogene pyroclastics) with a percentage of 21.4 and the least dominant class is Oligocene clastics with the percentage of 4.6. Three Neogene sequences (Neo1, Neo2 and Neo3) collectively cover 47.5 %of the area. Two classes of lava flows (basalts and andesites), on the other, cover 16.0 % of the area.

**Table 5.7** Frequency and percentages of study area, underground city (UC) and present settlement (PS) for rock type classes

| Rock type | Study area | | UC | | PS | | UC minus study area | PS minus study area |
|---|---|---|---|---|---|---|---|---|
| | (km2) | (%) | (#) | % | (#) | % | | |
| Alluvium | 1559,2 | 16,1 | 29 | 22,8 | 62 | 16,2 | 6,75 | 0,06 |
| Basalt | 711,2 | 7,3 | 6 | 4,7 | 19 | 4,9 | -2,61 | -2,39 |
| Andesite | 842,9 | 8,7 | 5 | 3,9 | 17 | 4,4 | -4,76 | -4,27 |
| Neo1 | 2078,0 | 21,4 | 25 | 19,7 | 67 | 17,5 | -1,75 | -3,99 |
| Neo2 | 889,7 | 9,2 | 32 | 25,2 | 55 | 14,3 | 16,02 | 5,15 |
| Neo3 | 1634,8 | 16,9 | 20 | 15,8 | 71 | 18,5 | -1,12 | 1,63 |
| Oligocene | 448,6 | 4,6 | 1 | 0,8 | 27 | 7,0 | -3,84 | 2,40 |
| Basement | 1530,0 | 15,8 | 9 | 7,1 | 66 | 17,2 | -8,70 | 1,41 |
| **TOTAL** | 9694,4 | 100,0 | 127 | 100,0 | 384 | 100,0 | | |

Percentages of the underground cities and the present settlements for different rock types are shown in Figure 5.7-B. For underground cities, four classes (alluvium and three Neogene classes other than andesite) have percentages more than 15 among which Neo2 (pyroclastic dominant Neogene sequence) is the most dominant one (25.2 %). Other four classes (Quaternary basalt, Neogene andesite, Oligocene clastics and pre-Oligocene basement rocks) have percentages less than 8. The least dominant class is Oligocene clastics with 0.8 %.

Distribution of the present settlements seems to be similar in rock types with minor variations. Five classes (Quaternary alluvium, three Neogene classes other than andesite and pre-Oligocene basement rocks) have percentages more than 10, while other three classes (Quaternary basalt, Neogene andesite and Oligocene clastics) have percentages less than 7. The maximum and minimum percentages are 18.5 and 4.4 for Neo3 (sedimentary dominant Neogene sequence) and Neogene andesite, respectively.

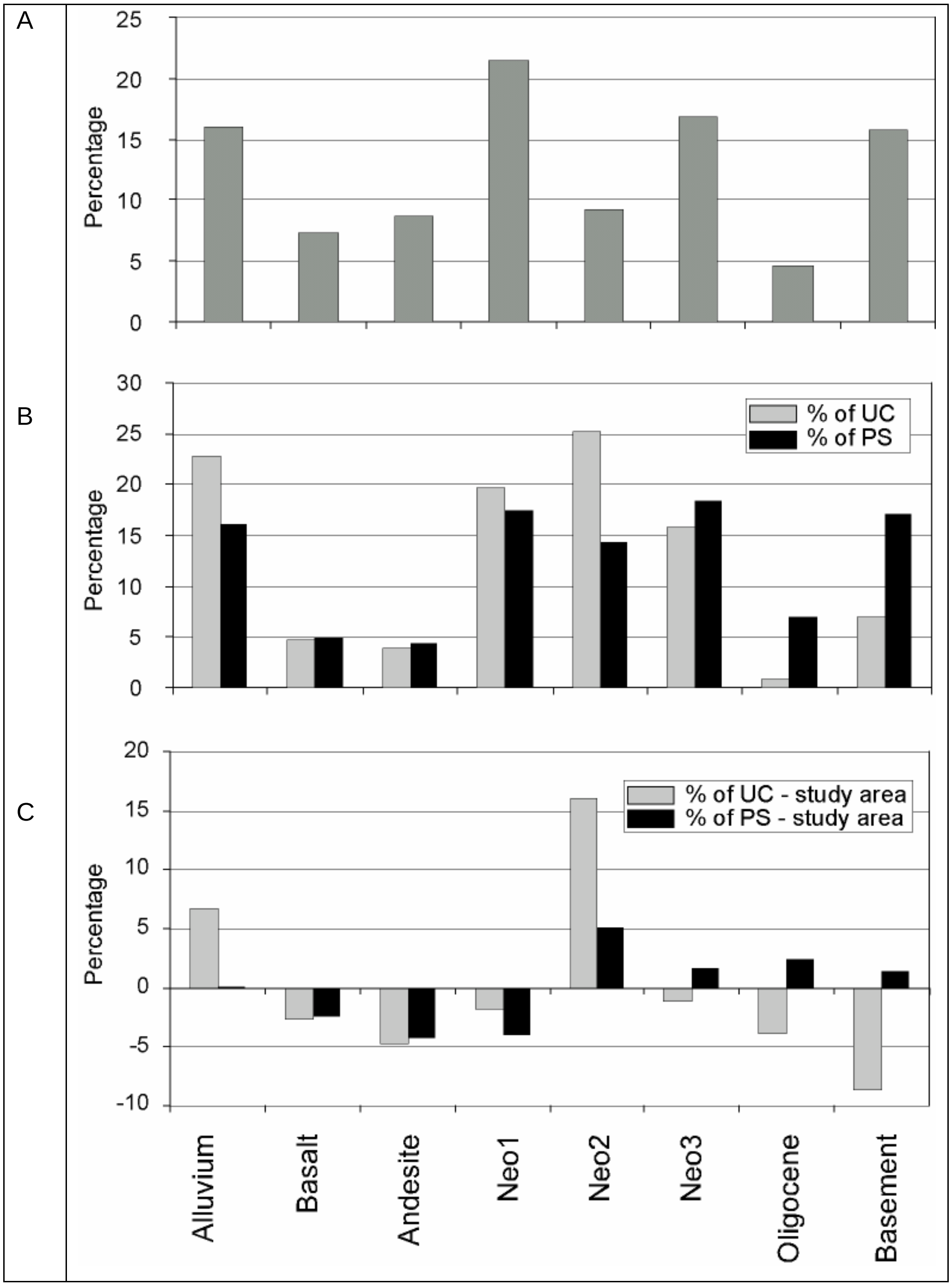

**Figure 5.7** Histograms prepared from data shown in Table 5.7
A. Histogram of the rock types in the study area
B. Histogram of the underground cities and present settlements
C. Histogram of the differences

The percentages of the underground cities and the present settlements, as done in the previous section, are subtracted from the percentages of the areas of the rock types to investigate the relationship between the rock types and uc/ps. Resultant histograms are shown in Figure 5.7-C. Following observations can be made on the relationship between rock types and uc/ps percentages based on the histogram in Figure 5.7-C.

- For the underground cities, pyroclastic dominant Neogene sequence (Neo2) is the most distinctive class with a score of +16.02. Therefore, this rock type is the most favoured unit for an underground city. This class is followed by alluvium that has a score of +6.75. All other rock types have negative scores ranging from -8.7 (pre-Oligocene basement rocks) to -1.12 (sedimentary dominant Neogene sequence).
- For present settlements, there is not an obvious preference or avoidance as indicated by the scores in a close range (from -4.27 to +5.15). Neogene andesite, Quaternary basalt and Neogene pyroclastics (Neo1) have negative scores; other rock types have positive scores.
- Comparison of the values for the underground cities and the present settlements gives several significant results. First of all, the most popular rocks type is the pyroclastic dominant Neogene sequence for both types of sites. Second, three classes are avoided for both underground cities and present settlements. These are Quaternary basalt, Neogene andesite and Neogene pyroclastics (Neo1). Third, tendencies of the underground cities and the present settlements are different for three classes namely Neo3 (sedimentary dominant Neogene sequence), Oligocene clastics and pre-Oligocene basement rocks. All these classes have negative

scores for the underground cities and positive scores for the present settlements.

Alluvium has a positive value for the underground cities (6.75) and a negligible positive value for the present settlements (0.06). Accordingly for underground cities it is the second preferred class whereas for present settlements it can be deduced as neither preferred nor avoided. Interpretation of preference of alluvium for underground cities should be made carefully because this class is not suitable to carve an underground city within due to its loose, unconsolidated nature. All of the underground cities seem to be carved within alluvium are actually located within the rock type just beneath the alluvium because alluvium is generally composed of a thin cover layer that overlies one of other classes existing in the area. Therefore, the underground cities located within the alluvium are redistributed to other classes estimating the rock type beneath the alluvium.

In initial database, 29 underground cities are located within Quaternary alluvium (Table 5.7). These cities are re-distributed to other classes as shown in Table 5.8. Neo1 (Neogene pyroclastics) is the class to which the maximum number of underground cities (11) is transferred. Oligocene clastics and basement rocks, on the other hand did not receive any underground city during this re-distribution.

Since the percentages of the underground cities are modified, calculations made above are repeated with new values. These values are illustrated in Table 5.9 and Figure 5.8.

**Table 5.8** Frequencies of underground cities disregarding alluvium

| Rock type | Initial number | Number transferred from alluvium | Total number after alluvium is removed |
|---|---|---|---|
| Basalt | 6 | 1 | 7 |
| Andesite | 5 | 1 | 6 |
| Neo1 | 25 | 11 | 40 |
| Neo2 | 32 | 8 | 40 |
| Neo3 | 20 | 4 | 24 |
| Oligocene | 1 | 0 | 1 |
| Basement | 9 | 0 | 9 |
| **TOTAL** | 98 | 29 | 127 |

According to the new configuration without alluvium, Neo2 (Pyroclastic dominant Neogene sequence) rock type is still the most favoured rock type with a score of +20.6. Other positive score belongs to Neo1 (Neogene pyroclastics) with +6.0. All other rock type classes have negative scores ranging between -11.7 and -1.2.

**Table 5.9** Scores for underground cities disregarding alluvium

| Rock Type | Area | | UC | | UC minus study area |
|---|---|---|---|---|---|
| | (km2) | % | (#) | (%) | |
| Basalt | 711,2 | 8,7 | 7 | 5,5 | -3,2 |
| Andesite | 842,9 | 10,3 | 6 | 4,7 | -5,6 |
| Neo1 | 2078,0 | 25,5 | 40 | 31,5 | 6,0 |
| Neo2 | 889,7 | 10,9 | 40 | 31,5 | 20,6 |
| Neo3 | 1634,8 | 20,1 | 24 | 18,9 | -1,2 |
| Oligocene | 448,6 | 5,5 | 1 | 0,8 | -4,7 |
| Basement | 1530,0 | 18,8 | 9 | 7,1 | -11,7 |
| **TOTAL** | 8135,2 | 100,0 | 127 | 100,0 | |

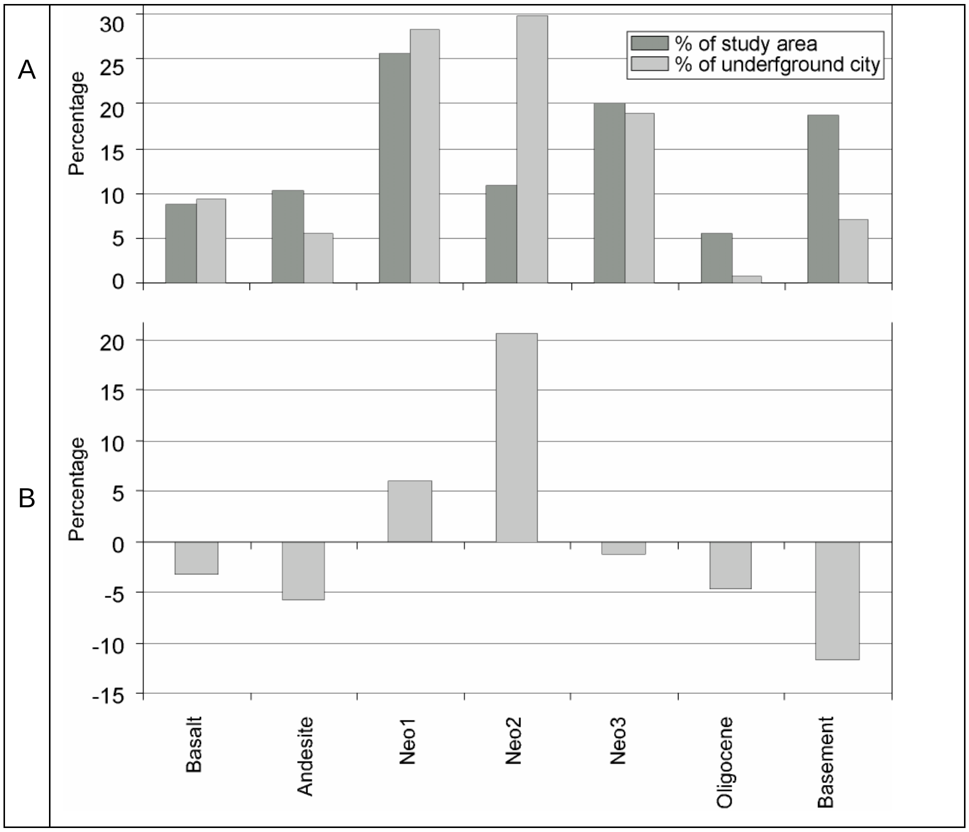

**Figure 5.8** Histograms prepared from data shown in Table 5.9
A. Histogram of the study area and underground cities
B. Histogram of the differences

### 5.3.3 Relationship between Morphological Classes and Rock Types

In the previous two sections relationships between the underground cities/the present settlements with morphological classes and rock types are investigated. From the histograms given in Figures 5.6 and 5.8 it is concluded that certain morphological classes and rocks types are preferred while some others are avoided. A summary of these results is shown in Table 5.10 only for underground cities. Accordingly, two rocks types (Neo1 and Neo2) and one morphological class (mesa) are preferred. Three rocks types (Neogene andesite, Oligocene clastics and Pre-Oligocene basement rocks) and three morphological classes (footslope, trough and high mountain) are avoided. Other rock types and morphological classes seem to have neither positive nor negative effect on the site selection of an underground city.

**Table 5.10** Summary of the relationships between the underground cities with rock types and morphological classes (This table is based on the histograms in Tables 6.6 and 5.8.) (NA: No relationship. Alluvium not regarded).

| Rock type | Relation | | Morphological class | Relation |
|---|---|---|---|---|
| Alluvium | - | | Flood Plain | NA |
| Basalt | NA | | Hill in plain | NA |
| Andesite | Negative | | Footslope | Negative |
| Neo1 | **Positive** | | Low plains | NA |
| Neo2 | **Positive** | | Mesa | **Positive** |
| Neo3 | NA | | Low mountain | NA |
| Oligocene | Negative | | Troughs | Negative |
| Basement | Negative | | High Mountain | Negative |

In this section the relationship between two parameters, namely rock types and morphological classes, are investigated to test how these parameters affect each other. Result of the test justifies whether these two parameters are interdependent or not.

The first step in the analysis is to intersect the rock type map with morphological class map. This intersection produced sixty-four classes (eight rock types by eight morphological classes). Area covered for each class is given in Table 5.11. This table is reorganized to show percentages of rock types for each morphological class (Table 5.12) and percentages of morphological class for each rock type (Table 5.13). Sum of each column in both tables is 100 %. Bold numbers refer to the largest value in this class. As this number increases, the dependence of rock type and morphological class increases.

**Table 5.11** Initial data produced by intersection of rock type map with morphological class map (Numbers are surface areas for resultant sixty-four classes in km$^2$.)

| | **Flood plain** | **Hill in plain** | **Footslope** | **Low plain** | **Mesa** | **Low mountain** | **Trough** | **High mountain** | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| **Alluvium** | 203,5 | 27,0 | 131,1 | 688,3 | 337,3 | 45,9 | 111,6 | 9,2 | **1553,8** |
| **Basalt** | 51,3 | 39,2 | 55,9 | 250,3 | 165,3 | 28,0 | 0,0 | 120,4 | **710,4** |
| **Andesite** | 0,0 | 4,5 | 193,7 | 14,0 | 17,2 | 52,3 | 0,0 | 555,4 | **837,1** |
| **Neo1** | 16,2 | 28,8 | 530,0 | 228,6 | 1021,5 | 45,7 | 0,0 | 195,1 | **2065,8** |
| **Neo2** | 108,4 | 14,3 | 23,3 | 41,1 | 561,8 | 65,0 | 24,5 | 49,1 | **887,4** |
| **Neo3** | 353,7 | 6,0 | 21,4 | 138,0 | 343,4 | 181,2 | 587,2 | 0,0 | **1630,9** |
| **Oligocene** | 71,2 | 0,0 | 5,3 | 0,9 | 64,0 | 117,8 | 189,1 | 0,0 | **448,4** |
| **Basement** | 82,5 | 23,7 | 105,7 | 9,1 | 110,5 | 917,1 | 270,7 | 5,0 | **1524,2** |
| **Total** | **886,8** | **143,5** | **1066,3** | **1370,3** | **2620,9** | **1452,9** | **1183,1** | **934,0** | **9657,9** |

For the morphological classes, the highest value belongs to low mountain class with 63.1 % covered by pre-Oligocene basement rocks. This is followed by high mountain class with 59.5 % being covered by Neogene andesites. Next three classes are also dominantly composed of one rock type (50.2 % of low plain by Quaternary alluvium, 49.7 % of footslope by Neo1 and 49.6 % trough by Neo3). These five classes are, therefore, genetically controlled by certain rock types. Other three classes, including the most preferred mesa class, are composed of a variety of rock types. Mesa class, for example, is made up of 39.0 % of Neo1, 21.4 % of Neo2, 13.1 % of Neo3 and 12.9 % of Quaternary alluvium.

For the rock types, the effect of morphological classes is much more emphasized (Table 5.13). Six rock types contain one morphological class that has range from 42.2 % to 66.3 %. The two preferred rock types (Neo1 and Neo2) (Table 5.10) are both dominant in the mesa morphological class.

**Table 5.12** Distribution of rock types in morphological classes in terms of percentage (Bold numbers are the largest rock type areas percentages covered within the corresponding morphological class.)

| | Flood plain | Hill in plain | Footslope | Low plain | Mesa | Low mountain | Trough | High mountain |
|---|---|---|---|---|---|---|---|---|
| **Alluvium** | 22,9 | 18,8 | 12,3 | **50,2** | 12,9 | 3,2 | 9,4 | 1,0 |
| **Basalt** | 5,8 | **27,3** | 5,2 | 18,3 | 6,3 | 1,9 | 0,0 | 12,9 |
| **Andesite** | 0,0 | 3,2 | 18,2 | 1,0 | 0,7 | 3,6 | 0,0 | **59,5** |
| **Neo1** | 1,8 | 20,1 | **49,7** | 16,7 | **39,0** | 3,1 | 0,0 | 20,9 |
| **Neo2** | 12,2 | 10,0 | 2,2 | 3,0 | 21,4 | 4,5 | 2,1 | 5,3 |
| **Neo3** | **39,9** | 4,1 | 2,0 | 10,1 | 13,1 | 12,5 | **49,6** | 0,0 |
| **Oligocene** | 8,0 | 0,0 | 0,5 | 0,1 | 2,4 | 8,1 | 16,0 | 0,0 |
| **Basement** | 9,3 | 16,5 | 9,9 | 0,7 | 4,2 | **63,1** | 22,9 | 0,5 |
| **Total** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** |

**Table 5.13** Distribution of morphological classes in rock types in terms of percentage (Bold numbers are the largest morphological class areas percentages covered within the corresponding rock type.)

| | Alluvium | Basalt | Andesite | Neo1 | Neo2 | Neo3 | Oligocene | Basement |
|---|---|---|---|---|---|---|---|---|
| **Flood plain** | 13,1 | 7,2 | 0,0 | 0,8 | 12,2 | 21,7 | 15,9 | 5,4 |
| **Hill in plain** | 1,7 | 5,5 | 0,5 | 1,4 | 1,6 | 0,4 | 0,0 | 1,6 |
| **Footslope** | 8,4 | 7,9 | 23,1 | 25,7 | 2,6 | 1,3 | 1,2 | 6,9 |
| **Low plain** | **44,3** | **35,2** | 1,7 | 11,1 | 4,6 | 8,5 | 0,2 | 0,6 |
| **Mesa** | 21,7 | 23,3 | 2,1 | **49,4** | **63,3** | 21,1 | 14,3 | 7,2 |
| **Low mountain** | 3,0 | 3,9 | 6,2 | 2,2 | 7,3 | 11,1 | 26,3 | **60,2** |
| **Trough** | 7,2 | 0,0 | 0,0 | 0,0 | 2,8 | **36,0** | **42,2** | 17,8 |
| **High mountain** | 0,6 | 16,9 | **66,3** | 9,4 | 5,5 | 0,0 | 0,0 | 0,3 |
| **Total** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** | **100,0** |

## 5.4 Neighbourhood Analysis

Purpose of neighborhood analysis is to understand whether the location of an underground city or a present settlement within a polygon (of rock type or morphological class) has a tendency to be along the margins of this polygon. Logic of identification of a site within a polygon is illustrated in Figure 5.9. Two parameters are measured for the analysis. The first one is the shortest distance to the nearest polygon whose angle is $90^o$ (y in the figure); the second one is the width of the polygon (y in the figure), which is at the same direction with the y. For the polygons that extend beyond the map area, the "x" distance is measured by using the actual distance of a larger map occupying the whole of that polygon. Therefore, the distance to the margin of the map is not considered.

The ratio y/x is calculated for all sites and used as neighborhood index. This number theoretically ranges between 0 and 0.5. It is zero when the settlement is exactly on the boundary because y=0. It is 0.5 when the settlement is located at the midway of x.

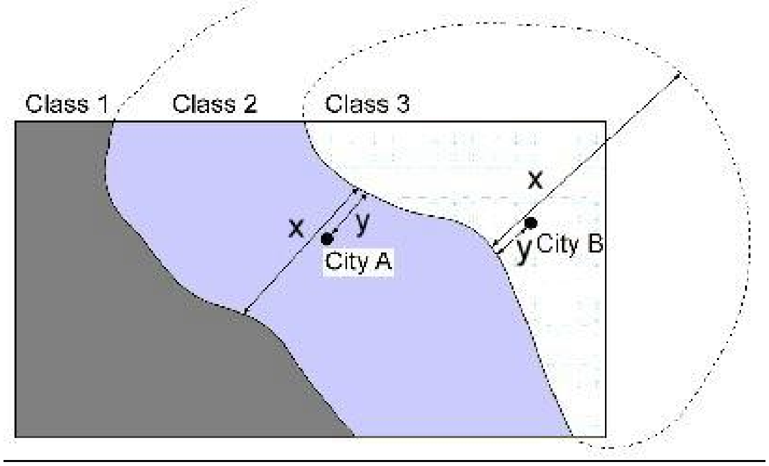

**Figure 5.9** Measurements of the neighbourhood parameters x and y

Two sets of measurements are carried out for the underground cities for the neighborhood analysis. The first is for rock types and the second is for morphological classes.

### 5.4.1 Neighbourhood Analysis for the Rock Types

In the rock type analysis the Quaternary alluvium class is omitted because alluvium is exposed only at the surface as a thin layer and there cannot be an underground settlement carved within the alluvium. During the measurement of x and y, therefore, the boundary that passes beneath alluvium is based on. Results of the measurements for all underground cities are illustrated in Figure 5.10. The pattern of the histogram indicates a gradual decrease from 0 to 0.5 suggesting that the underground cities are located dominantly along the margins of the rock type polygons. Separate histograms are prepared to investigate the behavior of each rock type (Figure 5.11).

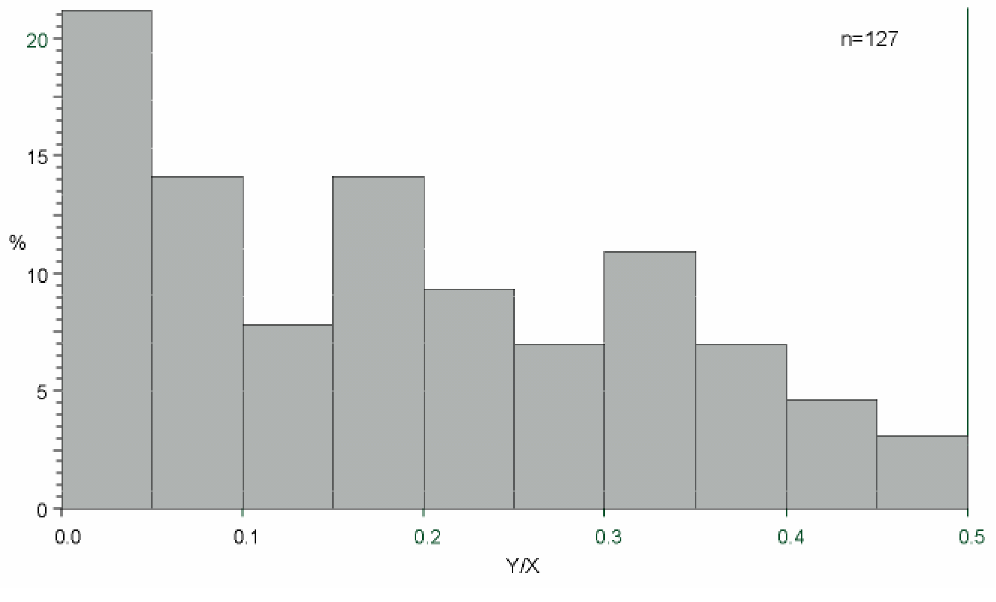

**Figure 5.10** Results of the neighbourhood analysis for all rock types

In four classes (Quaternary basalt, Neogene andesite, Oligocene clastics and pre-Oligocene basement rocks) frequency of the underground cities is low and therefore the graph is not clear to derive a relationship. For other three rocks types, on the other hand, it can be concluded that: 1) for the underground cities in Neo1 class (Neogene pyroclastics), frequencies along the margins of the polygons are dominant and gradually decrease towards the centers; 2) for Neo2 class (pyroclastic dominant Neogene sequence), having a bimodal distribution, frequencies increase towards the centers indicating that any place in this class is suitable for underground cities; 3) for Neo3 class (sedimentary dominant Neogene sequence), other than three underground cities located almost at the centers of the polygons, generally the frequencies seem to decrease from margins to the centers.

### 5.4.2 Neighbourhood Analysis for the Morphological Classes

Same analysis is carried out for the morphological classes. “Hill in plain” class is not used because there is no underground city in this class. The results for individual classes are shown in Figure 5.12 (all cities) and Figure 5.13.

General appearance of the diagram in Figure 5.12 clearly indicates that, frequency of the cities decreases from margin to the center. Therefore, as in rock types, the boundaries of the morphological classes are preferred for the location of underground cities.

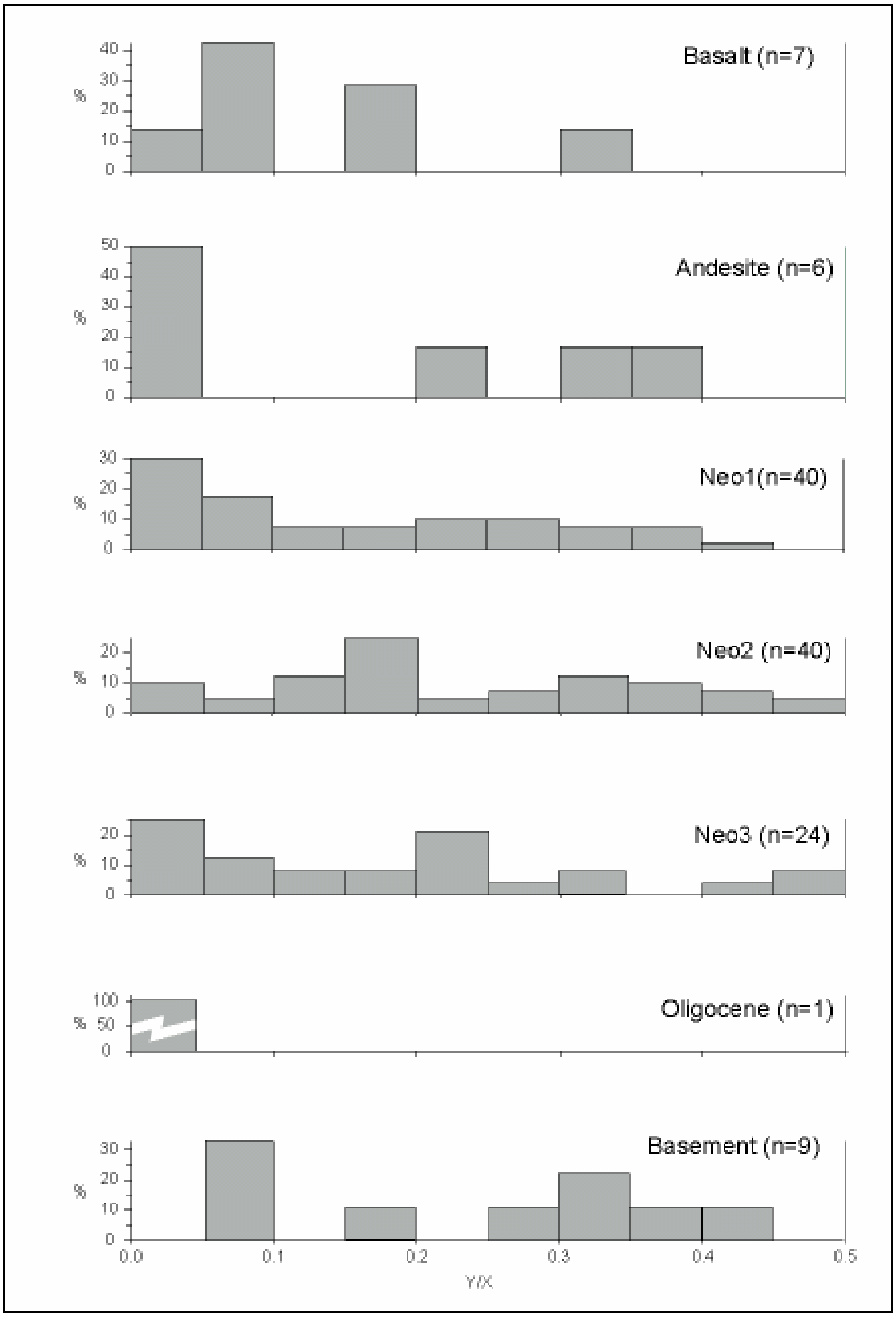

**Figure 5.11** Results of the neighbourhood analysis for different rock types

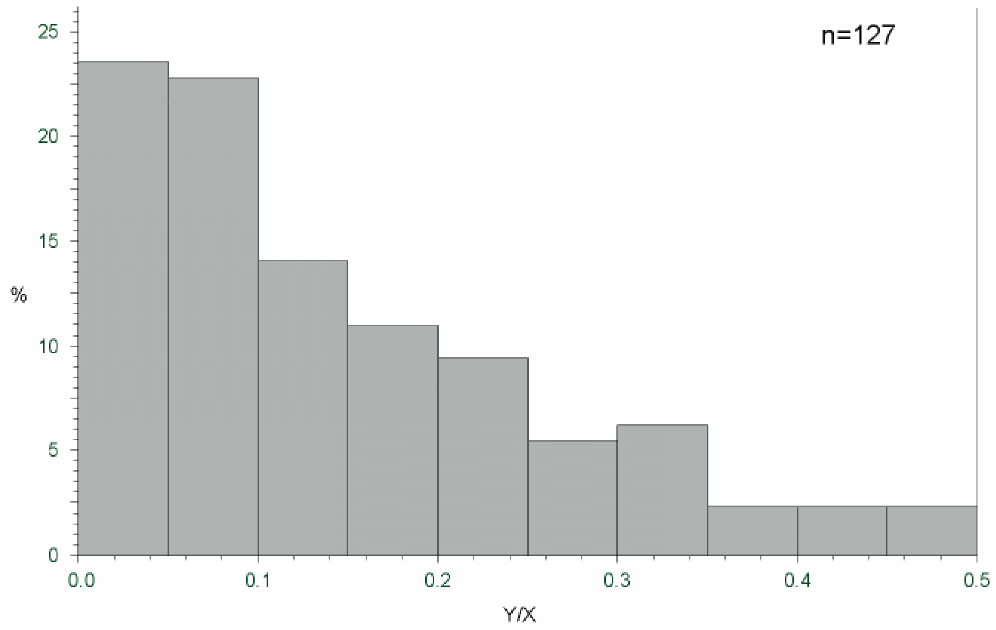

**Figure 5.12** Results of the neighbourhood analysis for all morphological classes

Following observations can be made for the individual classes based on Figure 5.13:

- For flood plain polygons there is not any clear concentration within the polygon. Since flood plains are mostly represented by alluvium in the area, this observation might be due to the availability of suitable rock type beneath thin fluvial deposits.
- In footslope polygons, the concentration seems to be at one-third distance of the value x. However, from the diagram it is clear whether this distance is towards the upper or lower elevations.
- Low plain class has the most distinctive pattern with a decreasing frequency from margins towards the centers of the polygons.
- In mesa class, which is the most populated class (n=54), underground cities are also concentrated along the margins of the polygons.

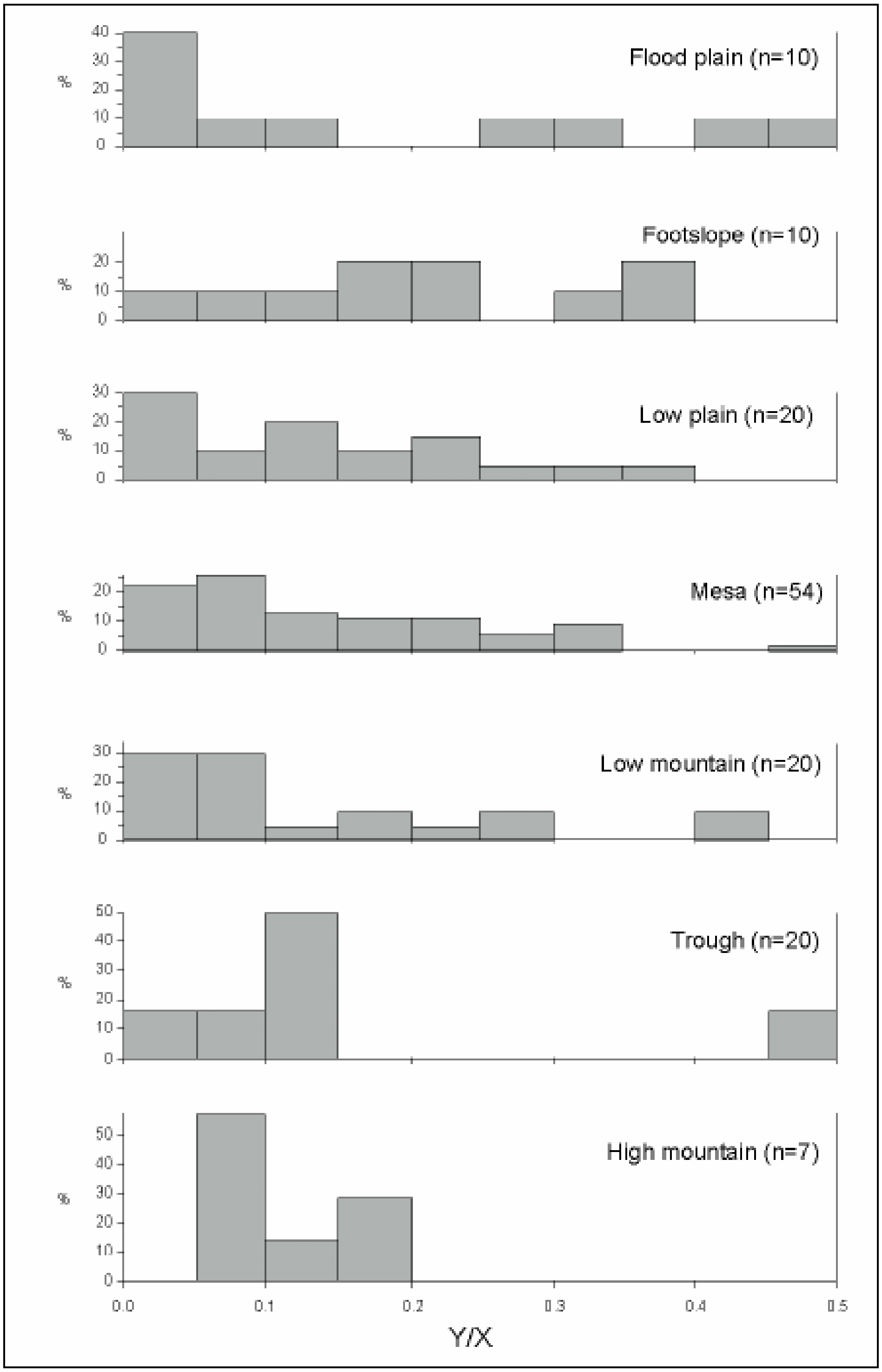

**Figure 5.13** Results of the neighborhood analysis for different morphological classes

- In low mountain class, although there are few underground cities located at a distance from the margin, the sudden decrease in the frequency suggest that, margins of the polygons are preferred for this class.
- For trough class except three underground cities located at the center of polygons, all others are observed along the margins.
- In high mountain class, almost all of the underground cities are located along the margins of the polygons.

# CHAPTER VI

# DISCUSSIONS AND CONCLUSION

This chapter deals with various aspects of the thesis, which can be discussed in five parts. These parts are:

1. Extend of the study area
2. Accuracy of input data
3. Prediction of unexplored underground cities
4. Evaluation of the results obtained
5. Recommendations

## 6.1 Extend of the Study Area

The border of the area in this study should correspond to the real border of the Cappadocian civilization. This boundary, however, could not be used because of several reasons:

- First of all, border of Cappadocia had never been stable throughout the history and changed from time to time. Since this study is not focused in a certain period of time, historical boundaries are not used during the compilation of data.
- Using the provincial boundary of cities (eg. Nevşehir or Aksaray) would not be appropriate, because such a border does not reflect a geographical or cultural relation. Nevertheless, Nevşehir province

seems to be the most populated region and as one diverge from Nevşehir, existence of underground cities decreases. Therefore, during determination of the study area Nevşehir area is intended to be at the center of the area.

- One possibility is to select the boundary of Cappadocian Volcanic province (CVP) (map in Figure 2.2), which controls the rock types and the morphological classes in the area and has a genetic relationship with the location of underground cities. This boundary, however, is avoided mostly because of the lack of data in other regions of CVP.

For all these reasons, a study area covering four 1/100000 scaled topographical maps (K32, K33, L32, L33), centering Nevşehir where the underground cities are dense is preferred.

### 6.1 Accuracy of Input Data

Four data sets used in the study (morphological classes, rock types, present settlements, and underground cities) have some accuracy problems. These problems and the reasons for them are discussed below.

#### 6.2.1 Morphological Class Data

The morphological data used in the study is prepared from the SRTM of the study area. There are three important points related with the creation of this data.

1. The morphological classes are created according to the aim of the study. First, a set of morphological classes is suggested considering general morphologic features of the area. This classification scheme,

therefore, will produce a definite map. As long as these are morphological classes and not geomorphologic classes which are definitely described and accepted in the literature, another classification may be proposed by somebody else, and that may produce a different output.

2. The borders of the polygons are completely user defined and are products of the visual interpretation. Hence, another researcher may trace the borders differently, shifting the number and the sizes of the polygons.

3. The morphological classes map is not a detailed map, because it is prepared from 90 m pixel size SRTM data and integrated with 1/500.000 scale geology map. Therefore, the classes in this map are regional scale features and minor topographic variations are not considered. For example, in mesa morphologic class several small-scale valleys exist in the area that are not shown in the map used.

Differences in these approaches will affect the accuracy and nature of the morphological map, which, in turn, will affect the results obtained after the analyses.

### 6.2.2 Rock Type Data

The initial data used for the preparation of the rock type map is the geological map prepared by MTA (General Directorate of Mineral Research and Exploration) at 1/500.000 scale. Two aspects of the rock type map prepared in this study can affect the results obtained:

1. Scale of the map is selected as 1/500.000. The choice of scale is due to the area covered according to the definition. Yet, this choice is not appropriate because at this scale, however, some details might be missed and wrong results might be obtained. So further researchers may require larger scaled maps.

2. The reclassification of the rock units in MTA map is performed considering the age and lithological characteristics. This is again a subjective classification because it is a user-defined process. Another expert might base on a different rock classification that will produce a different map.

### 6.2.3 Present Settlement Data

This data is the most reliable data source used in the study. The database created for the present settlements contains all minor and major settlements in the area. The only problem with this database is to express the exact locations of large settlements (cities, towns etc.) with points.

### 6.2.4 Underground City Data

The most important input data, the underground city database, is almost completely compiled from literature. Although the preparation of this database is not an objective of this study, its accuracy will directly affect the results obtained. Since such a database is not available, a long time period is consumed to create it including the names and the locations of underground cities.

The database lacks some important aspects of the underground cities. Examples of these are: the period(s) in which the underground cities are hewn and initially settled; the ages when the habitants changed, 3-D plans of the underground cities, aim of the use (military, civil, stable, warehouse, etc.), natural resources around and regional road-network. As long as a complete database of the underground cities is insufficient, a comprehensive study couldn't be possible. Anyhow, the thesis can still be considered as guide to further studies because the importance of such a study is the new point of view to underground cities even though the scope is limited with only lithology and morphology as mentioned in chapter one.

### 6.2.5 Reasons for Lack of Information

Cappadocia region, which is one of the seven sites included in the World Heritage List, has recently become a museum of rock-cut structures famous in cultural terms. On the contrary, the studies about the underground cities are so restricted that the documentation appears to be full of gaps, and is incoherent and quite superficial or unfounded. Considering the documentation directly collected and the result of surveys carried out in the area up to the time, Bixio (1995) came up with four reasons why the underground structures have not been given much attention by scholars:

1. The historical records of the surface area of Cappadocia are so numerous and interesting that those structures hidden underground have been pushed into the background;

2. The exploration of underground structures involves technical difficulties and even risk. For this reason it is necessary to have specific equipment and experience in speleological activity;
3. Surveys of underground excavated structures involve more problems than those of surface surveys;
4. The domestic architecture is less interesting for scholars than the finds of monumental structures.

### 6.3 Prediction of Unexplored Underground Cities

As known from several written and oral sources, the real number of underground cities is unknown. A number of underground cities are identified each year according to the statements of the authorities in museums of the region. This identification is not based on a systematic survey carried out, but rather by chance or the help of the local people.

Prediction of unexplored underground cities is not fully possible with existing database because the database is not enough to set the decision rules for these unexplored ones. Present study uses two external data sets (rock types and morphological classes) and two internal data sets (known underground cities and present settlements). To predict the location of an underground city, however, some other information and data are necessary. Examples of these data can be:

- Water resources (present and past)
- Site catchment capacity of area
- Land cover use
- Main ancient routes
- Size and population of known underground cities
- Local site features

If necessary information is available, Geographic Information System (GIS) can be applied to predict unknown underground cities. This study, in general, should involve three steps to achieve the purpose:

1- Defining a set of criteria (decision rules) using underground cities in the database such as: which rock type, which morphological class, at what minimum distance to another one, how far from a water source (surface or underground), minimum distance to a main road, etc.
2- Querying the database by GIS, using the decision rules, finding areas that fit the rules and finally to be able to say that, these areas are promising regions that may contain an underground city.
3- Ground truth studies to check the results and finalize the task.

## 6.4 Evaluation of the Results Obtained

- The mean distance between two underground cities is about 4km. But we have to put that this value is a result of a database, which has 127 entries and this is not the real number of the whole underground cities in the region. To calculate this distance always the distance to the nearest underground city is considered. This distance is tested by two more techniques (Table 5.3). As it is known, some parts of the area are not settled because of the unsuitability of the terrain. If the whole area were equally settled an empirical distance of about 9km would be expected. The mean distance between two present settlements, on the other hand, is about 2,5km, which is considerably less, compared to the mean distance between two underground cities. The main reason for this is that the higher frequency of the present settlements (384) than that of the underground cities (127).

- The mean distance of an underground city to the nearest present settlement is about 700 m and this value is at most 500 m for almost 70% of the total of such distances. This result shows us for most of the sites of the underground cities the habit of settling continued till recent times.

- Density analysis indicates that underground cities are concentrated in a belt that extends in NE-SW direction (Figure 5.4-A). The most populated underground cities are observed in Derinkuyu, Nevşehir and Özkonak belt. The reason for this may be the high amount of settling in this area because of its popularity and attraction among tourists. So the probability of finding an underground city may be much more than that of a rural area. Comparison of the regions where the underground cities are concentrated with that of the present settlement (Figure 5.4-B) suggests that, the area preferred by present settlements, which is along Aksaray, Ortaköy and Hacıbektaş, greatly differs from the former one. An explanation of this change might be the change in the use of land from ancient times to present.

- Mesa landform, among the morphological classes, is the most preferred class for underground cities (Figure 5.6). Whereas trough and high mountain classes are the most avoided ones. Other classes seem to have no effect on the site selection of an underground city. Distribution of the present settlements, on the other hand, suggests that none of the morphological classes seems to affect the location of these settlements. The increasing building techniques with the increasing population seem to be the reasons for these results.

- Two rock types (when Quaternary alluvium is disregarded), namely, Neogene pyroclastics (Neo 1) and pyroclastic dominant Neogene sequence (Neo 2) are widely preferred for the location of the underground settlements while all other types are (slightly or strongly) avoided (Figure 5.8). The mostly avoided rock type is pre-Oligocene basement rocks. The main reason for the preference of Neo1 and Neo2 types is that, these rocks contain thick and widespread ignimbrites (tuff), which are suitable for carving. For the present settlements, although there is not an obvious relationship, four rock types are slightly preferred (pyroclastic dominant Neogene sequence, sedimentary dominant Neogene sequence, Oligocene clastics, pre-Oligocene basement rocks); other four types are slightly avoided (Quaternary alluvium, Quaternary basalt, Neogene andesite and Neogene pyroclastics).

- So it can be stated that for underground cities the rock types and morphological classes are controlling factors for site selection where as not for that of modern settlements.

- The last analysis (neighbourhood analysis) aims to see whether the underground cities within the polygons of rock types or morphological classes are along the margins of those polygons or not. Accordingly it is seen that for both rock types and morphological classes, the margins of the polygons are preferred. The reason for this is that the boundary (either for rock type or for morphological class) produces a suitable landform such as a scarp or slope where, most probably, water resources or other natural structures exist.

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# APPENDIX A:TABLE OF UNDERGROUND CITIES

| No. | Name | Alt. Name | Easting | Northing | Mrph. Cl. | Rock Type | Province | Status | PS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Acıgöl | None | 631375 | 4268125 | low pln. | quater. alluvium | Nevşehir | visited | yes |
| 2 | Açıksaray | None | 644500 | 4289000 | flood pln. | pyro. dom. neo. sq. | Nevşehir | visited | no |
| 3 | Ağadam Mv | None | 613500 | 4272750 | low pln. | sedi. dom. neo. sq. | Nevşehir | known | no |
| 4 | Ağıllı | Topada | 631500 | 4259750 | mesa | pyro. dom. neo. sq. | Nevşehir | known | yes |
| 5 | Akçakent | None | 595500 | 4215875 | footslope | neo. andesite | Aksaray | known | yes |
| 6 | Akdam | Aktepe | 627250 | 4286625 | mesa | pyro. dom. neo. sq. | Nevşehir | biblio. | . |
| 7 | Akin | None | 590750 | 4257500 | mesa | sedi. dom. neo. sq. | Aksaray | known | yes |
| 8 | Akmezar | None | 614750 | 4258000 | low mnt. | pre oligo. bas. rocks | Aksaray | biblio. | . |
| 9 | Alayhanı | None | 616000 | 4266000 | low mnt. | sedi. dom. neo. sq. | Aksaray | biblio. | . |
| 10 | Apsarı | Çatasu | 605500 | 4251125 | mesa | quater. alluvium | Niğde | biblio. | . |
| 11 | Avanos | None | 660000 | 4287500 | flood pln. | quater. alluvium | Nevşehir | biblio. | . |
| 12 | Avare T. | None | 629500 | 4285500 | mesa | quater. alluvium | Nevşehir | biblio. | . |
| 13 | Ayazma De | None | 658625 | 4295250 | low mnt. | pyro. dom. neo. sq. | Nevşehir | known | no |
| 14 | Ayvalı | None | 663000 | 4268250 | mesa | neo. pyro. | Nevşehir | known | yes |
| 15 | Bebek | None | 605500 | 4262125 | mesa | sedi. dom. neo. sq. | Niğde | biblio. | . |
| 16 | Belha Sığ | None | 658375 | 4295375 | low mnt. | pyro. dom. neo. sq. | Nevşehir | known | no |
| 17 | Belisırma | None | 613125 | 4236500 | mesa | neo. pyro. | Aksaray | biblio. | . |
| 18 | Boğazköy | None | 642500 | 4267750 | mesa | quater. alluvium | Nevşehir | visited | no |
| 19 | B. Pörnek | Pörnekler | 604375 | 4276500 | low mnt. | pre oligo. bas. rocks | Aksaray | biblio. | . |
| 20 | Camiliören | None | 621000 | 4263000 | mesa | pyro. dom. neo. sq. | Aksaray | known | yes |
| 21 | Civelek | None | 643125 | 4294500 | flood pln. | sedi. dom. neo. sq. | Nevşehir | known | yes |
| 22 | Çağıl | None | 608000 | 4261750 | mesa | sedi. dom. neo. sq. | Aksaray | biblio. | . |
| 23 | Çakıllı | Giledız | 644750 | 4254750 | low mnt. | pyro. dom. neo. sq. | Nevşehir | known | yes |
| 24 | Çanlı Kilise | None | 599375 | 4239625 | mesa | pyro. dom. neo. sq. | Aksaray | visited | no |
| 25 | Çardak | None | 624500 | 4228750 | low pln. | neo. pyro. | Aksaray | biblio. | . |
| 26 | Çardak | None | 645520 | 4268625 | mesa | neo. pyro. | Nevşehir | biblio. | . |
| 27 | Çavuşin | None | 660250 | 4281625 | mesa | quater. alluvium | Nevşehir | known | yes |
| 28 | Çekiçler | None | 593875 | 4274125 | footslope | pre oligo. bas. rocks | Aksaray | biblio. | . |
| 29 | Çekme Mh | None | 656375 | 4245750 | mesa | quater. alluvium | Nevşehir | biblio. | . |
| 30 | Çeltek | Suüstü | 600675 | 4242250 | mesa | pyro. dom. neo. sq. | Aksaray | biblio. | . |
| 31 | Çolaknabi | None | 587750 | 4275250 | footslope | sedi. dom. neo. sq. | Niğde | biblio. | . |
| 32 | Derinkuyu | None | 651500 | 4248625 | low pln. | sedi. dom. neo. sq. | Nevşehir | visited | yes |
| 33 | Doğala | Doğalar | 638875 | 4255250 | mesa | neo. pyro. | Nevşehir | known | no |
| 34 | Dorukini | None | 592500 | 4252125 | mesa | sedi. dom. neo. sq. | Aksaray | biblio. | . |
| 35 | Düğüz | None | 618875 | 4261875 | low mnt. | pre oligo. bas. rocks | Niğde | biblio. | . |
| 36 | Edikli | None | 670500 | 4235125 | mesa | neo. pyro. | Niğde | biblio. | . |
| 37 | Filikören | Filiktepe | 613750 | 4275500 | trough | sedi. dom. neo. sq. | Niğde | visited | no |
| 38 | Gelegüle | Sevinçli | 597250 | 4246250 | mesa | oligo. clastics | Nevşehir | known | no |
| 39 | Gelesin | Babakonağı | 610500 | 4273500 | low pln. | pyro. dom. neo. sq. | Aksaray | biblio. | . |
| 40 | Gidiriç Mh | Gidiriç Yay. | 588250 | 4220750 | low pln. | neo. pyro. | Aksaray | biblio. | . |
| 41 | Gine | Elmacık | 603625 | 4231500 | mesa | quater. alluvium | Niğde | biblio. | . |

| No. | Name | Other Name | Easting | Northing | Mrph. Cl. | Rock Type | Province | Status | P.S. |
|---|---|---|---|---|---|---|---|---|---|
| 42 | Göbel T. | Göble | 642375 | 4261375 | low mnt. | neo. andesite | Nevşehir | biblio. | . |
| 43 | Gökçetoprak | Sivasa | 613350 | 4279800 | low mnt. | pre oligo. bas. rocks | Nevşehir | visited | no |
| 44 | Gölcük | Misli | 655500 | 4232750 | low pln. | quater. alluvium | Niğde | biblio. | . |
| 45 | Göre | None | 650500 | 4272500 | low mnt. | pyro. dom. neo. sq. | Nevşehir | known | yes |
| 46 | Göreme | None | 659625 | 4278500 | mesa | pyro. dom. neo. sq. | Nevşehir | known | no |
| 47 | Göreme De | Göreme Hr | 660250 | 4277750 | mesa | pyro. dom. neo. sq. | Nevşehir | known | no |
| 48 | Göstük | Doğantarla | 606500 | 4247250 | mesa | quater. alluvium | Aksaray | biblio. | . |
| 49 | Göynük | None | 662750 | 4295250 | low mnt. | sedi. dom. neo. sq. | Nevşehir | known | no |
| 50 | Gözlükuyu | Munamak | 596250 | 4226375 | footslope | neo. pyro. | Aksaray | biblio. | . |
| 51 | Gülşehir | Arapsun | 640500 | 4289500 | flood pln. | pyro. dom. neo. sq. | Nevşehir | known | yes |
| 52 | Gümüşkent | Salanda | 633125 | 4298375 | flood pln. | sedi. dom. neo. sq. | Nevşehir | known | yes |
| 53 | Güvercinlik | None | 657125 | 4277000 | mesa | neo. pyro. | Nevşehir | visited | no |
| 54 | Güzelyurt | Gelveri | 620000 | 4237500 | high mnt. | pyro. dom. neo. sq. | Aksaray | visited | yes |
| 55 | Halaçlı Mv | Hallaçlar | 673150 | 4282250 | mesa | neo. pyro. | Nevşehir | known | no |
| 56 | Hasanköy | Hasaköy | 649250 | 4232000 | low pln. | quater. alluvium | Niğde | biblio. | . |
| 57 | Helvadere | None | 605750 | 4227500 | high mnt. | neo. andesite | Aksaray | biblio. | . |
| 58 | Hicip | Gürsu | 619375 | 4253500 | low pln. | pyro. dom. neo. sq. | Niğde | biblio. | . |
| 59 | İçik | None | 639875 | 4263125 | mesa | quater. alluvium | Nevşehir | visited | yes |
| 60 | İğdeli T | None | 633625 | 4247250 | low pln. | quater. alluvium | Nevşehir | known | no |
| 61 | Ihlara Vd | Mumyalar | 614500 | 4233375 | mesa | quater. alluvium | Aksaray | biblio. | . |
| 62 | Ilısu | None | 617750 | 4232625 | footslope | quater. alluvium | Aksaray | biblio. | . |
| 63 | Kaçkale T. | Kazkale | 639250 | 4253500 | low pln. | quater. alluvium | Nevşehir | known | no |
| 64 | Kadı Kal. | None | 666625 | 4278000 | mesa | pyro. dom. neo. sq. | Nevşehir | biblio. | . |
| 65 | Kalaba | Karayusuf | 673000 | 4314750 | trough | sedi. dom. neo. sq. | Nevşehir | biblio. | . |
| 66 | Karaburna | None | 626500 | 4303875 | flood pln. | quater. basalt | Nevşehir | known | yes |
| 67 | Karaburna Kl | None | 625250 | 4304250 | flood pln. | quater. basalt | Nevşehir | known | no |
| 68 | Karacaören | None | 593375 | 4220750 | footslope | quater. basalt | Aksaray | biblio. | . |
| 69 | Karacaören | None | 638875 | 4266750 | mesa | quater. alluvium | Nevşehir | biblio. | . |
| 70 | Karacaşar | Kırağcaşar | 636750 | 4284750 | mesa | quater. basalt | Kayseri | biblio. | . |
| 71 | Karapınar | None | 635000 | 4264500 | low mnt. | quater. alluvium | Nevşehir | visited | yes |
| 72 | Karataş | None | 595625 | 4234875 | low pln. | quater. alluvium | Aksaray | biblio. | . |
| 73 | Karşı Mh | Karşı Mv | 648875 | 4285375 | flood pln. | pyro. dom. neo. sq. | Nevşehir | visited | yes |
| 74 | Kaymaklı | None | 653125 | 4258500 | low pln. | quater. alluvium | Nevşehir | visited | yes |
| 75 | Kılıçlar De. | Kılıçlar Vd. | 660375 | 4279375 | mesa | pyro. dom. neo. sq. | Nevşehir | known | no |
| 76 | Kırkgöz Mğ | None | 614750 | 4243875 | mesa | pyro. dom. neo. sq. | Aksaray | biblio. | . |
| 77 | Kırkkız Mv | Kırkgöz Mv | 642875 | 4265250 | mesa | quater. alluvium | Nevşehir | visited | no |
| 78 | Kızılkaya | None | 607500 | 4246625 | mesa | pyro. dom. neo. sq. | Aksaray | biblio. | . |
| 79 | Kızlar Kale T. | Göktaş | 611875 | 4248625 | mesa | pyro. dom. neo. sq. | Aksaray | biblio. | . |
| 80 | Konaklı | Misli | 661750 | 4226750 | footslope | neo. pyro. | Niğde | biblio. | . |
| 81 | Kürt Kasımlı | None | 614625 | 4301250 | flood pln. | pyro. dom. neo. sq. | Nevşehir | visited | yes |
| 82 | Lefkere | Bozcatepe | 619500 | 4269500 | low mnt. | pre oligo. bas. rocks | Niğde | biblio. | . |
| 83 | Macarlı | None | 587500 | 4271750 | mesa | sedi. dom. neo. sq. | Niğde | biblio. | . |
| 84 | Mahmattatar | None | 670875 | 4305500 | trough | sedi. dom. neo. sq. | Nevşehir | known | yes |
| 85 | Mamasun | Gökçe | 602750 | 4252500 | mesa | quater. alluvium | Aksaray | biblio. | . |

| No. | Name | Other Name | Easting | Northing | Mrph. Cl. | Rock Type | Province | Status | P.S. |
|---|---|---|---|---|---|---|---|---|---|
| 86 | Mandama | Bozcayurt | 621375 | 4243875 | high mnt. | quater. basalt | Niğde | biblio. | . |
| 87 | Mazıköy | None | 660500 | 4259750 | mesa | neo. pyro. | Nevşehir | visited | yes |
| 88 | Meskendir V | None | 660750 | 4280250 | mesa | pyro. dom. neo. sq. | Nevşehir | known | no |
| 89 | Narköy | Nargöl | 626500 | 4243250 | high mnt. | neo. pyro. | Niğde | biblio. | . |
| 90 | Nenezi | Bekarlar | 626750 | 4249375 | low pln. | neo. pyro. | Niğde | biblio. | . |
| 91 | Orhanlı | None | 665000 | 4240750 | mesa | neo. pyro. | Niğde | biblio. | . |
| 92 | Ortahisar | None | 662500 | 4276500 | mesa | neo. pyro. | Nevşehir | known | yes |
| 93 | Ovaören | Göstesin | 612500 | 4277500 | low pln. | pre oligo. bas. rocks | Nevşehir | visited | yes |
| 94 | Ozancık | None | 604500 | 4281000 | low pln. | sedi. dom. neo. sq. | Aksaray | known | yes |
| 95 | Ören Mv | Hüyük T. | 644500 | 4296000 | low mnt. | pre oligo. bas. rocks | Nevşehir | known | no |
| 96 | Özkonak | Genezin | 659550 | 4297750 | trough | pyro. dom. neo. sq. | Nevşehir | visited | yes |
| 97 | Özlüce | Zile | 646625 | 4257500 | low mnt. | neo. pyro. | Nevşehir | visited | yes |
| 98 | Paşabucağı | Paşabağ | 661500 | 4282625 | low mnt. | pyro. dom. neo. sq. | Nevşehir | known | no |
| 99 | Pınarbaşı | Geyral Mh | 611125 | 4255875 | low mnt. | pre oligo. bas. rocks | Aksaray | known | yes |
| 100 | Saratlı | None | 607875 | 4256625 | mesa | pyro. dom. neo. sq. | Aksaray | visited | yes |
| 101 | Sarıağıl | None | 606625 | 4273625 | trough | sedi. dom. neo. sq. | Niğde | biblio. | . |
| 102 | Selime | None | 610125 | 4240250 | mesa | quater. alluvium | Aksaray | known | yes |
| 103 | Sığırkaraca | Sağırkaraca | 592125 | 4266125 | mesa | quater. alluvium | Niğde | biblio. | . |
| 104 | Sığırlı | None | 625750 | 4297500 | flood pln. | quater. alluvium | Nevşehir | known | yes |
| 105 | Sinasa | Çilhöyük | 604500 | 4231125 | mesa | neo. pyro. | Niğde | biblio. | . |
| 106 | Sivrihisar Kl | Şahinkalesi | 623625 | 4236375 | high mnt. | pyro. dom. neo. sq. | Aksaray | biblio. | . |
| 107 | Sofular | None | 673125 | 4286750 | mesa | neo. pyro. | Nevşehir | biblio. | . |
| 108 | Soğanlı | None | 673125 | 4245500 | mesa | neo. pyro. | Kayseri | known | yes |
| 109 | Susadı | None | 605125 | 4268125 | trough | sedi. dom. neo. sq. | Niğde | biblio. | . |
| 110 | Suvermez | None | 643625 | 4248500 | low pln. | quater. basalt | Nevşehir | known | yes |
| 111 | Şeyhler | None | 625250 | 4226125 | high mnt. | neo. pyro. | Niğde | biblio. | . |
| 112 | Taşpınar | None | 589875 | 4226875 | low pln. | sedi. dom. neo. sq. | Aksaray | biblio. | . |
| 113 | Tatlarin | None | 629500 | 4277625 | footslope | neo. pyro. | Nevşehir | visited | no |
| 114 | Tepeören | Örentepe | 632500 | 4250875 | low pln. | quater. alluvium | Nevşehir | known | no |
| 115 | Tilköy | None | 658750 | 4254000 | mesa | neo. pyro. | Nevşehir | known | yes |
| 116 | Tırhan | None | 649625 | 4234000 | low pln. | quater. alluvium | Niğde | biblio. | . |
| 117 | Tokarız | Dikmen | 596125 | 4223750 | footslope | neo. andesite | Niğde | biblio. | . |
| 118 | Topaktaş | Topakkaya. | 629500 | 4212875 | high mnt. | neo. andesite | Niğde | biblio. | . |
| 119 | Uçhisar | None | 657125 | 4277500 | mesa | neo. pyro. | Nevşehir | known | yes |
| 120 | Uzunkaya | Eskinuz | 606500 | 4239250 | mesa | pyro. dom. neo. sq. | Aksaray | visited | yes |
| 121 | Yağanköy | None | 590750 | 4266250 | mesa | sedi. dom. neo. sq. | Niğde | biblio. | . |
| 122 | Yallı Damı | None | 658250 | 4295125 | low mnt. | pyro. dom. neo. sq. | Nevşehir | known | no |
| 123 | Yalman | None | 621625 | 4266625 | low mnt. | pyro. dom. neo. sq. | Aksaray | known | yes |
| 124 | Yaprakhisar | None | 610500 | 4239500 | mesa | quater. alluvium | Aksaray | visited | yes |
| 125 | Yenipınar | Hacıgaybı | 609875 | 4226000 | footslope | neo. pyro. | Aksaray | biblio. | . |
| 126 | Yeniyuva | Nürgüz | 587750 | 4269250 | mesa | quater. alluvium | Niğde | biblio. | . |
| 127 | Zelve | None | 662125 | 4281875 | low mnt. | pyro. dom. neo. sq. | Nevşehir | visited | no |

# APPENDIX B: TABLE OF PRESENT SETTLEMENTS

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 1 | Abuuşağı | 614650 | 4301300 | flood pln. | pyro. dom. neo. sq. | Gülşehir | Nevşehir |
| 2 | Acıgöl | 631300 | 4268150 | low pln. | quater. alluvium | Acıgöl | Nevşehir |
| 3 | Ağaçlı | 617700 | 4250500 | low pln. | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 4 | Ağcaşar | 651050 | 4243200 | low pln. | quater. alluvium | Merkez | Niğde |
| 5 | Ağcaşar | 673250 | 4281200 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 6 | Ağıllı | 631700 | 4259750 | mesa | pyro. dom. neo. sq. | Acıgöl | Nevşehir |
| 7 | Ağzıkarahan | 599600 | 4255900 | mesa | neo. pyro. | Merkez | Aksaray |
| 8 | Ahmetören | 638450 | 4298550 | low mnt. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 9 | Akarca | 669050 | 4313600 | trough | sedi. dom. neo. sq. | Avanos | Nevşehir |
| 10 | Akçakent | 595700 | 4215800 | footslope | neo. andesite | Merkez | Aksaray |
| 11 | Akçaören | 612200 | 4208600 | low pln. | neo. pyro. | Altunhisar | Niğde |
| 12 | Akhisar | 596400 | 4240150 | mesa | oligo. clastics | Merkez | Aksaray |
| 13 | Akin | 590850 | 4257500 | mesa | sedi. dom. neo. sq. | Mucur | Kırşehir |
| 14 | Akıncı | 611200 | 4312350 | trough | oligo. clastics | Merkez | Aksaray |
| 15 | Akmezar | 614750 | 4258100 | low mnt. | pre oligo. bas. rocks | Gülağaç | Aksaray |
| 16 | Akpınar | 587800 | 4290750 | trough | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 17 | Akpınar | 613800 | 4232250 | mesa | neo. pyro. | Güzelyurt | Aksaray |
| 18 | Aksaklı | 619200 | 4316750 | low mnt. | oligo. clastics | Mucur | Kırşehir |
| 19 | Aksaray | 589700 | 4247750 | low pln. | quater. alluvium | Merkez | Aksaray |
| 20 | Aktaş | 655400 | 4210200 | footslope | pre oligo. bas. rocks | Merkez | Niğde |
| 21 | Akyamaç | 621150 | 4238800 | high mnt. | quater. basalt | Güzelyurt | Aksaray |
| 22 | Alacaşar | 638650 | 4275900 | mesa | neo. pyro. | Merkez | Nevşehir |
| 23 | Alanyurt | 615000 | 4244700 | low pln. | pyro. dom. neo. sq. | Güzelyurt | Aksaray |
| 24 | Alaoğlu Çift. | 640800 | 4313650 | low mnt. | oligo. clastics | Hacıbektaş | Nevşehir |
| 25 | Alayhanı | 616150 | 4265850 | low mnt. | sedi. dom. neo. sq. | Merkez | Aksaray |
| 26 | Alayköy | 649050 | 4235700 | low pln. | quater. alluvium | Merkez | Niğde |
| 27 | Alemli | 642400 | 4302300 | trough | oligo. clastics | Gülşehir | Nevşehir |
| 28 | Alkan | 641850 | 4295200 | low mnt. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 29 | Altınyazı | 623400 | 4317400 | trough | quater. alluvium | Mucur | Kırşehir |
| 30 | Altıpınar | 660750 | 4310700 | low mnt. | pre oligo. bas. rocks | Avanos | Nevşehir |
| 31 | Anapınar | 633850 | 4308150 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 32 | Apsarı | 605700 | 4251000 | mesa | quater. alluvium | Gülağaç | Aksaray |
| 33 | Arafa | 646800 | 4300300 | trough | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 34 | Asmakaradan | 625750 | 4317350 | trough | sedi. dom. neo. sq. | Mucur | Kırşehir |
| 35 | Asmasız | 631000 | 4223650 | footslope | neo. pyro. | Çiftlik | Niğde |
| 36 | Aşağı | 602650 | 4293500 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 37 | Aşağıasmaz | 621850 | 4207050 | footslope | neo. andesite | Altunhisar | Niğde |
| 38 | Aşağıbarak | 646100 | 4309850 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 39 | Aşıklar | 632450 | 4309750 | trough | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 40 | Atdamı | 634450 | 4295400 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 41 | Avanos | 660700 | 4287600 | flood pln. | quater. alluvium | Avanos | Nevşehir |
| 42 | Avcıköy | 615900 | 4309650 | low mnt. | oligo. clastics | Mucur | Kırşehir |
| 43 | Avuç | 644100 | 4317750 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 44 | Aydoğmuş | 618100 | 4304750 | flood pln. | pyro. dom. neo. sq. | Mucur | Kırşehir |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 45 | Ayhan | 650200 | 4299200 | low mnt. | pre oligo. bas. rocks | Avanos | Nevşehir |
| 46 | Ayhanlı | 650900 | 4298850 | low mnt. | pre oligo. bas. rocks | Avanos | Nevşehir |
| 47 | Ayvalı | 662950 | 4268250 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 48 | Azatlı | 633200 | 4225750 | high mnt. | quater. alluvium | Çiftlik | Niğde |
| 49 | Babakonağı | 610300 | 4273800 | trough | pyro. dom. neo. sq. | Merkez | Aksaray |
| 50 | Babanınpınar | 634450 | 4315350 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 51 | Babur | 617350 | 4315700 | low mnt. | oligo. clastics | Mucur | Kırşehir |
| 52 | Bağcalı | 661150 | 4268450 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 53 | Bağlama | 645500 | 4234100 | low pln. | quater. alluvium | Merkez | Niğde |
| 54 | Bağlı | 593800 | 4236050 | low pln. | quater. alluvium | Merkez | Aksaray |
| 55 | Bağlıca | 624000 | 4277600 | low mnt. | pre oligo. bas. rocks | Acıgöl | Nevşehir |
| 56 | Bakıbağı | 635800 | 4314050 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 57 | Balcı | 595750 | 4286850 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 58 | Balçın | 641400 | 4274950 | mesa | neo. pyro. | Merkez | Nevşehir |
| 59 | Ballı | 645900 | 4215200 | footslope | quater. basalt | Merkez | Niğde |
| 60 | Basansarnıç | 633400 | 4282350 | mesa | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 61 | Başköy | 669300 | 4251500 | mesa | neo. pyro. | Yeşilhisar | Kayseri |
| 62 | Bayramhacılı | 673650 | 4296600 | low mnt. | sedi. dom. neo. sq. | Kocasinan | Kayseri |
| 63 | Bebek | 605550 | 4262500 | footslope | pre oligo. bas. rocks | Merkez | Aksaray |
| 64 | Bekarlar | 624800 | 4249650 | low pln. | quater. basalt | Çiftlik | Niğde |
| 65 | Bektaşdere | 587500 | 4274150 | footslope | sedi. dom. neo. sq. | Merkez | Aksaray |
| 66 | Belbarak | 647300 | 4315300 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 67 | Belisırma | 612900 | 4236450 | mesa | quater. alluvium | Güzelyurt | Aksaray |
| 68 | Boğazkaya | 596100 | 4239000 | mesa | oligo. clastics | Merkez | Aksaray |
| 69 | Boğazköy | 642400 | 4267700 | mesa | quater. alluvium | Merkez | Nevşehir |
| 70 | Borucu | 596850 | 4272350 | footslope | pre oligo. bas. rocks | Merkez | Aksaray |
| 71 | Bozcayurt | 621350 | 4244150 | high mnt. | quater. basalt | Güzelyurt | Aksaray |
| 72 | Bozkır | 597550 | 4294450 | trough | pyro. dom. neo. sq. | Ortaköy | Aksaray |
| 73 | Bozköy | 629850 | 4233600 | high mnt. | neo. pyro. | Çiftlik | Niğde |
| 74 | Boztepe | 619550 | 4269450 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 75 | Bölükören | 622700 | 4278550 | mesa | sedi. dom. neo. sq. | Acıgöl | Nevşehir |
| 76 | Bucaklı | 655650 | 4307300 | low mnt. | sedi. dom. neo. sq. | Avanos | Nevşehir |
| 77 | Büyükkayapa | 615150 | 4306350 | flood pln. | pyro. dom. neo. sq. | Mucur | Kırşehir |
| 78 | Büyükkışla | 648200 | 4305500 | trough | pyro. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 79 | Camiliören | 621250 | 4262850 | low pln. | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 80 | Cavlaklar | 612600 | 4317150 | trough | sedi. dom. neo. sq. | Mucur | Kırşehir |
| 81 | Ceceli | 608450 | 4287900 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 82 | Cemilköy | 668600 | 4265700 | mesa | pyro. dom. neo. sq. | Ürgüp | Nevşehir |
| 83 | Cirikler | 619750 | 4290750 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 84 | Civelek | 643150 | 4294550 | low mnt. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 85 | Cumalı | 601850 | 4282200 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 86 | Çağıl | 607950 | 4261700 | mesa | sedi. dom. neo. sq. | Merkez | Aksaray |
| 87 | Çakıllı | 644800 | 4254750 | low mnt. | pyro. dom. neo. sq. | Derinkuyu | Nevşehir |
| 88 | Çalıbekir | 598850 | 4273000 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 89 | Çalış | 661550 | 4316750 | trough | sedi. dom. neo. sq. | Avanos | Nevşehir |
| 90 | Çankıllı | 592350 | 4272500 | footslope | quater. alluvium | Merkez | Aksaray |
| 91 | Çardak | 624450 | 4228750 | low pln. | neo. pyro. | Çiftlik | Niğde |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---:|:---|---:|---:|---:|---:|---:|---:|
| 92 | Çardak | 654150 | 4268650 | mesa | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 93 | Çarıklı | 675100 | 4226650 | footslope | neo. pyro. | Merkez | Niğde |
| 94 | Çatalarkaç | 615700 | 4312750 | low mnt. | oligo. clastics | Mucur | Kırşehir |
| 95 | Çatköy | 644250 | 4282500 | mesa | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 94 | Çatalarkaç | 615700 | 4312750 | low mnt. | oligo. clastics | Mucur | Kırşehir |
| 94 | Çatalarkaç | 615700 | 4312750 | low mnt. | oligo. clastics | Mucur | Kırşehir |
| 95 | Çatköy | 644250 | 4282500 | mesa | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 96 | Çavdarlı | 666450 | 4217300 | footslope | neo. pyro. | Merkez | Niğde |
| 97 | Çavuşini | 660300 | 4281650 | mesa | quater. alluvium | Avanos | Nevşehir |
| 98 | Çayır | 638550 | 4312900 | trough | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 99 | Çayırlı | 672450 | 4215200 | footslope | quater. alluvium | Merkez | Niğde |
| 100 | Çekiçler | 594350 | 4274300 | footslope | pre oligo. bas. rocks | Merkez | Aksaray |
| 101 | Çekme | 656400 | 4245650 | mesa | quater. alluvium | Derinkuyu | Nevşehir |
| 102 | Çeltek | 600750 | 4242200 | mesa | pyro. dom. neo. sq. | Merkez | Aksaray |
| 103 | Çetin | 603000 | 4282000 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 104 | Çiftevi | 588750 | 4299150 | low mnt. | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 105 | Çiftlik | 630150 | 4226450 | low pln. | quater. alluvium | Çiftlik | Niğde |
| 106 | Çiftlikköy | 629700 | 4282200 | mesa | quater. alluvium | Merkez | Nevşehir |
| 107 | Çiğdem | 631500 | 4318000 | trough | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 108 | Çilhöyük | 604450 | 4231100 | mesa | neo. pyro. | Merkez | Aksaray |
| 109 | Çınarlı | 636900 | 4228350 | high mnt. | neo. andesite | Çiftlik | Niğde |
| 110 | Çivril | 630750 | 4314200 | trough | oligo. clastics | Hacıbektaş | Nevşehir |
| 111 | Çomaklı | 674300 | 4211300 | low mnt. | quater. alluvium | Merkez | Niğde |
| 112 | Çökek | 669200 | 4283750 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 113 | Çömlek | 613150 | 4317650 | trough | sedi. dom. neo. sq. | Mucur | Kırşehir |
| 114 | Çömlekçi | 616800 | 4212850 | high mnt. | neo. pyro. | Altunhisar | Niğde |
| 115 | Çullar | 621300 | 4281400 | mesa | sedi. dom. neo. sq. | Acıgöl | Nevşehir |
| 116 | Dadağı | 643200 | 4300550 | low mnt. | oligo. clastics | Gülşehir | Nevşehir |
| 117 | Dadılar | 587150 | 4297700 | low mnt. | pre oligo. bas. rocks | Ağaçören | Aksaray |
| 118 | Dedeli | 596400 | 4307200 | low mnt. | sedi. dom. neo. sq. | Merkez | Kırşehir |
| 119 | Değirmenkaşı | 605000 | 4303350 | flood pln. | sedi. dom. neo. sq. | Merkez | Kırşehir |
| 120 | Değirmenli | 666750 | 4212150 | low mnt. | pre oligo. bas. rocks | Merkez | Niğde |
| 121 | Delihebil | 613150 | 4261300 | low mnt. | pre oligo. bas. rocks | Gülağaç | Aksaray |
| 122 | Delileratik | 638700 | 4295550 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 123 | Delilercedit | 640800 | 4294050 | flood pln. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 124 | Demirci | 612400 | 4248950 | mesa | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 125 | Derinkuyu | 651500 | 4248800 | low pln. | sedi. dom. neo. sq. | Derinkuyu | Nevşehir |
| 126 | Devedamı | 589800 | 4309150 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 127 | Devepınarı | 610950 | 4310200 | low mnt. | pre oligo. bas. rocks | Mucur | Kırşehir |
| 128 | Devret | 667500 | 4253400 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 129 | Dikmen | 596100 | 4223800 | footslope | neo. andesite | Merkez | Aksaray |
| 130 | Doğala | 638850 | 4255500 | mesa | neo. pyro. | Derinkuyu | Nevşehir |
| 131 | Doğantarla | 606450 | 4247300 | mesa | quater. alluvium | Gülağaç | Aksaray |
| 132 | Dorukini | 592850 | 4252150 | mesa | sedi. dom. neo. sq. | Merkez | Aksaray |
| 133 | Durhasanlı | 603800 | 4288150 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 134 | Duvarlı | 628300 | 4229900 | low pln. | neo. pyro. | Çiftlik | Niğde |
| 135 | Düğüz | 618800 | 4261850 | low mnt. | pre oligo. bas. rocks | Gülağaç | Aksaray |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 136 | Ecikağıl | 595750 | 4313450 | flood pln. | oligo. clastics | Merkez | Kırşehir |
| 137 | Edek | 588300 | 4277000 | footslope | pre oligo. bas. rocks | Merkez | Aksaray |
| 138 | Edikli | 670800 | 4234900 | mesa | neo. pyro. | Merkez | Niğde |
| 139 | Eğrikuyu | 633450 | 4289000 | flood pln. | quater. basalt | Gülşehir | Nevşehir |
| 140 | Ekecikgödeler | 590900 | 4272850 | footslope | quater. alluvium | Merkez | Aksaray |
| 141 | Ekicektol | 595950 | 4262650 | mesa | sedi. dom. neo. sq. | Merkez | Aksaray |
| 142 | Ekicekyeniköy | 598100 | 4264850 | footslope | pre oligo. bas. rocks | Merkez | Aksaray |
| 142 | Ekicekyeniköy | 598100 | 4264850 | footslope | pre oligo. bas. rocks | Merkez | Aksaray |
| 142 | Ekicekyeniköy | 598100 | 4264850 | footslope | pre oligo. bas. rocks | Merkez | Aksaray |
| 143 | Ekincioğlu | 606600 | 4294550 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 144 | Elmacık | 603650 | 4231350 | mesa | quater. alluvium | Merkez | Aksaray |
| 145 | Emmiler | 619850 | 4292750 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 146 | Engel | 637300 | 4303900 | low mnt. | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 147 | Fakıuşağı | 614000 | 4294550 | flood pln. | pyro. dom. neo. sq. | Gülşehir | Nevşehir |
| 148 | Fatmauşağı | 587650 | 4272850 | mesa | quater. alluvium | Merkez | Aksaray |
| 149 | Gaziemir | 622200 | 4244250 | high mnt. | quater. basalt | Güzelyurt | Aksaray |
| 150 | Geyral | 611050 | 4256150 | low mnt. | pre oligo. bas. rocks | Gülağaç | Aksaray |
| 151 | Gidiriç | 587800 | 4220750 | low pln. | sedi. dom. neo. sq. | Merkez | Aksaray |
| 152 | Gökçetoprak | 613350 | 4279800 | low mnt. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 153 | Gökkaya | 587200 | 4278950 | footslope | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 154 | Gökler | 590450 | 4293900 | trough | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 155 | Göksugüzel | 601500 | 4263800 | footslope | sedi. dom. neo. sq. | Merkez | Aksaray |
| 156 | Gölcük | 655400 | 4232750 | low pln. | quater. alluvium | Merkez | Niğde |
| 157 | Göre | 649450 | 4272750 | low mnt. | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 158 | Göreme | 659300 | 4278750 | mesa | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 159 | Gösterli | 630050 | 4243150 | high mnt. | pyro. dom. neo. sq. | Çiftlik | Niğde |
| 160 | Göynük | 663700 | 4295600 | trough | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 161 | Gözlükuyu | 596200 | 4226350 | footslope | neo. pyro. | Merkez | Aksaray |
| 162 | Gücünkaya | 598750 | 4250450 | mesa | pyro. dom. neo. sq. | Merkez | Aksaray |
| 163 | Güllüce | 648400 | 4212350 | footslope | neo. pyro. | Merkez | Niğde |
| 164 | Güllüce | 631600 | 4227450 | low pln. | quater. alluvium | Çiftlik | Niğde |
| 165 | Gülşehir | 640650 | 4289600 | flood pln. | pyro. dom. neo. sq. | Gülşehir | Nevşehir |
| 166 | Gümüşkent | 633150 | 4298350 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 167 | Güneyce | 661300 | 4261800 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 168 | Gürsu | 619300 | 4253450 | low pln. | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 169 | Güvercinlik | 652700 | 4268950 | mesa | neo. pyro. | Merkez | Nevşehir |
| 170 | Güzelöz | 670800 | 4250800 | mesa | neo. pyro. | Yeşilhisar | Kayseri |
| 171 | Güzelyurt | 619900 | 4237550 | high mnt. | pyro. dom. neo. sq. | Güzelyurt | Aksaray |
| 172 | Hacıabdullah | 642750 | 4226400 | high mnt. | pyro. dom. neo. sq. | Merkez | Niğde |
| 173 | Hacıbektaş | 635500 | 4311750 | trough | oligo. clastics | Hacıbektaş | Nevşehir |
| 174 | Hacıbeyler | 602600 | 4292650 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 175 | Hacıhalil | 617400 | 4293900 | flood pln. | pyro. dom. neo. sq. | Gülşehir | Nevşehir |
| 176 | Hacılar | 624800 | 4299200 | flood pln. | quater. alluvium | Gülşehir | Nevşehir |
| 177 | Hamzalı | 620650 | 4291700 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 178 | Hançerli | 641600 | 4207200 | high mnt. | neo. andesite | Merkez | Niğde |
| 179 | Hasaköy | 649200 | 4231950 | low pln. | quater. alluvium | Merkez | Niğde |
| 180 | Helvadere | 605850 | 4227900 | high mnt. | neo. pyro. | Merkez | Aksaray |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 181 | Hıdırlar | 642750 | 4311600 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 182 | Himmetli | 670000 | 4210800 | low mnt. | pre oligo. bas. rocks | Merkez | Niğde |
| 183 | Hırkatepesidelik | 639550 | 4303700 | low mnt. | oligo. clastics | Hacıbektaş | Nevşehir |
| 184 | Hüyükköy | 667850 | 4225300 | low pln. | neo. pyro. | Merkez | Niğde |
| 185 | İbrahimpaşa | 661100 | 4274300 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 186 | İçik | 639850 | 4263150 | mesa | quater. alluvium | Merkez | Nevşehir |
| 187 | İğdelikışla | 648850 | 4306150 | trough | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 188 | Ihlara | 614500 | 4233350 | mesa | quater. alluvium | Güzelyurt | Aksaray |
| 189 | İlicek | 639800 | 4317000 | low mnt. | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 190 | Ilısu | 617750 | 4232800 | footslope | quater. basalt | Güzelyurt | Aksaray |
| 190 | Ilısu | 617750 | 4232800 | footslope | quater. basalt | Güzelyurt | Aksaray |
| 190 | Ilısu | 617750 | 4232800 | footslope | quater. basalt | Güzelyurt | Aksaray |
| 191 | İmampınarı | 601950 | 4252950 | mesa | pyro. dom. neo. sq. | Merkez | Aksaray |
| 192 | İnallı | 631500 | 4271500 | mesa | quater. alluvium | Acıgöl | Nevşehir |
| 193 | İnli | 646850 | 4226750 | footslope | neo. pyro. | Merkez | Niğde |
| 194 | İsmailuşağı | 639100 | 4295400 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 195 | İvazlı | 602000 | 4294400 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 196 | Kabaca | 623350 | 4315150 | trough | oligo. clastics | Mucur | Kırşehir |
| 197 | Kafesler | 603000 | 4293000 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 198 | Kalaba | 673300 | 4314750 | trough | sedi. dom. neo. sq. | Avanos | Nevşehir |
| 199 | Kalanlar | 591650 | 4248800 | mesa | quater. alluvium | Merkez | Aksaray |
| 200 | Kalebalta | 604150 | 4271400 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 201 | Karaatlı | 672750 | 4222250 | footslope | neo. pyro. | Merkez | Niğde |
| 202 | Karaburç | 623400 | 4305650 | low mnt. | quater. basalt | Hacıbektaş | Nevşehir |
| 203 | Karaburna | 626200 | 4303900 | flood pln. | quater. basalt | Hacıbektaş | Nevşehir |
| 204 | Karacalı | 621350 | 4316200 | trough | quater. alluvium | Mucur | Kırşehir |
| 206 | Karacaören | 672150 | 4276050 | mesa | quater. alluvium | Acıgöl | Nevşehir |
| 207 | Karacaören | 638950 | 4266700 | mesa | quater. alluvium | Merkez | Aksaray |
| 205 | Karacaören | 593500 | 4220800 | footslope | quater. basalt | Ürgüp | Nevşehir |
| 208 | Karacaşar | 636850 | 4284800 | mesa | quater. basalt | Gülşehir | Nevşehir |
| 209 | Karacauşağı | 666950 | 4308700 | low mnt. | pre oligo. bas. rocks | Avanos | Nevşehir |
| 210 | Karaçayır | 595700 | 4267750 | mesa | sedi. dom. neo. sq. | Merkez | Aksaray |
| 211 | Karahöyük | 622750 | 4302400 | flood pln. | quater. basalt | Gülşehir | Nevşehir |
| 212 | Karain | 673400 | 4273400 | mesa | pyro. dom. neo. sq. | Ürgüp | Nevşehir |
| 213 | Karakapı | 601650 | 4213150 | footslope | neo. andesite | Altunhisar | Niğde |
| 214 | Karakova | 613600 | 4269500 | low pln. | sedi. dom. neo. sq. | Merkez | Aksaray |
| 215 | Karakuyu | 608900 | 4315300 | trough | oligo. clastics | Merkez | Aksaray |
| 216 | Karakuyu | 611400 | 4265000 | trough | sedi. dom. neo. sq. | Mucur | Kırşehir |
| 217 | Karaören | 599400 | 4233700 | low pln. | quater. alluvium | Merkez | Aksaray |
| 218 | Karapınar | 635000 | 4264450 | low mnt. | quater. alluvium | Acıgöl | Nevşehir |
| 219 | Karapınar Çift. | 634750 | 4316600 | trough | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 220 | Karataş | 595750 | 4234650 | low pln. | quater. alluvium | Merkez | Aksaray |
| 221 | Kargın | 602500 | 4229500 | mesa | neo. pyro. | Merkez | Aksaray |
| 222 | Karlık | 673000 | 4269950 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 223 | Karşı | 607800 | 4256200 | mesa | quater. alluvium | Gülağaç | Aksaray |
| 224 | Karşı | 648850 | 4285300 | flood pln. | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 225 | Kavak | 658750 | 4271200 | mesa | neo. pyro. | Merkez | Nevşehir |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 226 | Kayı | 630550 | 4311350 | trough | oligo. clastics | Hacıbektaş | Nevşehir |
| 227 | Kayıköyü | 628300 | 4310750 | low mnt. | oligo. clastics | Hacıbektaş | Nevşehir |
| 228 | Kayırlı | 631400 | 4241800 | high mnt. | pyro. dom. neo. sq. | Çiftlik | Niğde |
| 229 | Kaymaklı | 652900 | 4258450 | low pln. | quater. alluvium | Derinkuyu | Nevşehir |
| 230 | Keçikalesi | 598100 | 4213350 | footslope | neo. pyro. | Altunhisar | Niğde |
| 231 | Kenar | 633100 | 4281850 | mesa | quater. basalt | Merkez | Nevşehir |
| 232 | Kepez | 616500 | 4315500 | low mnt. | oligo. clastics | Mucur | Kırşehir |
| 233 | Kepir | 596600 | 4286250 | trough | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 234 | Kesikköprü | 603650 | 4313650 | flood pln. | pre oligo. bas. rocks | Merkez | Kırşehir |
| 235 | Keşlik | 621900 | 4208000 | footslope | neo. andesite | Altunhisar | Niğde |
| 236 | Kiçiağaç | 661500 | 4214500 | footslope | quater. alluvium | Merkez | Niğde |
| 237 | Kiledere | 646900 | 4241350 | low pln. | quater. alluvium | Merkez | Niğde |
| 238 | Killik | 644700 | 4307850 | trough | oligo. clastics | Hacıbektaş | Nevşehir |
| 238 | Killik | 644700 | 4307850 | trough | oligo. clastics | Hacıbektaş | Nevşehir |
| 238 | Killik | 644700 | 4307850 | trough | oligo. clastics | Hacıbektaş | Nevşehir |
| 239 | Kırkpınar | 643750 | 4210600 | high mnt. | neo. andesite | Merkez | Niğde |
| 240 | Kışla | 604550 | 4229900 | mesa | quater. alluvium | Merkez | Aksaray |
| 241 | Kışla | 639900 | 4295300 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 242 | Kitreli | 618200 | 4225750 | footslope | neo. pyro. | Çiftlik | Niğde |
| 243 | Kıyı | 593200 | 4226250 | footslope | neo. andesite | Merkez | Aksaray |
| 244 | Kızılağıl | 653350 | 4318250 | trough | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 245 | Kızılağıl | 611750 | 4307900 | flood pln. | sedi. dom. neo. sq. | Mucur | Kırşehir |
| 246 | Kızılcın | 642400 | 4261700 | low mnt. | neo. pyro. | Merkez | Nevşehir |
| 247 | Kızılkaya | 607350 | 4246650 | mesa | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 248 | Kızılkaya | 623500 | 4284500 | mesa | quater. alluvium | Gülşehir | Nevşehir |
| 249 | Kızılköy | 629500 | 4285600 | mesa | quater. alluvium | Gülşehir | Nevşehir |
| 250 | Kocabey | 596650 | 4316350 | flood pln. | sedi. dom. neo. sq. | Merkez | Kırşehir |
| 251 | Kocaboğaz | 599400 | 4312650 | flood pln. | sedi. dom. neo. sq. | Merkez | Kırşehir |
| 252 | Kocaş Çift. | 634050 | 4316150 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 253 | Konaklı | 661850 | 4226850 | footslope | neo. pyro. | Merkez | Niğde |
| 254 | Koyak | 598600 | 4268550 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 255 | Kozluca | 622250 | 4274450 | low mnt. | pre oligo. bas. rocks | Acıgöl | Nevşehir |
| 256 | Kömürcü | 637550 | 4238350 | high mnt. | neo. pyro. | Merkez | Niğde |
| 257 | Köşektaş | 651800 | 4316100 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 258 | Kula | 626850 | 4225750 | footslope | neo. pyro. | Çiftlik | Niğde |
| 259 | Kurtuluş | 591350 | 4247100 | footslope | oligo. clastics | Merkez | Aksaray |
| 260 | Kuruağıl | 602300 | 4310350 | flood pln. | pre oligo. bas. rocks | Merkez | Kırşehir |
| 261 | Kurugöl | 632450 | 4255500 | low pln. | quater. basalt | Acıgöl | Nevşehir |
| 262 | Kuyubaşı | 607000 | 4256650 | mesa | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 263 | Kuyulukışla | 649750 | 4304750 | trough | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 264 | Kuyulutatlar | 636450 | 4248250 | low pln. | quater. alluvium | Derinkuyu | Nevşehir |
| 265 | Küçükkayapa | 615700 | 4305400 | flood pln. | sedi. dom. neo. sq. | Mucur | Kırşehir |
| 266 | Küçükkkavak | 612850 | 4314050 | trough | oligo. clastics | Mucur | Kırşehir |
| 267 | Küçükpörnek | 605100 | 4274650 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 268 | Kümbet | 604050 | 4285700 | trough | quater. alluvium | Ortaköy | Aksaray |
| 269 | Kütükçü | 636900 | 4307150 | trough | oligo. clastics | Hacıbektaş | Nevşehir |
| 270 | Lalebağları | 592200 | 4245350 | footslope | oligo. clastics | Merkez | Aksaray |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 271 | Mahmatipşir | 669900 | 4305250 | low mnt. | sedi. dom. neo. sq. | Avanos | Nevşehir |
| 272 | Mahmattatar | 670850 | 4305600 | trough | sedi. dom. neo. sq. | Avanos | Nevşehir |
| 273 | Mahmutlu | 622400 | 4226900 | footslope | neo. andesite | Çiftlik | Niğde |
| 274 | Mamasun | 602700 | 4252650 | mesa | quater. alluvium | Merkez | Aksaray |
| 275 | Mamat | 669750 | 4304700 | low mnt. | sedi. dom. neo. sq. | Avanos | Nevşehir |
| 276 | Mazıköy | 660500 | 4259700 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 277 | Mikail | 625700 | 4314300 | trough | quater. alluvium | Hacıbektaş | Nevşehir |
| 278 | Murtaza | 640000 | 4225600 | high mnt. | neo. andesite | Çiftlik | Niğde |
| 279 | Mustafapaşa | 665400 | 4272500 | mesa | pyro. dom. neo. sq. | Ürgüp | Nevşehir |
| 280 | Narköy | 626600 | 4243150 | high mnt. | neo. pyro. | Çiftlik | Niğde |
| 281 | Narköy | 649450 | 4278550 | mesa | pyro. dom. neo. sq. | Merkez | Nevşehir |
| 282 | Nevşehir | 649400 | 4276600 | low mnt. | neo. pyro. | Merkez | Nevşehir |
| 283 | Obruk | 589150 | 4206750 | low pln. | quater. basalt | Emirgazi | Konya |
| 284 | Orhanlı | 665050 | 4241050 | mesa | neo. pyro. | Merkez | Niğde |
| 285 | Ortahisar | 662400 | 4276550 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 286 | Ortaköy | 661600 | 4297400 | trough | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 286 | Ortaköy | 661600 | 4297400 | trough | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 286 | Ortaköy | 661600 | 4297400 | trough | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 287 | Ortaköy | 590450 | 4288400 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 288 | Ovacık | 659500 | 4215600 | low pln. | pre oligo. bas. rocks | Merkez | Niğde |
| 289 | Ovalıbağ | 626350 | 4230000 | footslope | neo. pyro. | Çiftlik | Niğde |
| 290 | Ovaören | 612450 | 4277450 | low pln. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 291 | Ozancık | 604650 | 4280800 | low pln. | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 292 | Özkonak | 659550 | 4297700 | trough | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 293 | Özlüce | 646600 | 4257500 | low mnt. | neo. pyro. | Derinkuyu | Nevşehir |
| 294 | Pınarcık | 632250 | 4241050 | high mnt. | pyro. dom. neo. sq. | Çiftlik | Niğde |
| 295 | Pınarcık | 646550 | 4222200 | high mnt. | pyro. dom. neo. sq. | Merkez | Niğde |
| 296 | Pirli | 601200 | 4287550 | trough | pyro. dom. neo. sq. | Ortaköy | Aksaray |
| 297 | Pörnekler | 605050 | 4276600 | trough | pre oligo. bas. rocks | Merkez | Aksaray |
| 298 | Reşadiye | 606450 | 4295850 | low mnt. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 299 | Sağırkaraca | 592350 | 4266300 | mesa | quater. alluvium | Merkez | Aksaray |
| 300 | Sağlık | 593550 | 4240150 | low pln. | quater. alluvium | Merkez | Aksaray |
| 301 | Salarıgödeler | 601700 | 4284750 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 302 | Salmanlı | 599650 | 4271700 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 303 | Salur | 673950 | 4280700 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 304 | Sanırtol | 592150 | 4241850 | low pln. | quater. alluvium | Merkez | Aksaray |
| 305 | Saralıalaca | 595000 | 4297800 | trough | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 306 | Saratlı | 607300 | 4256800 | mesa | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 307 | Sarıağıl | 603800 | 4273700 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 308 | Sarıhıdır | 667900 | 4289250 | flood pln. | quater. alluvium | Ürgüp | Nevşehir |
| 309 | Sarıkaraman | 603850 | 4292100 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 310 | Sarılar | 655200 | 4308600 | low mnt. | pyro. dom. neo. sq. | Avanos | Nevşehir |
| 311 | Satansarı | 609550 | 4292850 | low mnt. | sedi. dom. neo. sq. | Ortaköy | Aksaray |
| 312 | Seksenuşağı | 587400 | 4284750 | low mnt. | pre oligo. bas. rocks | Ortaköy | Aksaray |
| 313 | Selime | 609950 | 4240500 | mesa | quater. alluvium | Güzelyurt | Aksaray |
| 314 | Sevinçli | 597100 | 4246150 | mesa | oligo. clastics | Merkez | Aksaray |
| 315 | Sığırlı | 625750 | 4297550 | flood pln. | quater. alluvium | Gülşehir | Nevşehir |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 316 | Sivrihisar | 623650 | 4236250 | high mnt. | pyro. dom. neo. sq. | Çiftlik | Niğde |
| 317 | Sofular | 673250 | 4287150 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 318 | Sofular | 624900 | 4245350 | high mnt. | neo. pyro. | Çiftlik | Niğde |
| 319 | Soğanlı A. | 673400 | 4245250 | mesa | neo. pyro. | Yeşilhisar | Kayseri |
| 320 | Soğanlı Y. | 672100 | 4246150 | mesa | neo. pyro. | Yeşilhisar | Kayseri |
| 321 | Sultanpınarı | 633550 | 4223250 | footslope | quater. basalt | Çiftlik | Niğde |
| 322 | Sulusaray | 649450 | 4284750 | flood pln. | neo. pyro. | Merkez | Nevşehir |
| 323 | Susadı | 605300 | 4268050 | trough | sedi. dom. neo. sq. | Merkez | Aksaray |
| 324 | Suvermez | 644100 | 4248450 | low pln. | quater. alluvium | Derinkuyu | Nevşehir |
| 325 | Süleyman Hyk. | 615650 | 4262600 | trough | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 326 | Şahinefendi | 669850 | 4259850 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 327 | Şahinler | 619900 | 4302150 | flood pln. | pyro. dom. neo. sq. | Gülşehir | Nevşehir |
| 328 | Şeyhler | 591750 | 4269700 | mesa | pre oligo. bas. rocks | Merkez | Aksaray |
| 329 | Şeyhler | 625850 | 4226200 | footslope | neo. pyro. | Çiftlik | Niğde |
| 330 | Tahar | 673750 | 4267700 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 331 | Taptık | 598300 | 4269100 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 332 | Taşkınpaşa | 669850 | 4262350 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 333 | Taşlıca | 644800 | 4209350 | high mnt. | neo. andesite | Merkez | Niğde |
| 334 | Taşpınar | 589850 | 4226400 | low pln. | sedi. dom. neo. sq. | Merkez | Aksaray |
| 334 | Taşpınar | 589850 | 4226400 | low pln. | sedi. dom. neo. sq. | Merkez | Aksaray |
| 334 | Taşpınar | 589850 | 4226400 | low pln. | sedi. dom. neo. sq. | Merkez | Aksaray |
| 335 | Tatlarinköy | 629050 | 4277650 | footslope | quater. alluvium | Acıgöl | Nevşehir |
| 336 | Tatlıca | 608100 | 4268500 | trough | sedi. dom. neo. sq. | Merkez | Aksaray |
| 337 | Tepeköy | 643750 | 4215300 | high mnt. | neo. andesite | Acıgöl | Nevşehir |
| 338 | Tepeköy | 636350 | 4271650 | mesa | quater. basalt | Merkez | Niğde |
| 339 | Tepesidelik | 592200 | 4259050 | mesa | sedi. dom. neo. sq. | Merkez | Aksaray |
| 340 | Terlemez | 613200 | 4288150 | low mnt. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 341 | Tilköy | 658750 | 4253950 | mesa | neo. pyro. | Derinkuyu | Nevşehir |
| 342 | Tırhan | 649550 | 4233950 | low pln. | quater. alluvium | Merkez | Niğde |
| 343 | Topaç | 635950 | 4259950 | low mnt. | neo. pyro. | Acıgöl | Nevşehir |
| 344 | Topayın A. | 632250 | 4306250 | low mnt. | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 345 | Topayın Y. | 630900 | 4306550 | low mnt. | pre oligo. bas. rocks | Hacıbektaş | Nevşehir |
| 346 | Topçu | 618900 | 4303550 | flood pln. | pyro. dom. neo. sq. | Gülşehir | Nevşehir |
| 347 | Tuzköy | 630000 | 4292100 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 348 | Ulaşlı | 670150 | 4282200 | mesa | neo. pyro. | Ürgüp | Nevşehir |
| 349 | Uluağaç | 661150 | 4212850 | low mnt. | pre oligo. bas. rocks | Merkez | Niğde |
| 350 | Ulukışla B. | 613650 | 4212500 | footslope | neo. pyro. | Altunhisar | Niğde |
| 351 | Ulukışla D. | 615000 | 4212900 | footslope | neo. andesite | Altunhisar | Niğde |
| 352 | Uluören | 604400 | 4214750 | footslope | neo. andesite | Altunhisar | Niğde |
| 353 | Ulupınar | 603850 | 4301100 | flood pln. | sedi. dom. neo. sq. | Merkez | Kırşehir |
| 354 | Usta | 637650 | 4303900 | low mnt. | oligo. clastics | Hacıbektaş | Nevşehir |
| 355 | Uzunkaya | 606150 | 4238950 | mesa | pyro. dom. neo. sq. | Güzelyurt | Aksaray |
| 356 | Üçhisar | 657250 | 4277350 | mesa | neo. pyro. | Merkez | Nevşehir |
| 357 | Ürgüp | 666400 | 4277750 | mesa | pyro. dom. neo. sq. | Ürgüp | Nevşehir |
| 358 | Yabannı | 635200 | 4314750 | trough | sedi. dom. neo. sq. | Hacıbektaş | Nevşehir |
| 359 | Yağanköy | 590650 | 4266100 | mesa | quater. alluvium | Merkez | Aksaray |
| 360 | Yakacık | 617850 | 4209900 | footslope | neo. pyro. | Altunhisar | Niğde |

| No. | Name | Easting | Northing | Mrph. Cl. | Rock Type | Town | Province |
|---|---|---|---|---|---|---|---|
| 361 | Yakacık | 621400 | 4246050 | footslope | pyro. dom. neo. sq. | Güzelyurt | Aksaray |
| 362 | Yakatarla | 618050 | 4288100 | mesa | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 363 | Yalıntaş | 616900 | 4284300 | low mnt. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 364 | Yalman | 621800 | 4266300 | low mnt. | pyro. dom. neo. sq. | Gülağaç | Aksaray |
| 365 | Yalnızceviz | 601900 | 4260500 | mesa | quater. alluvium | Merkez | Aksaray |
| 366 | Yamaç | 632850 | 4282000 | mesa | quater. basalt | Merkez | Nevşehir |
| 367 | Yamalı | 610250 | 4305650 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 368 | Yanyurt | 598500 | 4273850 | low mnt. | pre oligo. bas. rocks | Merkez | Aksaray |
| 369 | Yaprakhisar | 610700 | 4239400 | mesa | quater. alluvium | Güzelyurt | Aksaray |
| 370 | Yarhisar | 669050 | 4216100 | footslope | neo. pyro. | Merkez | Niğde |
| 371 | Yaylayolu | 646700 | 4217750 | footslope | neo. pyro. | Merkez | Niğde |
| 372 | Yazıhöyük | 643300 | 4245450 | low pln. | quater. alluvium | Derinkuyu | Nevşehir |
| 373 | Yeni | 630450 | 4244050 | hill in pln.s | quater. basalt | Çiftlik | Niğde |
| 374 | Yenice | 638050 | 4304050 | low mnt. | oligo. clastics | Hacıbektaş | Nevşehir |
| 375 | Yeniköy | 660650 | 4213350 | low mnt. | pre oligo. bas. rocks | Merkez | Niğde |
| 376 | Yenipınar | 609750 | 4225850 | footslope | neo. andesite | Merkez | Aksaray |
| 377 | Yeşilburç | 646600 | 4208850 | footslope | neo. pyro. | Merkez | Niğde |
| 378 | Yeşilli | 622800 | 4300850 | flood pln. | sedi. dom. neo. sq. | Gülşehir | Nevşehir |
| 379 | Yeşilöz | 646300 | 4293850 | flood pln. | pyro. dom. neo. sq. | Gülşehir | Nevşehir |
| 380 | Yukarıasmaz | 621450 | 4207150 | footslope | neo. andesite | Altunhisar | Niğde |
| 382 | Yuva | 601250 | 4233850 | mesa | neo. pyro. | Acıgöl | Nevşehir |
| 381 | Yuva | 623250 | 4270800 | low mnt. | pyro. dom. neo. sq. | Merkez | Aksaray |
| 383 | Yüksekli | 631100 | 4296500 | flood pln. | pre oligo. bas. rocks | Gülşehir | Nevşehir |
| 384 | Yürücek | 609550 | 4308550 | flood pln. | quater. alluvium | Mucur | Kırşehir |

# APPENDIX C: LAYOUTS OF BASIC PROGRAMS USED IN THE STUDY

## 1

```
REM
REM Calculation of distances between underground cities and present settlements
REM
CLS
DIM x1(500), y1(500), x2(500), y2(500), distan(500), PS$(500), UC$(500), village(500)
OPEN "in-uc.txt" FOR INPUT AS #1
  INPUT #1, number1
  FOR i = 1 TO number1: INPUT #1, UC$(i), x1(i), y1(i): NEXT
CLOSE #1
OPEN "in-ps.txt" FOR INPUT AS #2
  INPUT #2, number2
  FOR i = 1 TO number 2: INPUT #2, PS$(i), x2(i), y2(i): NEXT
  CLOSE #2
OPEN "distal.txt" FOR OUTPUT AS #3
FOR i = 1 TO number 1
   min = 999999999
   FOR j = 1 TO number 2
   distx = ABS(x1(i) - x2(j))
   disty = ABS(y1(i) - y2(j))
   sqx = (distx * distx)
   sqy = (disty * disty)
   dist = SQR(sqx + sqy)
   IF (dist < min) THEN min = dist: vil = j
10  NEXT
   distan(i) = min
   village(i) = vil
   NEXT
   FOR i = 1 TO number 1
   PRINT #3, UC$(i); ","; i; ",";
   PRINT #3, USING "########"; distan(i);
   PRINT #3, ","; MS$(village(i))
NEXT
   CLOSE #3
END
```

## 2

```
REM
REM Calculation of grid values for density analysis
REM
DIM x(500), y(500)
OPEN "in-uc.txt" FOR INPUT AS #1
INPUT #1, number
  FOR i = 1 TO number: INPUT #1, x(i), y(i): NEXT
CLOSE #1
OPEN "USgrid.txt" FOR OUTPUT AS #2
   FOR i = 583000 TO 675000 STEP 1000
   FOR j = 4212000 TO 4316000 STEP 1000
       toplam = 0
       FOR k = 1 TO number
       distx = ABS(x(k) - i)
       disty = ABS(y(k) - j)
       d1 = distx * distx
       d2 = disty * disty
       d = SQR(ABS(d1 + d2))
       IF d < 5000 THEN total = total + 1
       NEXT k
   PRINT #2, USING "########"; i; j; total
   NEXT j
   NEXT i
   CLOSE #2
   STOP
   END
```

### 3

```
REM
REM Calculation to put one pixel for each 1km²
REM
CLS
OPEN "ucgrid.txt" FOR INPUT AS #1
OPEN "psgrid.txt" FOR INPUT AS #2
OPEN "result.txt" FOR OUTPUT AS #3
FOR i = 1 TO 93
FOR j = 1 TO 105
INPUT #1, a!, b!, c!
INPUT #2, d!, e!, f!
IF a! <> d! OR b! <> e! THEN GOTO 20
PRINT #3, USING "########"; a!; b!; c! / 127 * 100; f! / 384 * 100
NEXT
NEXT
GOTO 30
20 PRINT "error"
30 CLOSE #1, #2, #3
STOP
END
```