# SOLAR ENERGY PLANNING

## a guide to residential settlement

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# PREFACE

Since the Arab oil embargo in the early 1970s, energy has become an important force in the design of buildings. In the United States alone, hundreds of thousands of buildings have been constructed using various energy-conservation techniques and solar energy technologies for space or water heating. By the year 1990 there could be as many as 5 million energy-responsive buildings. With this magnitude of growth, the need for solar energy planning is evident, particularly in the residential sector, where most of the solar energy systems will continue to be demonstrated.

In the search to satisfy the need for energy and the many other needs connected to housing, several questions arise. What kinds of solar energy systems are appropriate to the variety of residential building types? What are the energy implications of the use of these systems in multiple buildings? What limitations does density place upon energy-oriented design? In what ways can energy-conscious planning affect contemporary residential settlement patterns? It is the purpose of this book to identify the types of solar technologies presently in use and to describe their potential and limitations for larger-scale utilization.

Solar energy planning concepts ideally should be applied to all scales of the built environment, particularly to most areas of the building sector—residential, commercial, institutional, and industrial—and to the transportation sector. The last several years have seen a shift in interest from residential use of solar energy to commercial applications. Three demonstration cycles of the U.S. Department of Energy have revealed practical solutions to many types of commercial solar architecture. However, most of these demonstrations have been limited to small single buildings. For larger nonresidential buildings, many questions are still unanswered. The predominant use of solar technology remains with residential buildings. For this reason, this book focuses on planning issues at the various levels of *residential* settlement.

The solar energy industry has promoted energy-conservation measures in conjunction with solar mechanical technologies for single buildings. Many of the problems associated with multiple buildings have been overlooked. Protecting solar collection from shadows of adjacent buildings is certainly an important subject for both small and large scales of development. Land use, density, automobile circulation, and open-space design are also issues that can affect the quality of energy conservation. The book is written as a guide for planners and developers, architects and solar engineers, and educators and students so they may be alerted to some of the energy issues and limitations that exist at the larger scales.

The book begins with an introductory chapter of residential development patterns. The influences of energy, especially the use of solar energy in community planning, are described for many cultures and times throughout history. The second chapter presents some limitations of solar energy in an attempt to define realistic boundaries within which creative solar design and planning can occur. The chapter also serves to define state-of-the-art solar energy systems, primarily active and passive systems. The need for solar-access protection and the methods for solar-access planning at varying densities are the subjects of the third chapter. A checklist for solar-access planning is included at the end of the chapter. The first three chapters form a historical and theoretical foundation for the remaining chapters, in which the concepts are applied at various scales.

The remaining four chapters, in sequence, relate solar energy considerations in expanding scales of residential development: individual shelter design, cluster development, neighborhood planning, and residential settlement. The need to plan for solar energy is woven through these various scales from the technical concerns for a thermal zone or room to the broader and more complex concerns for an entirely planned community or new town. Applications of solar energy planning concepts are discussed at each of these scales. At the end of the book are three appendixes. Appendix A presents several simple computational methods for determining shadow patterns and protecting solar access. Appendix B presents information on solar covenants and ordinances. Appendix C is a table of selected conversion factors for use in converting customary measurements to metric, or SI, measurements. Throughout the book, the use of computer-generated graphics helps explain many of the solar planning ideas that otherwise would have been too difficult to illustrate.

The work presented here spans nearly 10 years, although the actual manuscript was prepared in only a year—thanks to my Apple III computer. The ideas and designs presented in this book have evolved from vague visions seeded a decade ago. During that time, many individuals have greatly influenced their growth. First, I would like to give thanks to my students at the University of Colorado who have worked long hours

under great pressure to produce some of the work for this book. James Elliott, Stephen Glascock, Deidra Heaton, David Horsley, and Dawn Marine developed many of the case studies illustrated in the book. James Hopperstead, Greg Lemon, Jeff Davis, and Pat Davies produced most of the illustrations. And Scott Wolfe digitized and produced most of the computer-aided drawings found throughout the book.

I would like to acknowledge the assistance and support of Jane Harris, who helped with the research and editing, Nelson Greene, who gave guidance for all of the computer-aided design work, Russ Derickson, who provided solar engineering concepts, Larry Peterson, who reviewed the manuscript, and Jan F. Kreider, who provided hundreds of useful suggestions that greatly improved the technical quality of the book, and my parents, who provided financial support. Very special thanks to my sons, Michael and David, for their aliveness and inspiration and to Myfanwy Lloyd-Tabb for her encouragement and helpful criticism throughout the creation of the manuscript.

Phillip Tabb

# INTRODUCTION

A view of the earth from outer space gives our generation a perspective never before experienced in history. It is now difficult to imagine the whole earth in any other way than as a sphere of blue and white surfaces floating in silence around the sun. Given energy from our sun millions of miles away, we are passengers on a planet involved in the intricate cycles of life. The full impact of this new perception is just unfolding; the wonderful changes that will occur as a result of this new picture of the Earth—so truly beautiful and contained—are yet to be manifested.

One way to visualize our life here on earth is to see it from afar. Imagine you are a traveler on a spaceship from Sirius, 25 trillion miles away. Our sun, although average in size, is a raging nuclear reactor 870,000 miles in diameter with nine planets. As you pass through our solar system and view the circling planets, one, with a composition of carbon, oxygen, and hydrogen that supports life, stands out. Approaching this planet and penetrating its atmosphere, you can see two white polar caps with large bodies of water and many land masses beneath the motion and whorls of a white gas. Human settlements on mountains and islands and in river valleys, plains, and deserts are apparent. They vary from small communities to large metropolitan networks. Having traveled so far, you may wonder about the ways in which this civilization relates to its unique solar system and more specifically to this special planet.

What is life on this planet really like? Further investigation would reveal a fairly complex physical and social organization that extends to most regions of this globe. The works of this civilization would be quite evident. There are dams and bridges and great mosaics of farms and fences. Highways stretch from one end of the land masses to the other. There are many airplanes, trains, ships, and automobiles, and there is an occasional space shuttle on the move. Great activity would be apparent. The larger cities stretch for miles, covered by blankets of smoke and other gases. At first glance, it would appear that there is a fairly energetic species at work. Who would suspect that "they"—we—are experiencing an energy crisis when so much energy is seemingly available?

The Sirius solar system and the planet from which you came may be very similar to this one. But perhaps your planet did not experience a fossil fuel era. Your technology, slightly more advanced than earth's, may be based upon star energy, synthetic fuels, and hydrogen. Your cities may be more strongly organized around those energy sources, and your dwellings may also be designed as little energy machines.

This voyage, though just a fantasy, gives us a quick opportunity to see ourselves, the way in which we live, and our physical and technological responses to the limited resources that are available to us. With a critical eye, we can identify those processes that seem to fit into this larger picture, for the next several centuries most certainly will bring greater space travel, more refined uses of our resources, the decline of the fossil fuel era, and new forms of energy.

A view of the earth from outer space gives us a simplified picture—the earth, our moon, and the sun in a dark, expansive context dotted with stars, planets, and other "travelers" in space. Certainly the relationship between the sun and the earth is a powerful one. In fact, most of the earth's energy—including most thermal energy and the energy in all of our food and the fossil fuels we are now consuming—is derived from the sun. It seems clear that we should evolve a stronger relationship to solar energy. This is not an easy task. With 4 billion fellow residents and social, economic, political, and physical structures very much based upon diminishing fossil fuels, we may need several centuries to accomplish the task. Planning now for greater utilization of solar energy can ease the transition from an age of fossil fuels and ensure plentiful energy for future generations.

Solar energy planning is concerned with creating another structure, one that allows for contemporary needs, is sensitive to the past, responds to the limitations of solar energy, and is more integrated with the forces of our universe. Solar energy planning is a design response. Decisions being made today are affecting this potential. The process can be organic; that is to say, it can grow from the prevailing planning and architectural methodologies. It can evolve slowly toward the building of solar buildings and solar communities. The opportunities are worldwide, and the challenge is exciting. A shift in this direction could reduce some of the preoccupation with nationalism, defense, isolation, and survival. We could be made more aware of the global community that we really are: one people, one planet.

Woven throughout solar energy planning is the concept of scales of response. Certain conditions must exist and be preserved for solar energy to be effectively utilized, for photosynthesis to take place, and for solar heating or solar power generation to be possible. Solar energy planning affects design decisions at various scales so that these conditions are encouraged and maintained. Solar energy planning involves many positive limitations on physical design at several scales:

1. Shelters (individual dwellings)
2. Clusters (small groupings of dwellings)
3. Neighborhoods (larger groupings or small communities)
4. Residential settlements (communities and new towns)

Imagine space travelers from Sirius experiencing the earth in 200 years. They might see dwellings with solar electric cells; clusters with shared energy systems; neighborhoods lush with gardens; and communities based upon large-scale solar collection, urban farms, and the use of solar electric vehicles. Perhaps there will be solar-powered space colonies. Many obstacles stand between the built environment and this vision. We must decide whether or not we will plan for solar energy.

A fitting ending to this introduction is a quote by Nigel Calder, author of *Spaceships of the Mind*.

> The human world, past and future, is shaped by constant pressure from the imagination and ambition of individuals who have big ideas. By a big idea I mean one that will prevail not by degree or even by persuasion but because it captures the enthusiasm of people who will struggle against great difficulties to make it happen.*

*N. Calder, *Spaceships of the Mind*, British Broadcasting Corporation, London, 1978.

# CONTENTS

CHAPTER 1

# DEVELOPMENT PATTERNS

*Man is a singular creature. He has a set of gifts which make him unique among the animals: so that, unlike them, he is not a figure in the landscape—he is a shaper of the landscape.*
J. BRONOWSKI*

People historically have bound together to form communities of various kinds. The physical and spiritual manifestations of these settlements have satisfied many needs, but principally their function has been to facilitate each group member's attainment of commodities necessary for life support and to contribute to the realization of individual emotional and intellectual needs and aspirations. The human settlement is a means of celebrating and coping with environmental changes as well as with fellow beings.

Ancient societies, disposed all over the globe, evolved similar city plans with orientation to the cardinal points of the compass so that all of the buildings, placed within a grid, would receive solar energy during the winter months. The Egyptians, the Greeks, the Chinese, the Aztecs, the Incas, and the Anasazi Indians alike created solar communities and architecture in response to the movement of the sun. For centuries these people lived with the energy from the sun and charcoal or wood. As wood and charcoal supplies dwindled, greater reliance was placed upon solar energy, and as a result, access to the sun became a stronger and more important planning determinant.

In modern times, much of this was lost. With vast quantities of coal, oil, and natural gas and with the promise of inexhaustible supplies of

*From Bronowski.[6] Copyright © 1973 by J. Bronowski.

nuclear energy, modern societies evolved city plans of undisciplined sprawl. World population exploded with over 4 billion inhabitants. Cities grew up and out using vast resources. Complex problems arose caused by rapid growth and changing technology. Complicated transportation networks, diverse and problematic land use, complex city services and maintenance schedules, water and waste distribution and purification, pollution, crime and other social problems—all added to the milieu of contemporary residential settlement. The confluence of these phenomena overshadowed direct use of the sun. It was not until recently that fossil fuels were recognized as being finite and nonrenewable; and it was not until actual experiences of energy shortages had occurred that solar energy was seen as a serious alternative.

A look at current energy-oriented design in relation to historical development is presented in this chapter. *Ancient development, post-industrial-revolution development,* and *modern development* are all compared in relation to energy sources and consumption. Contemporary *energy-responsive development* is discussed and illustrated, for the use of solar energy for heat and light is once again becoming an integral part of the planning process.

## HISTORICAL DEVELOPMENT

The origin of humankind is believed to have occurred some 5 million years ago near the equator in central Africa. Ancient stories put our species in a golden age, perhaps in the Garden of Eden, which may have been located in this place. Energy was probably not an important issue as the earth was very plentiful. Cold temperatures and hunger were probably rarely experienced. As time went on, people hunted and gathered and then began to migrate to other lands where they most likely found the need for additional food, clothing, housing, and fire for cooking. Ancient camps demonstrated basic environmental responses through location adjacent to rivers or streams, orientation to the sun, and breaks to the prevailing winds. These early camps may have used simple passive solar energy techniques for heating.

As villages grew into communities and communities grew into cities, residential settlements began to evolve development patterns maintaining orientation to the sun for warmth and light. Many ruins still exist today that demonstrate this pattern. Paths and streets were oriented along the east-west axis in order to allow for good solar access for each building. Buildings were designed to accept sunlight during the winter months and to provide shading in the summertime. Socrates, in the fourth century B.C., spoke of these simple design principles: "In houses that look toward the south, the sun penetrates the portico in winter, while in summer the path of the sun is right over our heads above the roof so that there is shade."[8]

### Early Responses to the Sun

Early Paleolithic camps, which are 300,000 years old, have been found in southern France around the Mediterranean Sea. Although there is no real physical evidence that the camps were primarily organized in response to the sun, the ruins seem to characterize communal life as it may have occurred at that time. Proximity to food and water, access to solar energy, protection from the winds, and views for defense seem to have been the primary planning forces. The camps were small enough that response to these forces was probably quite natural and uncomplicated. Figure 1-1 is an illustration of a camp that may have developed during this time period. As the camps grew into villages and as life became more diversified, the physical form required more order and planning. Beginning around 2800 B.C., several prehistoric monuments, such as those found at Stonehenge, Avebury, and Carnac, reveal great sensitivity and extraordinary discipline to the movement of the sun.

Stonehenge, located in Wiltshire on Salisbury Plain, England, evolved in four distinct phases and was used as a temple and burial ground for seventeen centuries. The ultimate design was made of concentric circles of stone. Going from the outside in, the circles included an outer earth berm, the Avebury holes and Y-shaped holes, the Sarsen circle of standing stones with curved lintels, the bluestone circle, the five giant triliths, and the altar stone. The five triliths in a horseshoe configuration weigh between 20 and 24 tons each. The altar stone and the heel stone located outside the monument proper were aligned with the mid-summer sunrise. Many other movements of the sun, the moon, and the wandering stars (the five visible planets) were observable within the monument. It

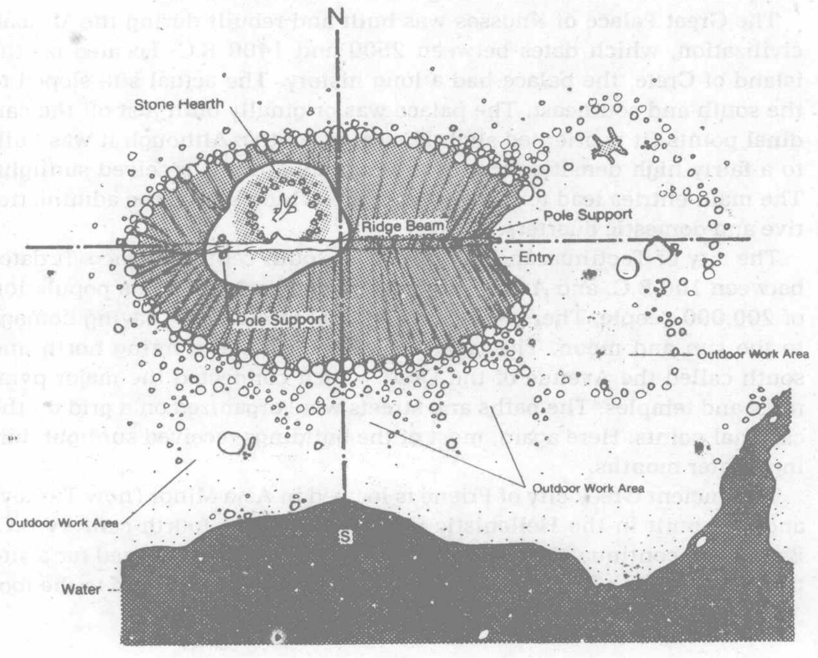


FIGURE 1-1 Paleolithic camp.

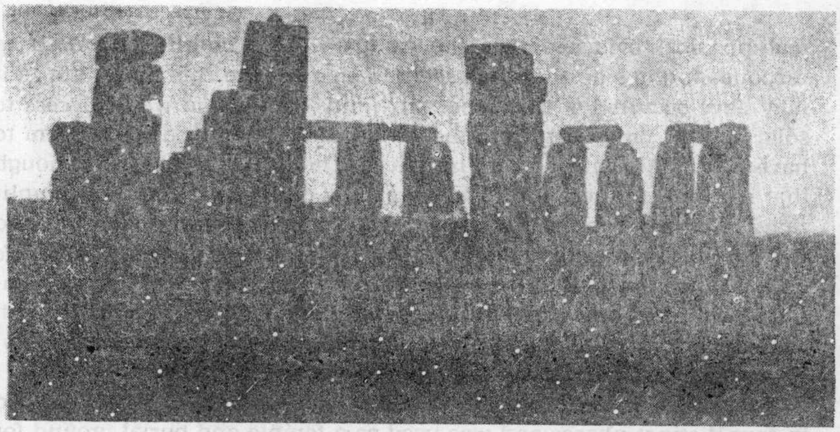

**FIGURE 1-2** Stonehenge, Salisbury Plain. (Photograph by Phillip Tabb.)

is believed that Stonehenge and other similar Neolithic and Bronze Age structures were built by fairly large populations, and mysteries surrounding these efforts still exist. Refer to Figure 1-2.

Although there are numerous examples of early solar planning, several cultures have been selected for examination here. Cities that are clearly organized in relation to the sun include the city of Knossos in Crete; the city of Teotihuacán located in Mexico; the ancient Greek city of Priene located in Asia Minor; cliff dwellings of the Anasazi Indians at Mesa Verde, Colorado; and the Chinese capital city of Ch'ang-an during the Tang dynasty. Each of these cities demonstrates use of solar energy and a profound organization in response to the orientation of the sun. Both city plans and architectural designs reflect this awareness.

The Great Palace of Knossos was built and rebuilt during the Minoan civilization, which dates between 2500 and 1400 B.C. Located on the island of Crete, the palace had a long history. The actual site sloped to the south and southeast. The palace was originally built just off the cardinal points (it is oriented slightly west of south). Although it was built to a fairly high density, most of the individual units received sunlight. The main entries lead to the central court, which served the administrative and domestic quarters.

The city of Teotihuacán was located in south central Mexico. It dates between 100 B.C. and A.D. 700. At its golden period it had a population of 200,000 people. There were architectural monuments paying homage to the sun and moon. The city had a large avenue running north and south called the Avenue of the Dead, which connected the major pyramids and temples. The paths and streets were organized on a grid on the cardinal points. Here again, most of the buildings received sunlight during winter months.

The ancient Greek city of Priene is located in Asia Minor (now Turkey) and was built in the Hellenistic period around the fourth century B.C. Because of continual flooding, the original city was abandoned for a site that was located on higher ground. The 4000 residents moved to the foot of nearby Mycale, a promontory that had varied topography sloping to the south and southeast. Despite the varying topography, the city was laid out on a grid on the cardinal points. The streets were oriented in a similar way to the earlier Olynthian street plans, which put major terraced streets along the east-west axis and minor streets along the north-south axis running up the mountain. This arrangement allowed nearly all of the buildings to have good solar access. Figure 1-3 illustrates the city plan.

The Anasazi culture rose, flourished, and then vanished over a period of approximately 1300 years. The Anasazi settled in the high desert region of southwestern Colorado around the time of Christ. Eventually they migrated south and east. It is speculated that they were either

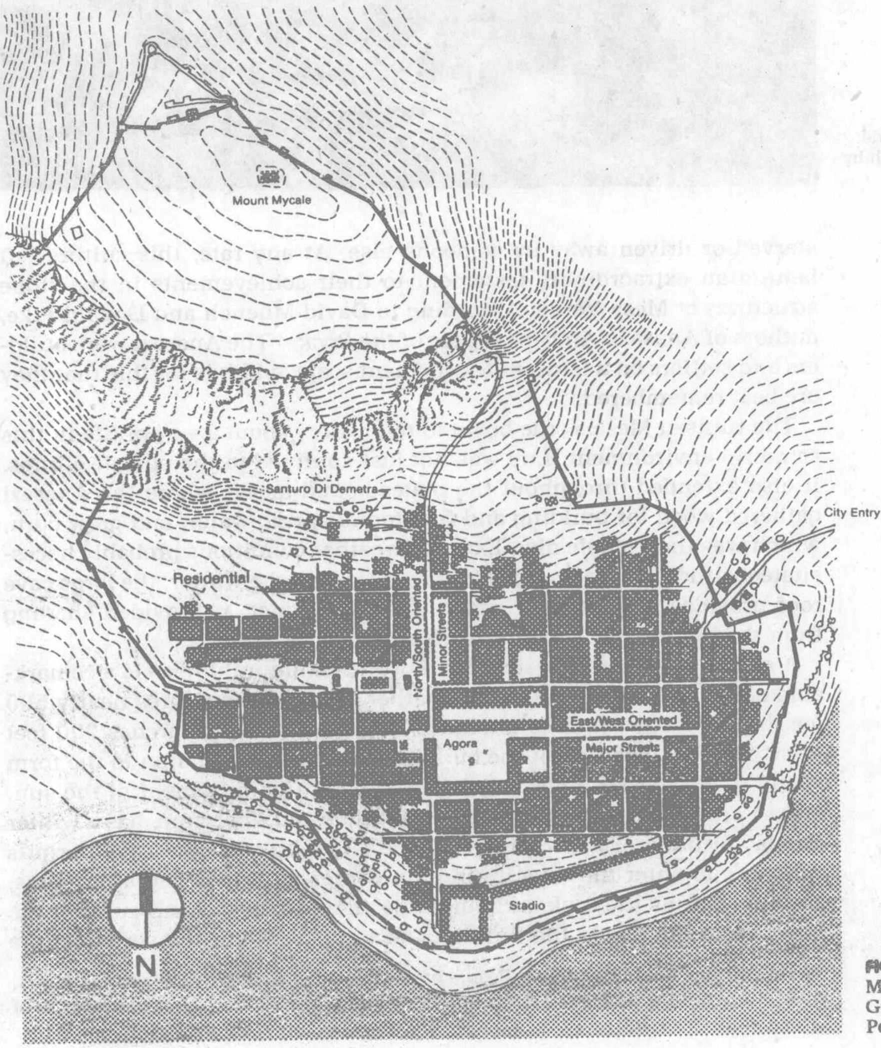


**FIGURE 1-3** Pianura Del Meandro, City of Priene, Greece. (From Butti and Perlin.[8])

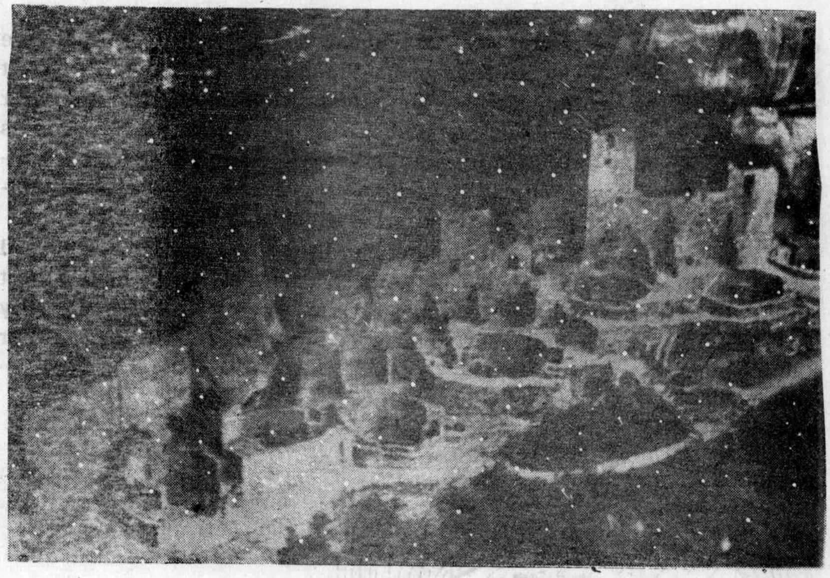

**FIGURE 1-4** Mesa Verde, Colorado. (Photograph by Jane Harris.)

starved or driven away by someone else. At any rate, this culture left behind an extraordinary testament to their achievements in the stone structures at Mesa Verde. According to David Muench and Donald Pike, authors of *Anasazi: Ancient People of the Rock,* "The Anasazi were builders and settlers on a large and permanent scale, and it is for this that they are best remembered."*

The ruins at Mesa Verde begin to tell a story about a way of life in this semiarid environment. Life was not just confined to the cliff dwellings. It also extended throughout the plateaus and mesas where the Anasazi gathered wood for building and fire, found spring water, and grew corn, which was their staple diet. Extreme weather conditions probably necessitated withdrawal to the cave for protection. In the winter, the large cave roof provided shelter from snow, and in summer, it provided shading from the hot midday and afternoon sun.

A close look at the physical form of the community reveals a remarkable ability to mitigate extreme weather. The cave measures nearly 500 feet in the east-west direction and 130 feet deep, and it arches 200 feet high. The juxtaposition of the building structures in relation to the form of the cave suggests a clear understanding of the movement of the sun. Mesa Verde is located near 37° north latitude and, therefore, has a winter midday altitude of approximately 29.6°. The brow of the cave permits sunshine to enter the cave during the winter mornings and afternoons, and this warms the rock and buildings alike. In spring and autumn the brow begins to shade the buildings at midday, when temperatures are

*Taken from *Anasazi: Ancient People of the Rock* by David Muench and Donald G. Pike.[44] Copyright © 1974 by American West Publishing Group. Used by permission of Crown Publishers, Inc.