GEOSC 20

GEOLOGY FIELD TRIPS IN THE APPALACHIAN MOUNTAINS

AN INTRODUCTION TO THE GEOLOGY OF THE NITTANY VALLEY

by

Terry Engelder

The Department of Geosciences
The Pennsylvania State University
University Park, Pennsylvania 16802

August 2006

Table of Contents (2006)

Preface

> "Geology is the study of the planet Earth including the materials of which it is made, the processes that act on these materials, the products formed, and the history of the planet and its life forms since its origin. Geology considers the physical forces that act on the Earth, the chemistry of the constituent materials, and the biology of its past inhabitants as revealed by fossils. Clues on the origin of the planet are sougth in a study of the Moon and other extraterrestrial bodies. The knowledge thus obtained is placed in the service of society — to aid in discovery of minerals and fuels of value in the Earth's crust, to identify geologically stable sites for major structures, and to provide foreknowledge of some of the dangers associated with the mobile forces of a dynamic Earth." AGI Glossary

Geologists can read rocks as if they were a book recording past events. Rather than letters and words, rock characteristics such as shape, color, composition, and grain size preserve a record of chemical, physical, and biological changes that took place in the distant past. The geological record is a language that takes time to learn. As a platform for learning the language of geology, the Nittany Valley is an outstanding classroom and laboratory. Over the entire surface of the Earth, there are very few campuses that rival Penn State for the same rich variety of rock structures found in the immediate vicinity of the campus.

The objective of GEOSC 20 is to promote active learning by taking advantage of the rich opportunities for a geological experience in the field at outcrops less than 15 miles from the Penn State campus. These field exercises call upon several geological techniques used to understand some of the more important principles of geology. Active learning is promoted by presenting the opportunity for a hands on experience that involves gathering data, recording it systematically, and then interpreting the data. These field exercises are designed to sharpen the student's ability to make observations in the real world. By recording observations and collecting data in a field notebook, the student will become more familiar with techniques that geologists use when 'reading' the rock record.

Because many GEOSC 20 students will later write reports based on some sort of data analysis in such disparate fields as business, agriculture, liberal arts, science, or engineering, it is appropriate that the student sharpen his/her writing skills by keeping a field notebook. This notebook shall also be a record of answers to questions about the nature of geological data gathered through the field trips and laboratory exercises. This pedagogic approach does not require the rote memorization of geological facts but rather leads the student to the heart of some important geological observations about the development of the Nittany Valley and, hence, changes in the rock record through time. Ultimately, it is hoped that each student will develop a better appreciation for the scientific method as it is practiced by professional geologists.

Corporate America has come to expect that top-notch universities will encourage collaboration. To further this need, many of the field trip exercises are designed for collaborative data collection and analysis.

Good luck and enjoy!

Terry Engelder, Friday, August 05, 2006

Acknowledgments

Your laboratory manual was initially developed during the Fall of 1994 with the help of graduate teaching assistant and laboratory coordinator, David McConaughy. Since then, many TA's have contributed to the further development of the laboratory exercises. Karen Bice and Mark Gibbs were responsible for obtaining the collection of Ordovician fossils used occasionally in this lab. We thank Ronald Greeley of Arizona State University for supplying photographs of planetary bodies.

This manual was extensively rewritten in response to the recent University Faculty Senate initiative to revamp General Education at Penn State. For this task, funding was provided by the Provost of the University during the summer of 1999.

Field Trip Regulations

☺ Follow the instructions of the laboratory teaching assistant (TA) at all times. When instructed to enter or leave the field trip bus, please do so in a timely manner.

☺ Some stops are along major highways including routes US 322, PA 45, and PA 26. Each stop is designed so that students have no reason to walk on highways or their immediate shoulders. Therefore, students are instructed to stay off these major roads. If students exit from the bus when it is parked on the shoulder of any of these major highways, each student will stay to that side of the bus at all times.

☺ Some stops are along minor county and town roads such as Branch Road, Tussey Mountain Road, and Taylor Hill Road. Students are instructed to remain on the shoulders of these roads. If students must cross these roads, they are instructed to look right and left before doing so.

☺ Some stops involve viewing geological features on private land including the meanders of Slab Cabin Run, a sinkhole in Pine Grove Mills, and Rock Spring. These features may be viewed from the public right of way offered by adjacent roads. Students are instructed not to enter upon the private land unless supervised by their TA.

☺ Some stops involve looking at rock in a steep road cut. Students are advised to approach these faces with caution because of the possibility of falling rock. These outcrops may be approached provided that the student stays away from overhanging rock. Rocks are not to be pulled down from the outcrops.

☺ Samples may be taken only with permission of the laboratory teaching assistant.

☺ During the visit to a cemetery, students are not to disturb the tombstones.

☺ Courtesy towards fellow students is required at all times. This includes refraining from the temptation of throwing objects at or around outcrops.

☺ Failure to comply with any of these eight regulations will result in immediate suspension from the course with the possibility of an F for the course grade.

Before the first field trip, students are instructed to read the field trip regulations and participant agreement. Students are required to sign the participant agreement and then hand it to the TA when boarding the bus for the first field trip.

Please also note that the cost of the eight field trips will incur an additional charge at the end of the semester. In past years this charge has been on the order of $60 depending on the number of students who actually register for the course.

PARTICIPANT AGREEMENT, INDEMNIFICATION, AND ACKNOWLEDMENT OF RISK FOR ADULTS

I acknowledge that my participation in eight field trips in Geosc 20 (Planet Earth) are significant learning experiences for that class. I have read and fully understand the field trip regulations as specified in the Geosc 20 laboratory manual.

Risks inherent in these exercises are injury from falling rocks and passing cars, and personal slips and falls from rock ledges and cliffs or within streams. These activities include known and unanticipated risks, which could result in physical or emotional injury, paralysis, death, or injury to oneself, to property, or to third parties. I understand that such risks simply cannot be eliminated without jeopardizing the essential qualities of the activity.

In consideration of being permitted by The Pennsylvania State University Department of Geosciences, University Park (hereafter, PSU), to participate in its activities and to use its equipment and facilities, I agree to indemnify and hold harmless PSU from any and all claims, demands, or causes of action which are brought by myself, and/or on behalf of myself against PSU and its employees, and which are in any way connected with such use or participation by myself.

I hereby represent that I am in good health, and that I have adequately informed PSU personnel of any special instructions regarding my current health and health care needs. I certify that I have adequate insurance to cover any injury or damage that I may suffer while participating, or else I agree to bear the costs of such injury or damage myself.

I authorize PSU personnel to call for medical care to transport me to a medical facility or hospital if, in the opinion of such personnel, I need medical attention. I further authorize appropriate personnel to render such medical treatment as is necessary for the health of myself, in their professional opinion. I agree that once I am in the care of medical personnel or a medical facility, PSU shall have no further responsibility for me and I agree to pay all costs associated with such medical care and transportation if these costs exceed the benefits provided by my insurance carrier.

Signature:____ Date______________

Print
Name:____

Address:____

Home Phone:_________________________Campus Phone:_______________________

Introduction:

GEOLOGY OF THE NITTANY VALLEY

Background

Pennsylvania is rich in geological history. The oldest rocks in Pennsylvania date back to the Precambrian times about 1.1 billion years ago. Although the youngest rocks of Pennsylvania were deposited about 200 million years ago, most landforms of Pennsylvania date from the latest landslide or flood. The topography of the Appalachian Mountains is less than 10 million years old and glaciers covered the northwestern portion of the state within the past 100,000 years. During the past billion years the state has experienced some of the most interesting geological changes found any place in the world. During the early Paleozoic, carbonate banks, like the Bahama Islands, covered the state. Later in the Paleozoic a large interior seaway like the Black Sea between Russia and Turkey covered much of the state. At the end of the Paleozoic, mountains approaching the height of the Andes were found to the southeast of the state. Much of the state was covered with huge piles of sediment eroded from those tall mountains. At about 250 million years ago, the crust under the southeastern edge of the state cracked to form a rift basin much like the Red Sea separating Egypt and Saudia Arabia.

This rich geological history is recorded in the pattern of geological provinces found within the borders of the state (Figure 0-1). To the

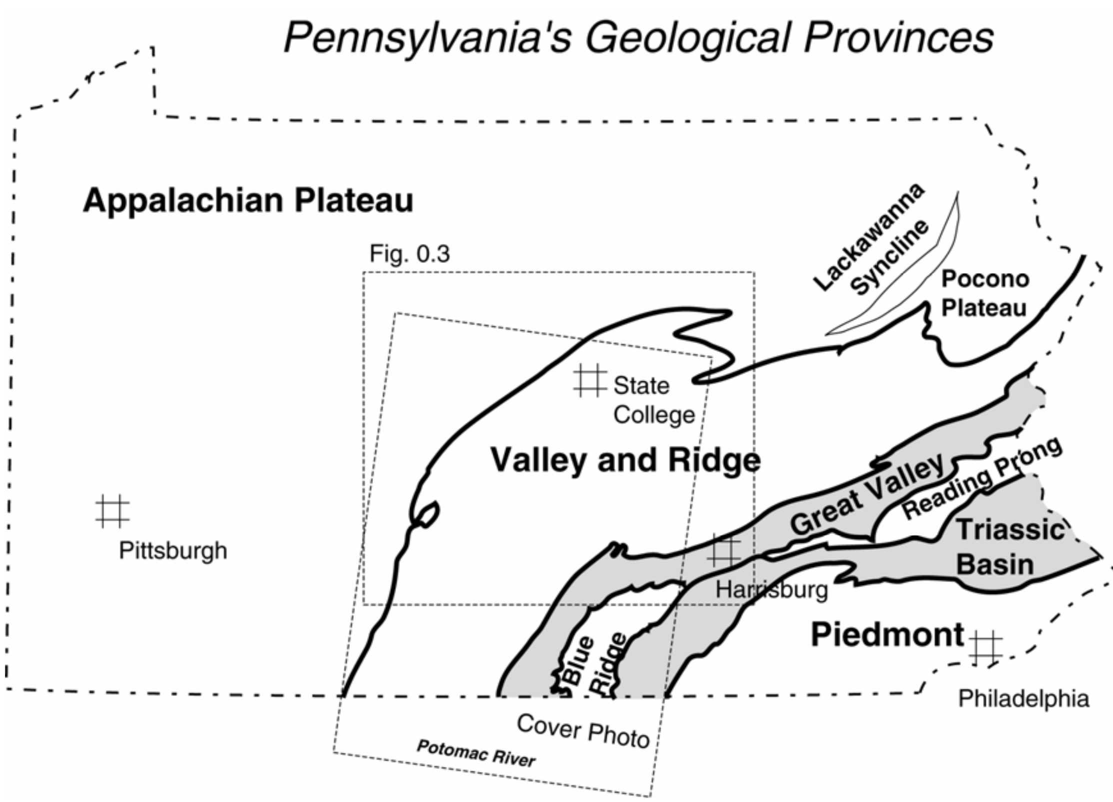


Figure 0-1. Prominent geographic features of Pennsylvania

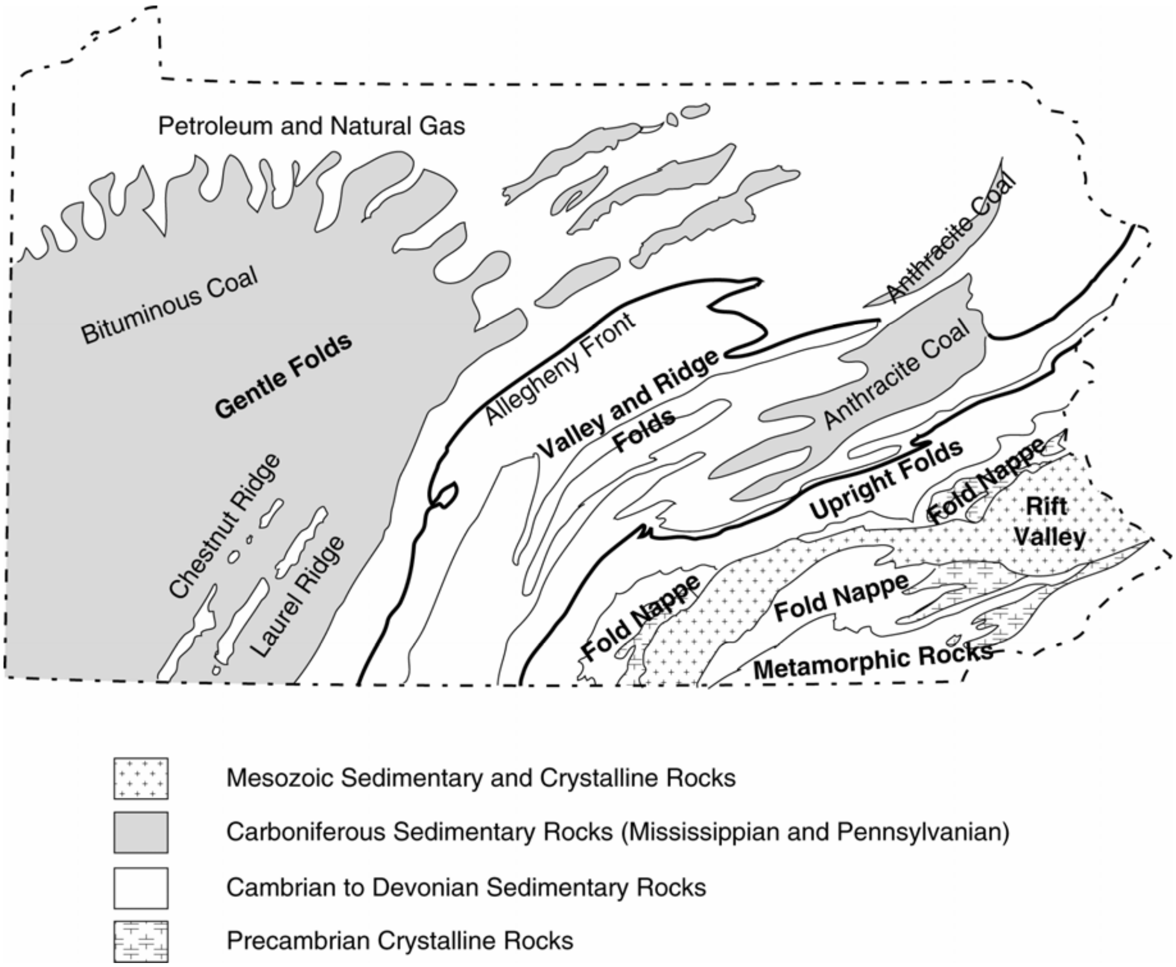


Figure 0-2. The geology of Pennsylvania divided into four major geological units.

northwest is the Appalachian Plateau, a province with gentle folds as a consequence of a distant force from the southeast about 280 million years ago. The Appalachian Valley and Ridge, located in the east-central portion of the state is folded and faulted as consequence of great plate tectonic forces generated during the Alleghanian Orogeny. Much of southeastern Pennsylvania also reflects this gargantuan collision between moving continents known as the Alleghanian Orogeny. These provinces include the Great Valley, the Piedmont, the Blue Ridge, and the Reading Prong. After the orogeny ceased, the continents broke by cracking and rifting. The cracking of continents left a scar in Pennsylvania called the Triassic Basin.

The economy of Pennsylvania, particularly during the industrial revolution, was heavily dependent on the natural resources of the state. A geological map showing the general age of rocks is also a good map on which to indicate the location of some of Pennsylvania's most important natural resources (Figure 0-2). Bituminous coal was found in the west, whereas anthracite coal was found in the east. Petroleum and natural gas were found throughout the northwestern portion of the state. For a portion of the industrial revolution, Pennsylvania was

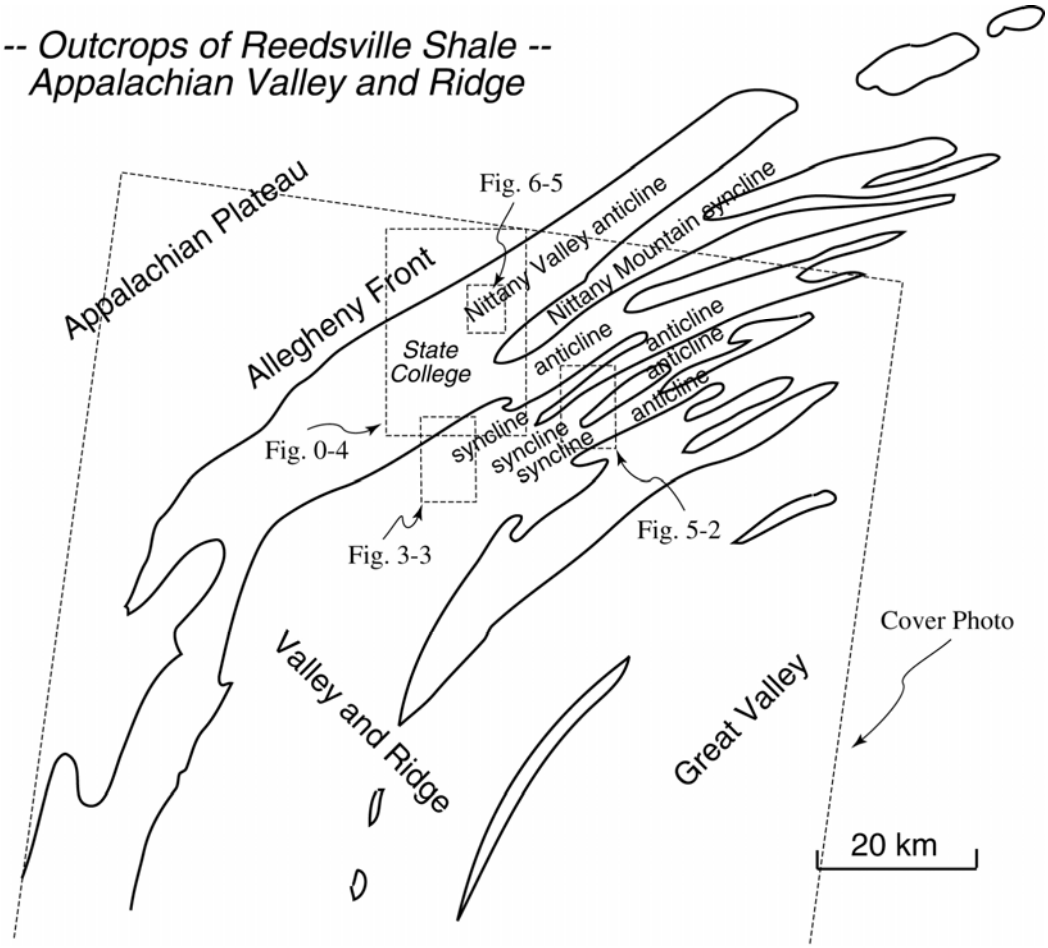


Figure 0-3. The geology of central Pennsylvania showing the outcrop pattern of the Reedsville Shale within theValley and Ridge.

the word's oil capital producing more oil than any other place. Iron came from the Clinton Formation in the Valley and Ridge Province. Limestone for refining the iron ore to produce steel was also found within the Valley and Ridge. All three important components necessary for manufacturing steel were located in the state so it was natural that the steel industry evolved in western Pennsylvania. Limestone valleys of the Piedmont fold nappes proved to be the base for very rich soils and even to this day some of the world's most productive farms are found in the state.

State College is located within the Valley and Ridge geological province. This is an area of the state that is dominated by a series of folds from which limestone and shale have been eroded so that resistive sandstones of several formations, mainly the Bald Eagle, Tuscarora, Pocono, and Pottsville, stand high as ridges. It is the former two sandstone units that make the ridges in the vicinity of State College. These ridges outline a series of anticlines and synclines. A simple geological map of central Pennsylvania might feature the outcrop pattern of just one formation. For example, Figure 0-3 shows the outcrop pattern of the Reedsville Formation, an Ordovician shale that was deposited as the first Paleozoic mountains were forming off the east coast of what was then largely a carbonate bank. The geological map of the Reedsville shows a series of anticlines and synclines, particularly to the southeast of State College. The Nittany Mountain syncline is seen to the east of State College and the campus of Penn State (Figure 0-3).

The Pennsylvania State University is located in a large valley, the Nittany Valley, which is flanked to the northwest by Bald Eagle Ridge and to the southeast by Tussey Ridge (Figure 0-4). To the east of the campus, the Nittany Valley is divided by Nittany Mountain, a prominent ridge marching up the valley toward the northeast. The campus is located near the northwestern edge of the Valley and Ridge Province of the Appalachian Mountains. Further to the northwest is the Appalachian Plateau, a prominent highland with elevations equivalent to the ridges flanking the Nittany Valley. Both bounding ridges, Nittany Mountain, and the Appalachian Plateau are composed of a resistive sandstone in the vicinity of the gray shading in Figure 0-4. The gray shading is the outcrop pattern of the Reedsville shale. The Nittany Valley is floored with carbonate rocks, particularly limestone which makes rich farmland. Nittany Mountain ends abruptly just east of the Penn State campus where Nittany Valley opens to its full extent between Tussey Ridge and Bald Eagle Ridge. Geographically, Nittany Mountain separates Penns Valley to the south and Nittany Valley to the north. Both Nittany Valley and Penns Valley are part of the same major structure called the Nittany Anticlinorium.

A geological map of the Nittany Valley shows various rock formations in linear patterns striking from southwest to northeast (Figure 0-5). You can see the outline of the Reedsville shale as shown in Figure 0-4. Such a map shows the distribution of each rock formation beneath the earth's soil. Such a geological map is drawn based on the distribution of outcrops of bare bedrock breaking through the soil to the earth's surface. On the geological map and in Table 0-1 each formation is identified by a upper case letters (the geological period) and lower case letters (the first letter of the formation name. For example, O_r is the Ordovician Reedsville Formation. Most formations in the Valley and Ridge are restricted to a very narrow band indicating that the rock is steeply dipping rather than flat-lying. Only northwest of Bald Eagle Valley (see Figure 0-4) are rocks nearly flat lying and that constitutes part of the Appalachian Plateau. The formations such as the Axemann Limestone (O_a) make some interesting curves on the map, and most of these denote large scale folds. Note that the trace of the Bald Eagle Formation around Nittany Mountain indicates that Nittany Mountain is some sort of a fold. In fact, the map pattern in the Nittany Valley to the southwest of Nittany Mountain indicates that the fold of Nittany Mountain extends further to the southwest even though Nittany Mountain ends abruptly east of State College. In fact, the Penn State campus is located on the northwest limb of the same fold that constitutes Nittany Mountain (Figure 0-5). The formations appear on opposite sides of the Nittany Valley suggesting that the valley itself is an even larger fold. The origin of these folds is discussed briefly below.

Rocks of the Nittany Valley and its flanks vary in age from Cambrian through Silurian.

These are exclusively sedimentary rocks deposited layer by layer in a number of

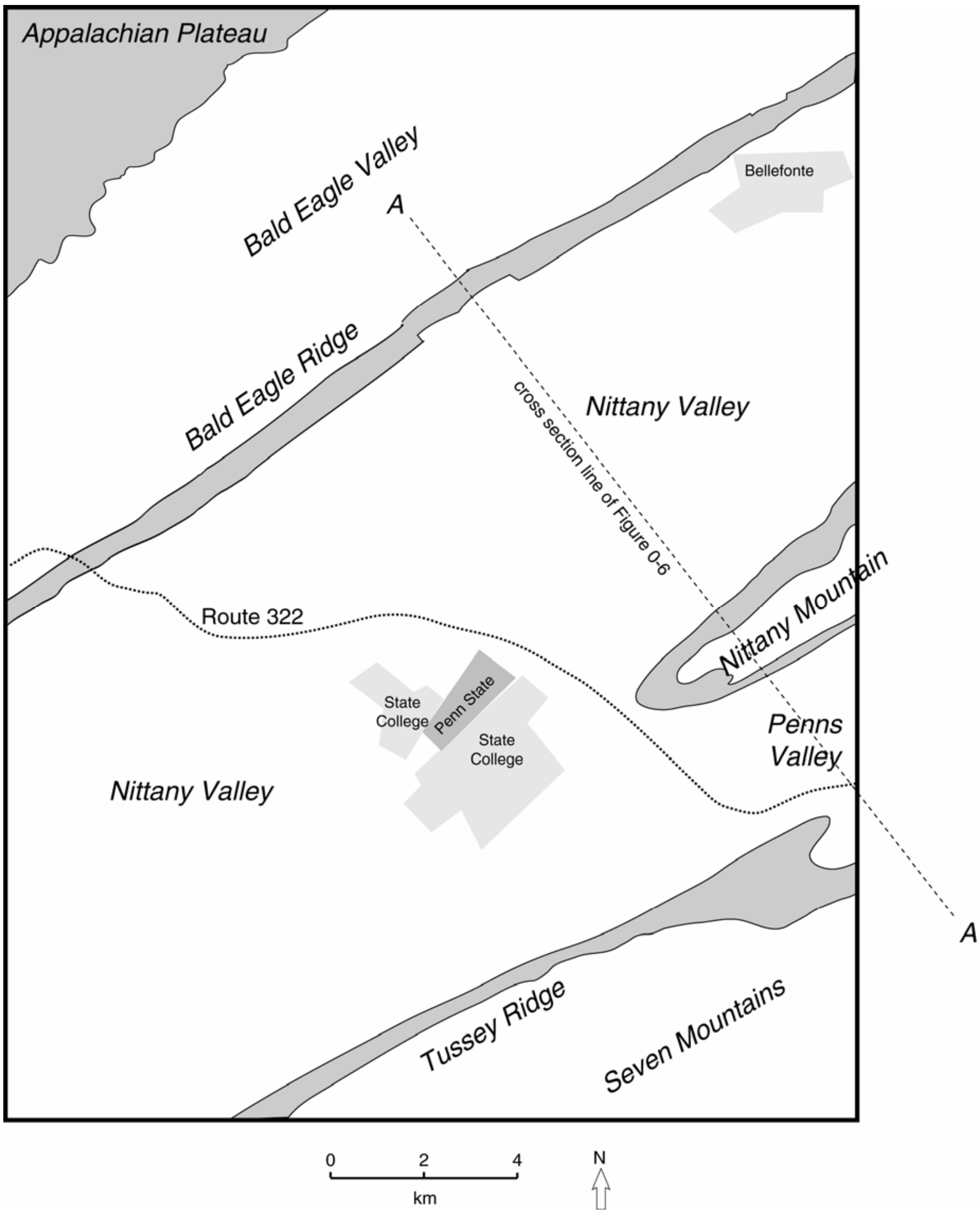


Figure 0-4. The stippled outcrops of Tussey Ridge, Nittany Mountain, and Bald Eagle Ridge consist of Reedsville shale. The stippled ooutcops of the Appalachian plateau are Mississippian sandstones. The trace of the cross section given in Figure 0-6 is shown as A-A'

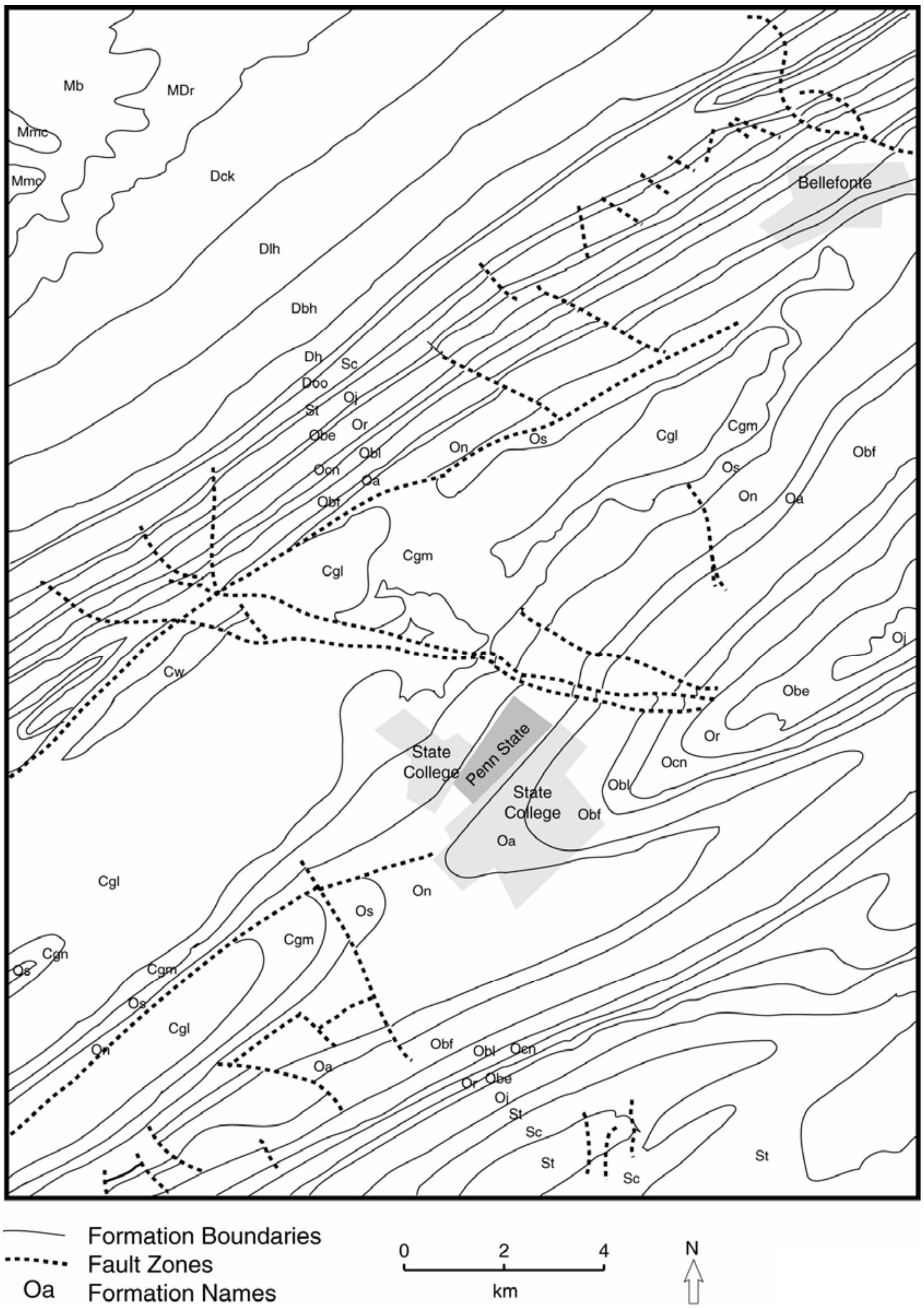


Figure 0-5. O_r is the geological symbol for Ordovician Reedsville Shale. See Table 0-1 for an explanation of the other geological symbols. Compare the outcrop pattern of the Reedsville shale in this map and that of Figure 0-4.

Table 0-1
Stratigraphic column for the Nittany Valley and Appalachian Plateau
oldest (bottom) to youngest (top)

Formation Name	Lithology	Formation Symbol*
Mauch Chuck	fluvial sandstone	M_{mc}
Burgoon	sandstone	M_b
Rockwell	sandstone	MD_r
Catskill	fluvial sandstone	Dc_k
Lock Haven	marine sandstone	D_{lh}
Brallier and Harrell	marine shale	D_{bh}
Hamilton	limestone	D_h
Onondaga and Old Port	limestone	D_{oo}
Clinton and Keyser	sandstone/limestone	S_c
Tuscarora	beach sandstone	S_t
Juniata	fluvial shale	O_j
Bald Eagle	sandstone	O_{be}
Reedsville	marine shale	O_r
Coburn, Salona	limestone with shale layers	O_{cn}
Nealmont, Linden Hall,		
Snyder, Loysburg	limestone without shale	O_{bl}
Bellefonte	dolomite	O_{bf}
Axemann	limestone	O_a
Nittany	dolomite	O_n
Stonehenge	limestone	O_s
Gatesburg - Mines Member	sandy dolomite	C_{gm}
Gatesburg - lower members	dolomite	C_{gl}
Warrior	limestone	C_w

* - Formation symbol includes the geologic period in Capital letters and the first letter of the formation name in lower case. Periods and Symbols:

Mississippian - M
Devonian - D
Silurian - S
Ordovician - O
Cambrian -C

environments. More than two dozen layers were recognized and given names as listed in a stratigraphic column, younger on older (Table 0-1). The oldest layers of rock are carbonates, limestones, and dolomites, deposited in shallow marine seas at or near equatorial latitudes about 500 million years ago. Deposition of formations such as the Bellefonte Dolomite (O_{bf}) occurred in environments equivalent to the modern Bahama lagoons, east of Miami. More than ten separate formations of carbonate rocks were recognized by geologists. This period of tropical lagoons lasted more than 50 million years after which clay muds started being carried to the region from mountains emerging to the east. The Coburn Limestone (O_{cn}) is an example of such mud bearing carbonates. Then a thick shale, the Reedsville Shale (O_r), was deposited over the entire carbonate bank. The source of sediment for this shale and later sandstones was the tall mountains of the Taconic Highlands to the east. These mountains have since eroded. Marine storms carried sandstones to the deep sea (Bald Eagle Formation, O_{be}). River muds (Juniata Formation, O_j) are found followed by clean beach sands of pure quartz without any carbonate shell fragments (Tuscarora Formation, St). Younger rocks are found to the southwest in the direction of Huntingdon and Mount Union and also to the northwest of the Nittany Valley on the Appalachian Plateau in the direction of Clearfield.

Rocks of the Nittany Valley are displayed in an obelisk, found on campus just south of the Willard Building. During the semester the GEOSC 20 class will visit the obelisk to hear a lecture about the obelisk and its connection with the tectonic history of North America. The rocks of the Nittany Valley (and the obelisk) are tied closely to the tectonic history of North America as explained in Appendix I, "The Obelisk: Revisited".

The origin of the large folds in the Nittany Valley is interesting. Nittany Valley is located on the northwestern side of the famous Valley and Ridge Province of Pennsylvania. The Valley and Ridge extends from Harrisburg in the south to its northern boundary, Bald Eagle Ridge. Further north the highlands of the Appalachian Plateau are found. The Valley and Ridge consists of a series of folds which developed during a period of tectonic deformation about 280 million years ago. This period of deformation, called the *Alleghanian Orogeny*, was one consequence of the collision between two large continental masses called Gondwana and Laurentia (see Figures 2, 3 & 4 in Appendix I, "The Obelisk: Revisited"). The present continental plates that show the effects of the Alleghanian Orogeny are Africa and North America, where the present mountains of northwestern Africa are a mirror image of the Appalachian Mountains on the eastern edge of North America. A simple model for folding of the Valley and Ridge might be that of a rug pushed on a slippery wooden floor. The 'rug' was huge, as much as 6 to 10 km thick and almost 400 km wide including the Appalachian Plateau. There are downfolds or synclines and upfolds or anticlines, side by side. The Z-shaped map pattern of the Axemann Limestone on Figure 0-5 is that of an anticline-syncline pair (Color the outcrop band of Axemann Limestone to help you see the Z-shaped pattern). Some folds are larger than others with the largest folds

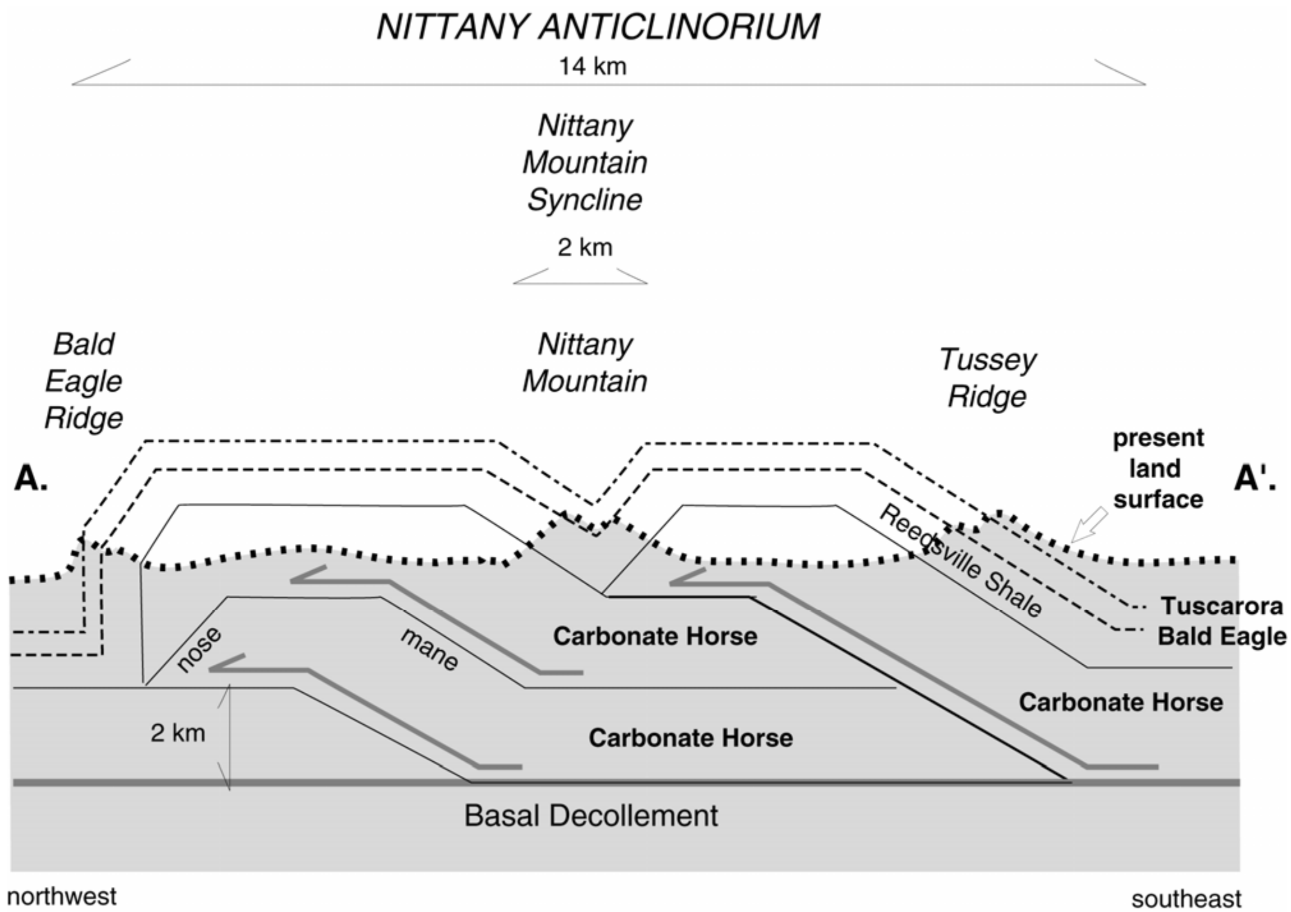


Figure. 0-6. A northwest (left) to southeast (right) cross section through Nittany Mountain and Nittany Valley in the vicinity of the Penn State campus. See Figure 0-4 for the line of the cross section.

being 10 km across and smallest being no larger than a piece of note paper.

The Alleghanian Orogeny and the push causing the Valley and Ridge came from the southeast, even southeast of Harrisburg. Rocks in that area are more highly deformed and formed a mountain range much like the modern Himalayan Mountains of Asia. As explained in Appendix I, the Alleghanian Orogeny is a manifestation of Africa colliding with North America.

Deformation from the Alleghanian Orogeny dies out gradually to the northwest across the Valley and Ridge where major folding ends abruptly at the Allegheny Front, the boundary between the Valley and Ridge and the Appalachian Plateau. Bald Eagle Valley marks the Allegheny Front. Deformation is found on the Appalachian Plateau but the folding is so mild that limbs of sides of anticlines dip just a couple of degrees. For reasons that are not fully understood, the largest upfolds or anticlines of the Valley and Ridge are found at the northwestern boundary. This rule applies all along the Appalachian Mountains from New York and Pennsylvania to Tennessee and Alabama. The Nittany Valley is the location of one of the largest of all these upfolds. The flanks of the Nittany Valley upfold, called the Nittany Anticlinorium, are the previously mentioned Bald Eagle and Tussey Ridges. This anticlinorium is 10 km across (Figure 0-6).

Smaller folds are superimposed on larger. All this means is that wrinkles can occur on more than one scale and that large wrinkles can carry smaller wrinkles on their surfaces. One of the best examples of superimposed folding is found at Nittany Mountain. Nittany Mountain is a second-order syncline (size = 1 km) called the Nittany Mountain Syncline. It is superimposed on a first-order anticline (size = 10 km), the Nittany Anticlinorium. This superposition is illustrated in Figure 0-6 where the sandstones of the Bald Eagle and the Tuscarora form a blanket over the several stacked layers of carbonate rocks. These layers of carbonates, stacked like a bent deck of cards, are called *horses*. The name, horse, is a term used by the 19th century English coal mining industry. In a cross sectional profile on can easily recognize the nose and mane of a horse. Each carbonate layer is more than 2 km thick, so that the Nittany Anticlinorium is stacked up as much as 6 km over the sliding base of the Valley and Ridge. The Axemann limestone, seen curving around the nose of Nittany Mountain, is clearly part of the Nittany Mountain syncline. Just to the southeast of Nittany Mountain is an anticline as indicated by the Axemann limestone wrapping around toward the southwest.

Because the Nittany Valley is a large upfold, it would seem natural that it should be a mountain rather than a valley. Erosion and weathering have a role in controlling the shape of the valley. The edges of the valley are sandstone ridges which weather slowly whereas the center of the valley consists of carbonates which weather more rapidly. The highest parts of an upfold are always weathered fastest. So, the sandstone with the highest elevation weathered through and permitted weathering the attack the limestones below. Once the carbonates are exposed they weather so rapidly that the topography is inverted, which is to say that the structural highs (anticlines) become the topographic lows (synclines). As the Nittany Valley erodes the lowest and last remnants of large upfold of sandstones is found as part of a second-order down fold (i.e., syncline), the Nittany Mountain syncline. The Bald Eagle sandstones (O_{be}) have yet to be eroded and are, in fact, responsible for the ridge which constitutes Nittany Mountain.

Cover photograph

The cover photograph is an infrared image of the Appalachian Mountains of Pennsylvania taken by Landsat, a satellite designed for photographing the surface of the Earth. The satellite carries a multispectral scanner (MSS) which records images at different wavelength bands including shorter wavelength ultraviolet or UV (< 0.4 μm), visible light (0.4 to 0.7 μm) and longer wave length infrared or IR, reflected (0.7 to 3 μm) and thermal (3 to 14 μm). Images from the Landsat are often called false color images and these require that the geologist understand what the various colors represent. Table 0-2 gives an indication of how to interpret the colors within the Landsat image of the Appalachians.

Table 0-2

Feature	Color
Healthy vegetation	Red, Orange
Clear Water	Very dark blue to black
Silty water	Light blue
Red Rock	Yellow
Bare soil, fallow fields	Light blue to green
Windblown sand	White to yellow
Clouds and snow	White
Shadows	Black
Cities and Towns	Deep blue

The cover photograph covers approximately the same area as Figure 0-3 but is narrower and extends down into Maryland so that that the Potomac River is seen in the bottom center of the photo. The Appalachian Plateau with a combination of forests (red-orange) and a few fields (light blue) is located in the upper left. The Valley and Ridge consists of valleys with crops (pink) and bear soil (light blue) and ridges covered with vegetation (orange) and shadows (black). The Great Valley is a patchwork of bear soil (light blue) and crops (pink). The Blue Ridge of South Mountain is covered with forests (red to orange) to the south east of the Great Valley and the Triassic Basin is the southeastern most feature in the photograph. Cities (deep blue) include Altoona, State College, Lewistown, Carlisle, Chambersburg, and Hagerstown, MD. The prominent river (black) in flowing through the central portion of the map area is the Juniata and Reystown Lake (black) is seen as a tributary to the Juniata. The west branch of the Susquehanna is seen in the upper left corner flowing across the Appalachian Plateau. Nittany Mountain, Bald Eagle Ridge, and Tussey Ridge are seen at the center top of the cover photo.

FIELD TRIP #1: GEOMORPHOLOGY OF THE NITTANY VALLEY

Purpose: *To introduce the GEOSC 20 student to the landforms of the Nittany Valley.*
To understand the role of lithology (i.e., rock type) and structure (i.e., large anticlines and synclines) in shaping the landforms of Nittany Mountain and the Nittany Valley.
To draw a topographic cross section.

Materials: *One bus.*
Good weather (However, this field trip will take place regardless of the weather).
Rain gear if necessary.
Lab manual with geologic map of the Nittany Valley.
Notebook for recording field observations.

Background:

One of the most attractive aspects of geology as a life's work is the prospect of working outside the office in wide-open spaces. Work of this type is called *field work*. For a geologist field work commonly consists of mapping, observing, or sampling many aspects of rock at the Earth's surface. Much of the Earth's surface, at least in Pennsylvania, is covered with soil or river deposits known as *alluvium*. Very little of the Earth's surface is bare rock, but where it is found the bare rock is called an *outcrop*.

Field work might be necessary if, for example, the petroleum geologist wishes to see examples of structures where oil is stored in rocks. The most common structures for oil storage in rock are *pore spaces*, the microscopic spaces between grains of sand that have not completely filled with cement, *vugs*, the open cavities commonly found in carbonate rocks, and *fractures*, including joints, faults, and other large breaks within the rock. Pores are so small that a microscope is require for observation but faults and joints may be seen cutting through rocks that are exposed in outcrops. To observe such faults and joints, the petroleum geologist might travel to an outcrop of rock near where the company is pumping oil. As we move into the 21st century most of the new oil is found overseas.

Appropriate outcrops may be some distance from the oil field and some distance from a road. Consequently, the geologist might have to hike to reach the spot. In other cases helicopters or boats are used to reach remote outcrops. Sometimes the logistics of field work are as complex as the observations required of the geologist. Some field trips can take weeks or maybe months to plan. Other trips require that the geologist be away from home for long periods. A geologist's spouse might complain about such extended trips.

Because rocks are the geologist's laboratory, the need to see these rocks offers the additional benefit of traveling to exotic places, sometimes out of the country. Combining field work with travel is commonly called a *field trip*. Prof. Engelder has done field work or participated on field trips in England, Italy, Switzerland, France, Spain, Norway, Austria, Russia, Tadzhikistan (former Soviet republic), Pakistan, Australia, China, Mexico, Canada, and Chile as well as many places throughout North America.

Other field trips can also be local and last no longer than a couple of hours. This lab exercise (and seven others) will involve a field trip of such a duration. The student will not have to plan the logistics of the trip but he/she is required to take note of the points made by the lab instructor during the trip and complete the exercises accompanying each field trip. Each field trip will involve several stops within the Nittany Valley and the adjacent ridges. Some stops will require that the student leave the bus for a short hike whereas the student will remain in the bus at other stops.

Geomorphology:

Geomorphology is the science that deals with the surface features of the land (i.e., landforms): their relief, form, and character. Geomorphology also deals with the relationship between the landforms and the underlying structures. The purpose of this first trip for GEOSC 20 is to introduce the student to the most prominent landforms of the Nittany Valley. The two major landforms are the ridges adjacent to Nittany Valley and the valley itself. Because the view from the Penn State campus is from the valley toward surrounding ridges, students might identify the ridges as major landforms while loosing track of the valleys. Both are equal partners in the geological history of central Pennsylvania.

For a post-trip exercise, the student will construct topographic cross sections through Nittany Mountain and through Tussey Ridge. These topographic profiles give some indication of the shape (i.e., relief) of the ridges flanking the Nittany Valley. The field trip will give some indication of the underlying structure that controls the geomorphology of the Nittany Valley. It is the underlying structure coupled with the stratigraphy that gives the ridges their unique shape.

The Nittany Valley consists of layer upon layer of rock that was folded during a tectonic disturbance called the Alleghanian Orogeny (please read the Introduction to this lab manual for a detailed explanation). An *orogeny* is an event in which layered rocks were deformed by faulting and folding as a consequence of plate tectonic deformation. Trip 1# will examine the effect of erosion into rocks that were faulted and folded during the Alleghanian Orogeny. In addition, the trip will allow the student to develop a preliminary understand of the complex interplay between erosion and the sedimentary layering of the Nittany Valley.

The field trip:

The field trip will traverse the Nittany Valley which is flanked on the south side by Tussey Ridge and on the north side by Bald

Eagle Ridge. Nittany Mountain is a ridge that extends to the northeast from State College in the middle of the Nittany Valley. During the trip the student should refer to the simplified geological map of Figure 1-1 which shows the location of stops within the Nittany Valley for field trip #1. The student will also wish to locate each stop on the Landsat image on the cover of this manual.

A geological map shows the areal distribution of the rock that would be found by digging downward through the soil to bedrock. Figure 1-1 is a very simple geological map showing just one rock unit in the Nittany Valley, the Reedsville Formation. Where the map is white (i.e., blank) other bedrock would be encountered when drilling through the soil. The outcrop pattern of the Reedsville Formation in Figure 1-1 outlines the Bald Eagle Ridge (just to its northwest), Nittany Mountain, and Tussey Ridge (just to its southeast).

Note that the trend of the outcrop pattern for the Reedsville Formation is roughly ENE-WSW. If you locate State College, Nittany Mountain, and the two flanking ridges in the Landsat image of the cover photograph, you will conclude that the trend of the ridges is consistent with the trend of the Reedsville in Figure 1-1.

<u>Stop 1</u>: *The double ridges of Tussey Ridge.* (Nixon Road between Route 26 and Whitehall Road)

Tussey Ridge is the south flank of the Nittany Anticlinorium, a large upfold formed during the Alleghanian Orogeny. On the south flank of an anticline, rocks are dipping (i.e., the bedding surfaces are tilted) to the south. The view from stop 1 is looking to the southsouthwest which means that the rocks of Tussey Ridge are dipping away from stop 1. The ridge is composed of four thick layers called rock *formations*. A formation is a local rock unit possessing some degree of internal lithological homogeneity. From oldest to youngest formation, these are the Reedsville Formation, a shale (Or), the Bald Eagle Formation, a sandstone (Obe), the Juniata Formation, a shale (Oj), and the Tuscarora Formation, a sandstone (St) (See the geological map shown as Figure 0-5 and Table 0-1 listing geological formations) .

Looking to the south, it immediately becomes apparent that Tussey Ridge consists of two ridge lines with the closer ridge line somewhat lower then the farther ridge line. Valleys are formed because limestones and shales weather faster in the humid mid-latitude forests than sandstone. Hence, in Pennsylvania, when a ridge such as Tussey consists of two subridges, the geologist is alerted to the presence of two sandstone formations. The front, lower ridge consists of the Bald Eagle Sandstone whereas the back, higher ridge consists of Tuscarora Sandstone. The Bald Eagle is a marine sandstone with grains such as feldspar which weathered more easily than quartz. The Tuscarora is a beach sandstone composed exclusively of quartz grains, a very resistive mineral. Hence, the slight difference in height between the two sub-ridges is a consequence of the difference in rate of weathering, with the Bald Eagle slightly weathering faster.

The Juniata Shale separates two sandstones and erodes to form a small valley between the sandstone ridges. The shale valley would consist of a long lake if it did not drain by cutting through a sandstone ridges. As might be predicted, the drainage streams were better able to cut down through the Bald Eagle

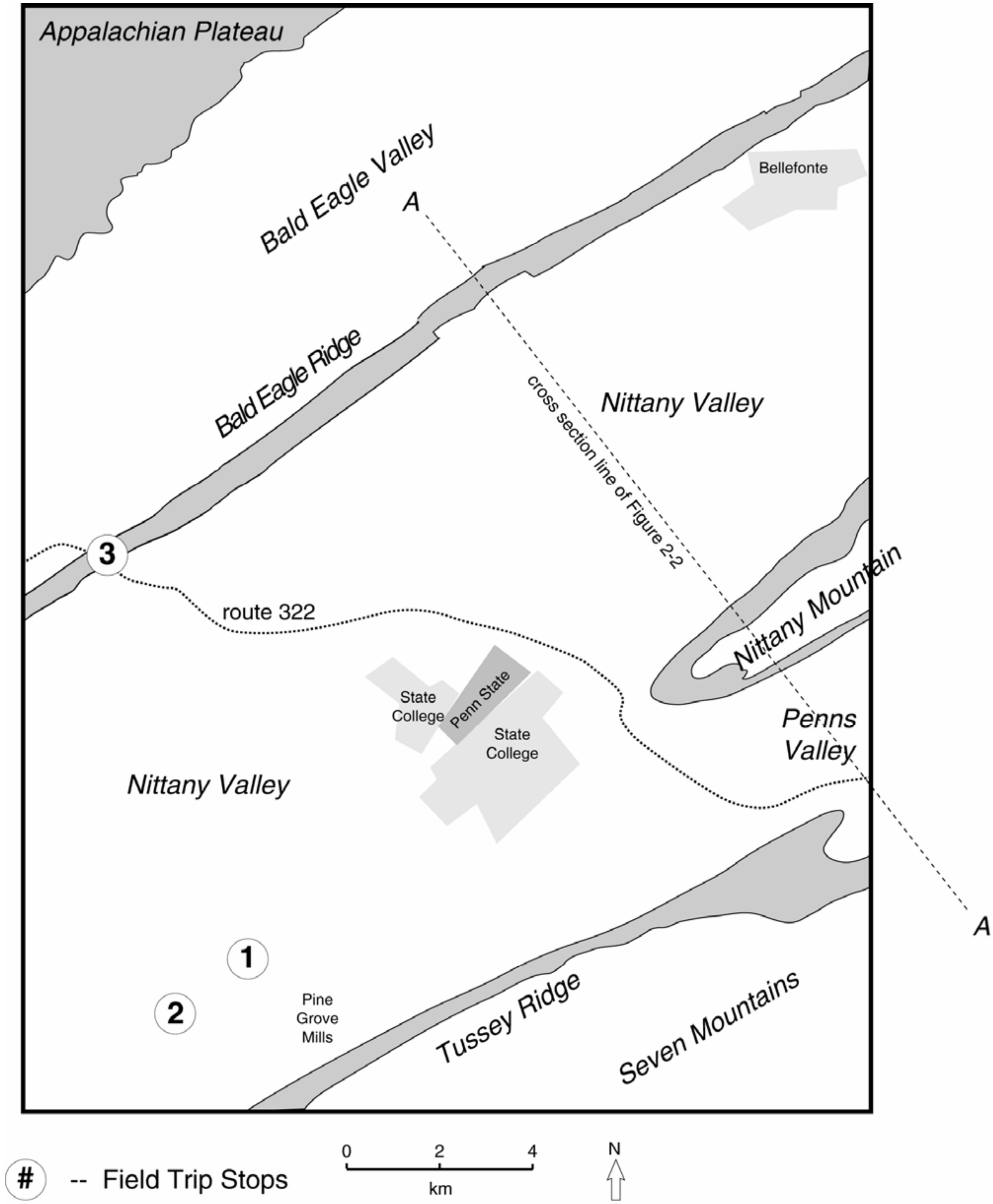


Figure 1-1. Location of Tussey Ridge, Nittany Mountain, and Bald Eagle Ridge. The stippled outcrops marking topographic features actually mark the Reedsville Formation, a shale found immediately below the sandstone ridges. The stippled outcrops marking the Appalachian Plateau in the northwest corner of the map are Mississippian Sandstones.

than the Tuscarora. Hence, the back, Tuscarora subridge is continuous and without stream valleys, whereas the Bald Eagle subridge is cut at very regular intervals by stream channels (called *water gaps*). The steep slope in front of the Bald Eagle Ridge is formed by the Reedsville Shale which weathers back very rapidly under the Bald Eagle. The Bald Eagle makes a 'roof' protecting the shale directly below it.

The water gap immediately in front is the gap above Pine Grove Mills where the head waters of Slab Cabin Creek are found. To the left is Musser Gap and to the right is Erb Gap. Further to the far right is Schalls Gap. Water from both Erb and Schalls Gap flows into sinkholes (field trip #4). The large water gap off to the far left (southeast) is the Shingletown Gap (a popular hiking and mountain biking area) from which flows a stream which was State College's major water supply for many years. Recently that surface water supply was closed because of bacteria from wild animals. However, water from this gap filters into the ground where it is pumped out by large wells for consumption in State College and at the University. It is possible that the shower that you took last night was water flowing out of Shingletown Gap less than a week ago.

<u>Exercise 1</u>: If the elevation of Tussey Ridge is 300 meters above the Nittany Valley, determine the distance between two water gaps along the Bald Eagle sandstone of Tussey Ridge. Hint: Fix a scale by sighting along your arm using a pencil or pen as the scale.

<u>Exercise 2</u>: Is the elevation of the back ridge of Tuscarora Formation constant? Does front ridge of Bald Eagle Formation always have a consistent elevation? Can you guess why not! Hint: This will be come apparent then viewing the profile of Nittany Mountain at stop 2#.

<u>Stop 2</u>: *Panorama of Nittany Mountain*. (Plainfield Road between Route 26 and Whitehall Road)

Looking to the east, it is apparent that Nittany Mountain is also a pair of subridges separated by a small depression. Unlike Tussey Ridge, only two rock formations are seen in the nose of Nittany Mountain, the older Reedsville Shale and the younger Bald Eagle Sandstone. The Bald Eagle Formation is responsible for the subridge on both flanks of the ridge called Nittany Mountain. The Bald Eagle Sandstone is down folded into the core of the ridge which means that in a view looking to the east, rocks on the southern flank dip to the north whereas rocks on the northern flank dip to the south (Figure 1-2). Such a down fold constitutes a syncline called the Mount Nittany Syncline. The valley between each flank is a manifestation of the Juniata Shale being eroded more rapidly than the Bald Eagle. The Tuscarora, which was once above the Juniata, has long since been eroded away at the nose of Nittany Mountain because the structure constituting the Nittany Mountain Syncline was much higher than surrounding ridges. The higher portions of the Tuscarora sandstone were eroded during a phase that predates the most recent uplift about 10 million years ago. This earlier phase of erosion lead to a flat erosional surface which is defined by the elevation of the present ridges and the Appalachian Plateau (Field trip #6).

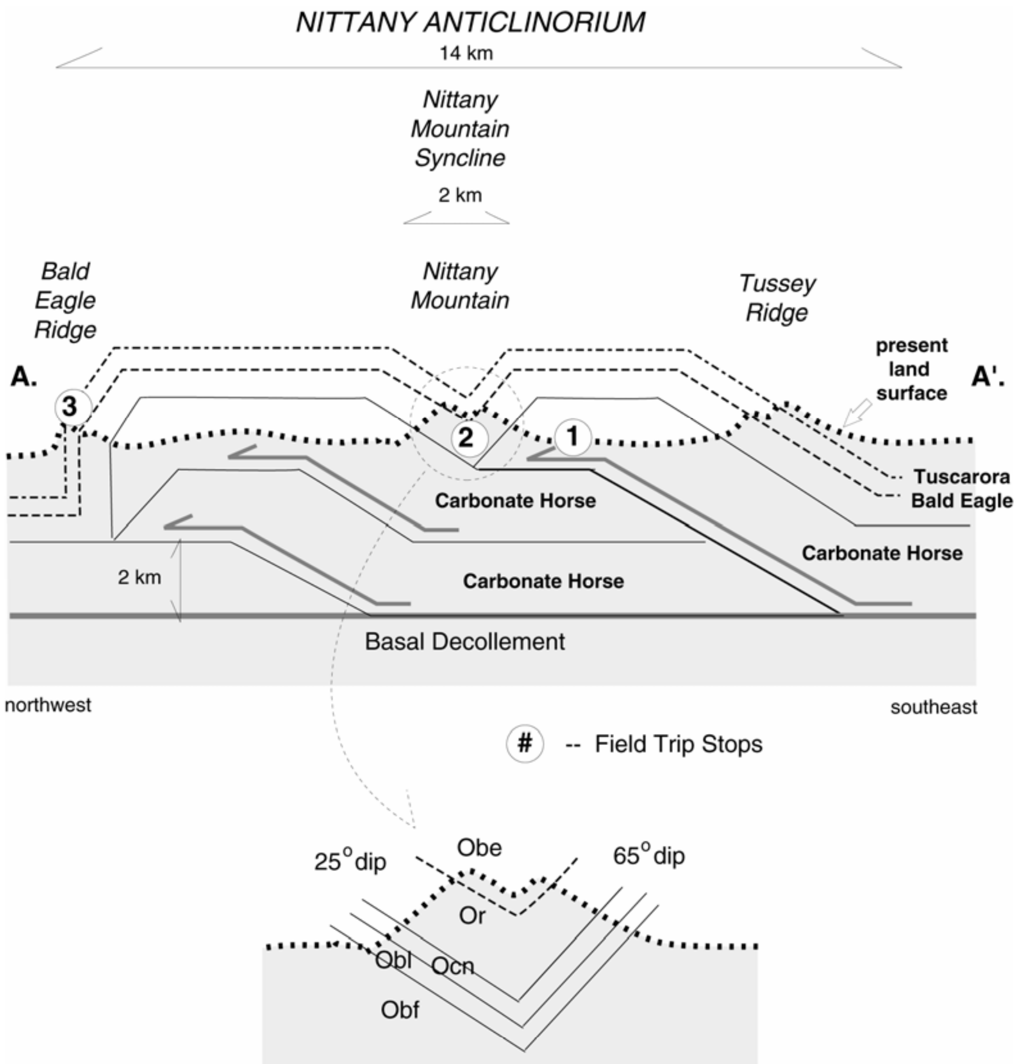


Figure 1-2. A profile through the Nittany Valley showing the rock structures that constitute the Nittany Mountain syncline. Note that the Nittany Mountain snycline is a second order fold which means that it is samller in size than the Nittany Anticlinorium which is a first order fold bounded by Bald Eagle and Tussey Ridges.

Note that the south flank of the Mount Nittany syncline is a relatively small knob without as much elevation as the north flank which much bulkier is size. The relative difference in size of the flanks of Nittany Mountain is a consequence of the difference in dip between the flanks. The northern flank of the syncline is south dipping at 25°, the same dip as that found in Bald Eagle of the Tussey Ridge. In contrast, the southern flank of the syncline is north dipping at 65°. Another rule of erosion is that rocks at a steeper dip (65°) erode faster than rocks at a shallower dip (25°). Hence, the south flank is a rather modest knob compared with the northern flank. This is the same explanation given for the relative differences in the present heights of Tussey Ridge (300 meters) and Bald Eagle Ridge (250 meters).

The shape of the Mount Nittany syncline is a consequence of its position relative to two carbonate thrust sheets called horses (see Figure 1-2). The sheets are thrust under the Reedsville shale so that the Bald Eagle Formation drapes over the folded carbonate sheets (i.e., horses) like a blanket. This geometry develops because there is a roof thrust which allows the Reedsville shale to detach from the carbonate sheets below the Reedsville shale.

Exercise 3: Draw a profile through Nittany Mountain. In the post-trip exercise you will use this profile to compare it with a profile drawn from a topographic map.

Stop 3: *Panorama of the Allegheny Front as viewed from Bald Eagle Ridge*
(Route 322 at Skytop)

The Allegheny Front is a major physiographic break in the Appalachian Mountains (Figure 0-2). To the south is the valley and ridge and to the north is the Appalachian plateau (0-1). The Front divides those rocks that have been folded so that bedding is tilted more than 30° from those rocks to the north that are generally nearly horizontal. The reason for a change in tilting is related to the nature of faulting in the subsurface. In brief, forces causing the tilting originated to the southeast. One can think in terms of the forces gradually dissipating toward the northwest with the gradual decrease in bedding dip as a manifestation of the dissipation.

Bald Eagle Ridge, like Tussey Ridge on the southwest side of the Nittany Valley, stands above the adjacent valleys because of the ability of the Tuscarora Formation to resist weathering. One difference between Tussey Ridge and Bald Eagle is the dip of bedding with beds on end (i.e., dip = 90°) at Skytop. In the vertical position, beds are more easily eroded that along Tussey Ridge where beds generally dip at about 25° to 30°.

Exercise 4: Looking across Bald Eagle Valley, the student can see several rows of knobs. Using Tussey and Bald Eagle Ridges as a model, explain the significance of the rows of knobs. In thinking about this puzzle be aware that the Plateau on the skyline consists of beds with virtually zero dip. Somehow, rocks have to change attitude from a 90° dip at the Allegheny From to 0° dip roughly 15 km to the north. Likewise, rocks of the Bald Eagle Ridge are Silurian in age whereas rocks on the skyline are younger (i.e., Mississippian in age). The rows of knobs in Bald Eagle Valley are rocks located between these extreme dips and they are of intermediate age (i.e., Devonian) between the Silurian and Mississippian.

Post-trip exercise: *Topographic Maps*

A *contour lines* connects imaginary points on a landscape that have the same elevation. *Topographic maps* consist of many contour lines each denoting some multiple of a unit distance above a convenient reference. Often that reference is mean sea level and unit distance is an interval on the order of a few meters. In countries with archaic units of measure, contour intervals may be measured in feet rather than meters. The Pennsylvania State University campus is roughly 1200 feet above mean sea level whereas the ridges surrounding the Nittany Valley are often more than 2000 feet above mean sea level (Guess which country is a real backwater when it comes to units of length, weight, and temperature?). Contour lines on a 1:24,000 U.S. Geological Survey topographic map give a very accurate picture or model for the surface of the land so that distances, directions, areas, elevations, and slope angles can be measured with great confidence. A skilled geologist can extract much information about the rocks of an area using just the shape of the landform as indicated by topographic maps.

Topographic maps are commonly used for determining direction and elevation. All U.S. Geological Survey topographic maps are printed so that true north is to the top of the page. Rarely does a map not have true north to the top of the page. On a 1:24,000 topographic map contour lines are commonly divided into 20-foot intervals called *contour intervals*. The approximate elevation of any point can be interpolated from contour lines provided the location is known, usually by correlation with nearby landmarks. If the location is half way between the 1100-foot contour and the 1120-foot contour, then the interpolated elevation is 1110 feet above sea level. The spacing of topographic lines gives some indication of the local slope of the land. Closely spaced lines mean that the land is rather steep. The relief is the difference in elevation between a high point and a low point. For example, the relief of the Nittany Valley is on the order of 1000 feet (i.e., the height of Nittany Mountain at 2070 feet above Spring Creek at 940 feet).

<u>Contour lines have the following characteristics</u>:

-- Contour lines parallel valley walls. If the valley is on the side of a mountain the contour line will trend up the valley, cross the stream, and extend down the valley on the opposite side. Thus the contour lines form a **V** pattern with the apex of the **V** pointing upstream. Stream valleys on the northwestern side of Tussey Ridge show Vs pointing to the southeast (Figure 1-3). The best example is seem in the upper center of Figure 1-3.

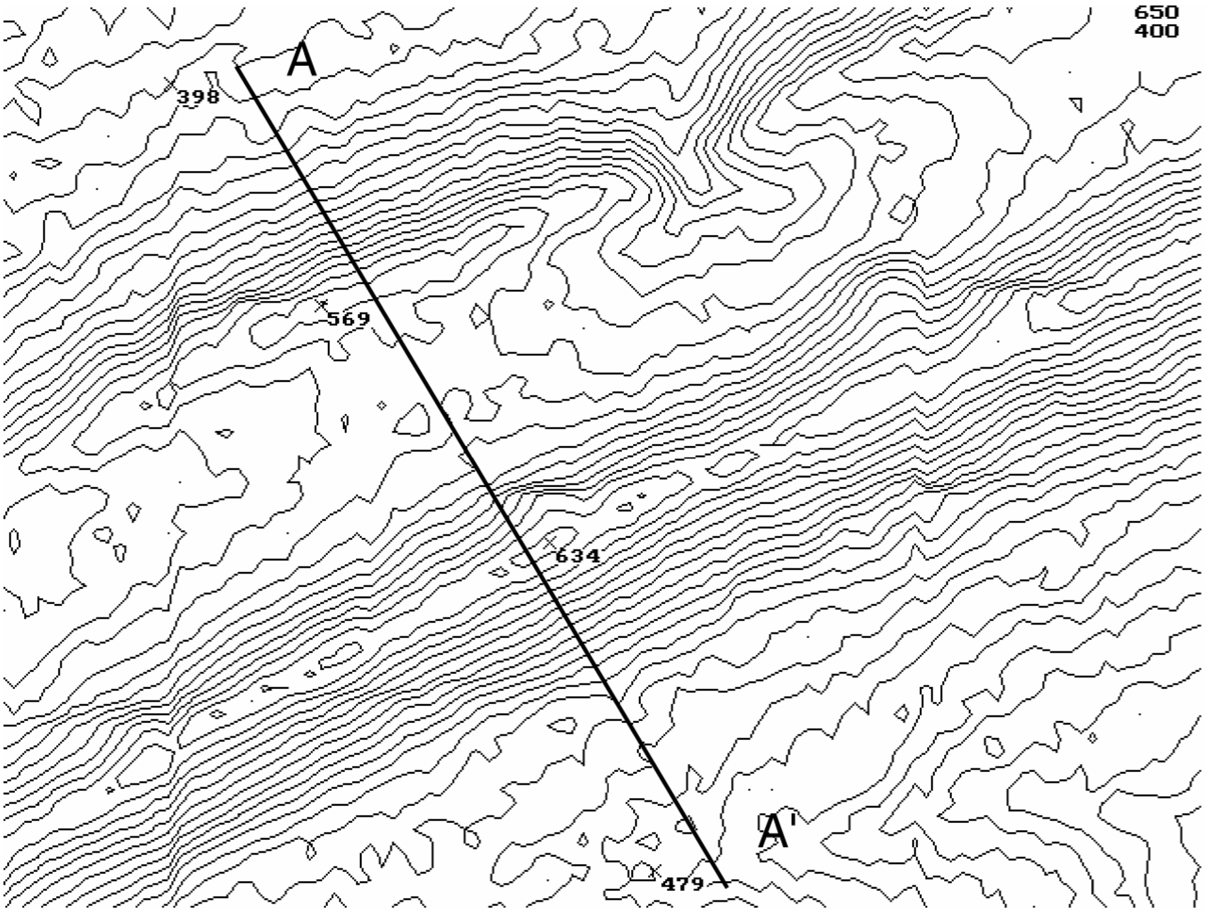
-- Contour lines never cross. Each contour line travels continuously around the nose (southwestern end) of Nittany Mountain (Figure 1-4).

-- Spacing of the contours reflects the gradient or slope of the land. A steep slope is seen in close contour lines. The side of Nittany Mountain shows more closely spaced contour lines than the lines on top of Nittany Mountain.

-- Ridges, hills and knobs are shown as closed contours. For example, contours on top of Nittany Mountain and Tussey Ridge are shown as closed.

-- Closed depressions such as sink holes in the Nittany Valley are shown by closed contours with hachures (short lines) pointing downslope.

Digital Elevation Maps The topographic maps that appear in this lab manual were constructed from digital elevation data (Figures



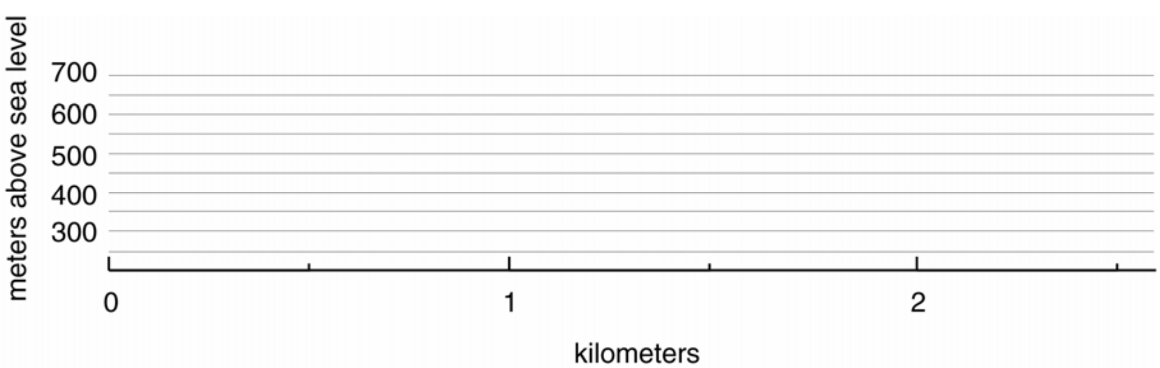


Figure 1-3. Digital contour map through Tussey Ridge southwest of State College. Contours are on ten meter intervals.

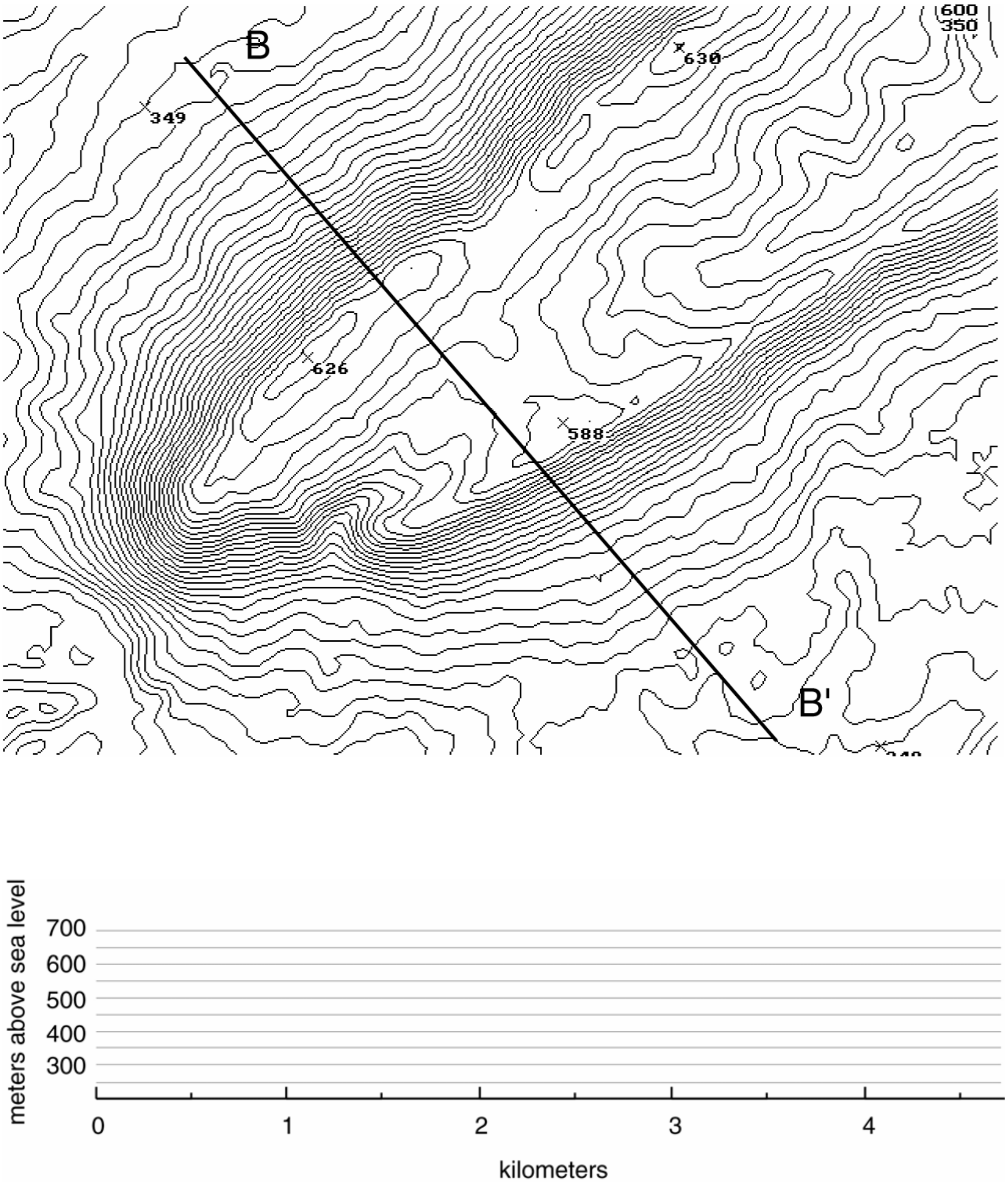


Figure 1-4. Digital contour map through the southwestern end of Nittany Mountain. Contours are on ten meter intervals.

1-3 and 1-4). The data were compiled using stereographic aerial photographs. These data are available through the United States Geological Survey (USGS). Each datum is spaced horizontally at 30 meters apart with the uncertainty of the datum location of about 7 meters. Vertical uncertainty is on the order of a couple of meters. Such digital elevation data can be quickly turned into topographic maps with arbitrary contour intervals using standard PC technology. Figures 1-3 and 1-4 have 10-meter contour intervals compared with the 20-foot intervals of the standard USGS topographic maps.

<u>Exercise 5</u>: Constructing a topographic profile from a digital elevation map. Topographic maps are viewed from above as in an airplane. This is called a map view. On the ground we see ridges and valleys in cross section or profile. The purpose of this exercise is to draw a topographic profile through Tussey Ridge (the ridge bounding the southern boundary of Nittany Valley).

-- Using a ruler draw a straight line at right angles to Tussey Ridge between points A and A' on Figure 1-3. For convenience, this has already been drawn.

-- Lay a strip of paper along the profile line and mark the points (A & A'). Next, mark the paper at the exact points where each contour, stream, and hilltop crosses the profile line.

-- Label each mark with the elevation of the contour the mark represents. For closely spaced contours, it is sufficient to label just the index contours (every fourth or fifth contour).

-- Place the paper with labeled marks at the bottom of the profile paper and project each contour onto the horizontal line of the same elevation.

-- Connect the points with a smooth line.

-- What is the scale of this map of Tussey Ridge?

<u>Exercise 6</u>: Repeat exercise 1 to construct a profile through Nittany Mountain between points B and B' (Figure 1-4).

-- Note that the vertical scale is somewhat larger than the horizontal scale. The ratio of the vertical scale to the horizontal scale is called vertical exaggeration. Determine the vertical exaggeration by measuring an arbitrary horizontal distance such as one kilometer and then the length of one kilometer in the vertical direction. Then divide the vertical length by the horizontal length to determine the vertical exaggeration. Most geological cross sections have a vertical exaggeration greater than one.

-- Find the water gaps in Nittany Mountain.

Itinerary: Field Trip #1

Time (Min.)	Distance (Miles)		Directions
0			Appear at the south entrance of Deike Building before the time that lab is scheduled to begin. Walk to pick-up area on street between PSU powerplant and Beta house. Board bus.
5	0	Bus leaves PSU	Right on Burrows, Right on W. College, take 26 S. to Whitehall Rd., turn right at light and head west to Nixon Road.
	3.1		Turn Right on Whitehall Road.
	4.3		Turn left on Nixon Road, pass 481 Nixon Road and stop at 40 MPH sign.
15	4.5	**STOP 1**, <u>Tussey Mountain as viewed from Nixon Road</u>	
35		Leave STOP 1	Return Whitehall Road
	4.7		Turn left on Whitehall Road.
	5.5		Turn left on Plainfield Road park at Ferguson Township adapt-a-road sign.
40	5.5	**STOP 2**, <u>A topographic profile of Nittany Mtn.</u>	
60		Leave STOP 2	Return to Whitehall Road and drive east to Nixon Road
	6.3		Left on Nixon Road.
	7.9		Right on Gatesburg Road
	9.3		Left on Science Park Road to Circleville Road
	12.2		Left on North Atherton (Route 322) and drive to Skytop
	15.4		Skytop: Pull right into parking lot of Skytop Chiropractic Life Center.
75	15.4	**STOP 3**, <u>Overview of the Allegheny Front at Skytop</u>	
95		Leave STOP 3	Bus turns around at the overview. Return to PSU via North Atherton.
110	16.6	Arrive PSU	

For Remaining Chapters

Contact:

engelder@geosc.psu.edu