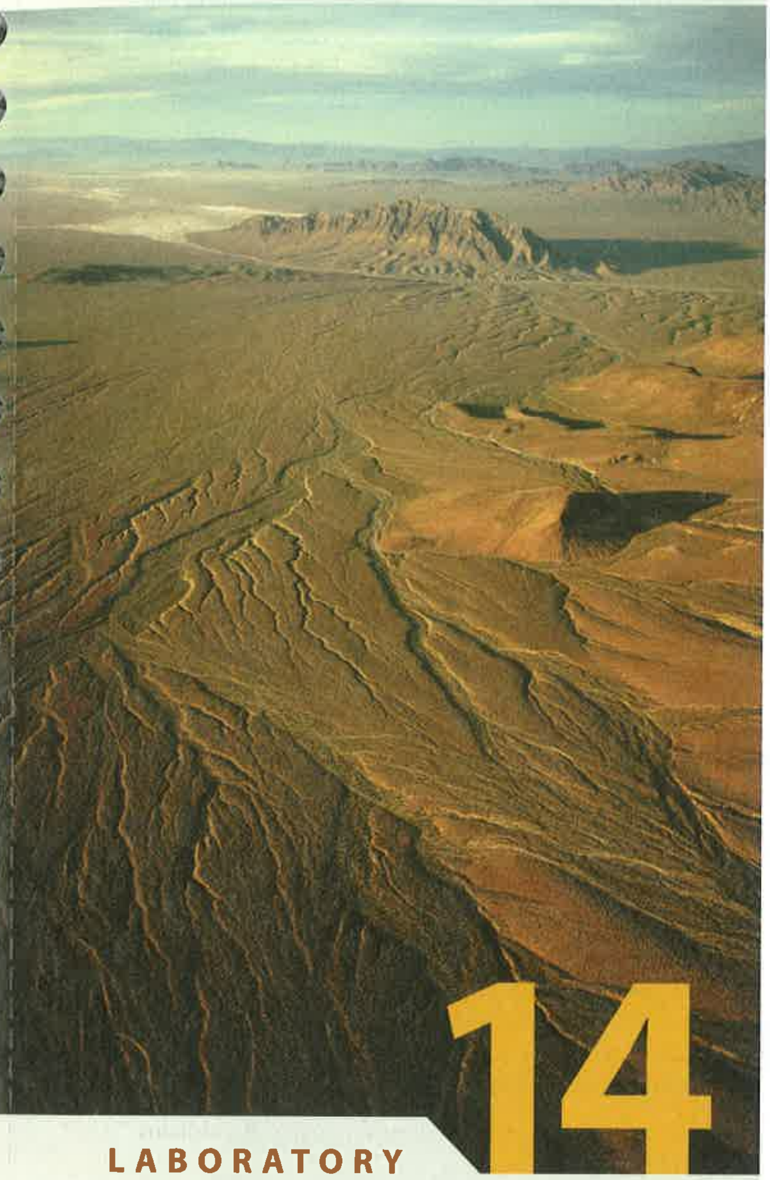

14

LABORATORY

Dryland Landforms, Hazards, and Risks

CONTRIBUTING AUTHORS

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Rain is rare in drylands, so there are few plants to trap and bind loose rocks among their roots or aid in the development of soil that would absorb rainwater. When it does rain, flash floods cut channels and shape the landscape. (Photo by Michael Collier)

BIG IDEAS

Drylands are lands of arid-to-dry, subhumid climates that generally have sparse vegetation and receive precipitation just a few days or one season of the year. Even so, water is one of the primary agents that produces characteristic dryland landforms and flood hazards. Wind is also a factor in the erosion and transportation of sediment, especially dust and the sand that makes dunes. Although many people live in drylands, true deserts do not support any agriculture without irrigation or a well.

FOCUS YOUR INQUIRY

THINK About It | What are some characteristic processes, landforms, and hazards of drylands?

THINK About It | What can we learn from topographic maps and satellite images about dryland processes and landforms?

THINK About It | How can topographic maps and aerial photographs of drylands be used to interpret how their environments have changed?

Introduction

Drylands are lands in arid, semi-arid, and dry-sub-humid climates. The United Nations Environment Programme (UNEP) estimates that drylands make up 41% of all land on Earth and that they support one-third of the world's human population. Sixteen percent of all existing drylands (about 6% of all land areas on Earth) are so dry that their biological productivity is too poor to support any type of agriculture (unless irrigation or wells are used). These regions are true **deserts.**

When people rely on land for farming or ranching, they must assess the potential for **land degradation**—a state of declining agricultural productivity due to natural and/or human causes. Humid lands (lands in humid climates) may undergo degradation from factors such as soil *erosion* (wearing away), farming without crop rotation or fertilization, overgrazing, or dramatic increases or decreases in soil moisture. However, degraded humid lands always retain the capability of some level of agricultural production. This is not true in drylands, where degradation may cause the land to become true desert with no agricultural value. This type of land degradation is called **desertification** (the process of land degradation toward drier, true desert conditions).

UNEP estimates that 70% of all existing drylands (about 25% of all land on Earth) are now experiencing the hazard of desertification from factors related to human population growth, climate change, poor groundwater use policies, overgrazing, and other poor land management practices. More than 100 nations now risk degradation of their productive cropland and grazeland to useless desert. For this reason, the Third World Academy of Sciences declared the 1990s as the "Decade of the Desert," and the United Nations General Assembly declared 2006 the International Year of Deserts and Desertification. In 2012, a United Nations Convention to Combat Desertification affirmed a goal of zero net land degradation.

ACTIVITY 14.1 Dryland Inquiry

THINK About It What are some characteristic processes, landforms, and hazards of drylands?

OBJECTIVE Analyze satellite images and photographs of American drylands and infer processes and hazards that occur there.

PROCEDURES

1. **Before you begin,** do not look up definitions and information. Use your current knowledge, and complete the worksheet with your current level of ability. Also, this is **what you will need** to do the activity:

   ____ Activity 14.1 Worksheet (p. 367) and pencil

2. **Complete the worksheet in a way that makes sense to you.**
3. **After you complete the worksheet,** be prepared to discuss your observations and classification with other geologists.

ACTIVITY 14.2 Mojave Desert, Death Valley, California

THINK About It What can we learn from topographic maps and satellite images about dryland processes and landforms?

OBJECTIVE Identify dryland landforms of Death Valley, California, and infer how the valley is forming.

PROCEDURES

1. **Before you begin,** read the Introduction and Eolian Processes, Dryland Landforms, and Desertification below. Also, this is **what you will need:**

   ____ colored pencils

   ____ Activity 14.2 Worksheet (p. 369) and pencil

2. **Then follow your instructor's directions** for completing the worksheets.

Eolian Processes, Dryland Landforms, and Desertification

Many drylands have specific landforms that result primarily from processes associated with degradation, erosion by streams and flash floods developed after infrequent rains (fluvial processes), or erosion and deposition associated with wind (eolian processes) (FIGURES 14.1, 14.2, 14.3). Fluvial and eolian processes erode dryland landscapes, transport Earth materials, and deposit sediments. Rocky surfaces, sparsely vegetated surfaces, sand dunes, and arroyos (steep-walled canyons with gravel floors) are typical of dryland landscapes. Therefore, humans living in drylands must adapt to these landforms, conditions, processes that have created the landforms, and the prospect of land degradation or even desertification.

Eolian Processes and Landforms

Water and ice are capable of moving large particles of sediment. The wind can move only smaller particles (FIGURES 14.4 and 14.5). For this reason, the eolian (wind-related) landforms may be subtle or even invisible on a topographic map. (However, they may be more evident on aerial photographs that have a higher resolution.) They may be superimposed on *fluvial* (stream-related) or *glacial* (ice- or glacier-related) features, particularly where recently exposed and unvegetated sediment occurs.

A lack of a dense vegetation cover is a prerequisite for significant wind erosion. This lack of vegetation can occur:

- On recently deposited sediment, such as floodplains and beaches.
- In areas where vegetation has been destroyed by fire, overgrazed, or removed by humans, or
- In true deserts, where the lack of water precludes substantial growth of vegetation.

When examining a topographic map, keep in mind that the green overprint represents only trees and shrubs. There could be an important soil-protecting grass cover present that is not indicated on the map. Your evaluation of the present climate of a topographic map area should consider surface water features, groundwater features, and the geographic location of the area.

Blowouts

The most common wind-eroded landform visible on a topographic map is usually a **blowout**—a shallow depression developed where wind has eroded and blown out the soil and fragmented rock (FIGURE 14.6C). Blowouts may

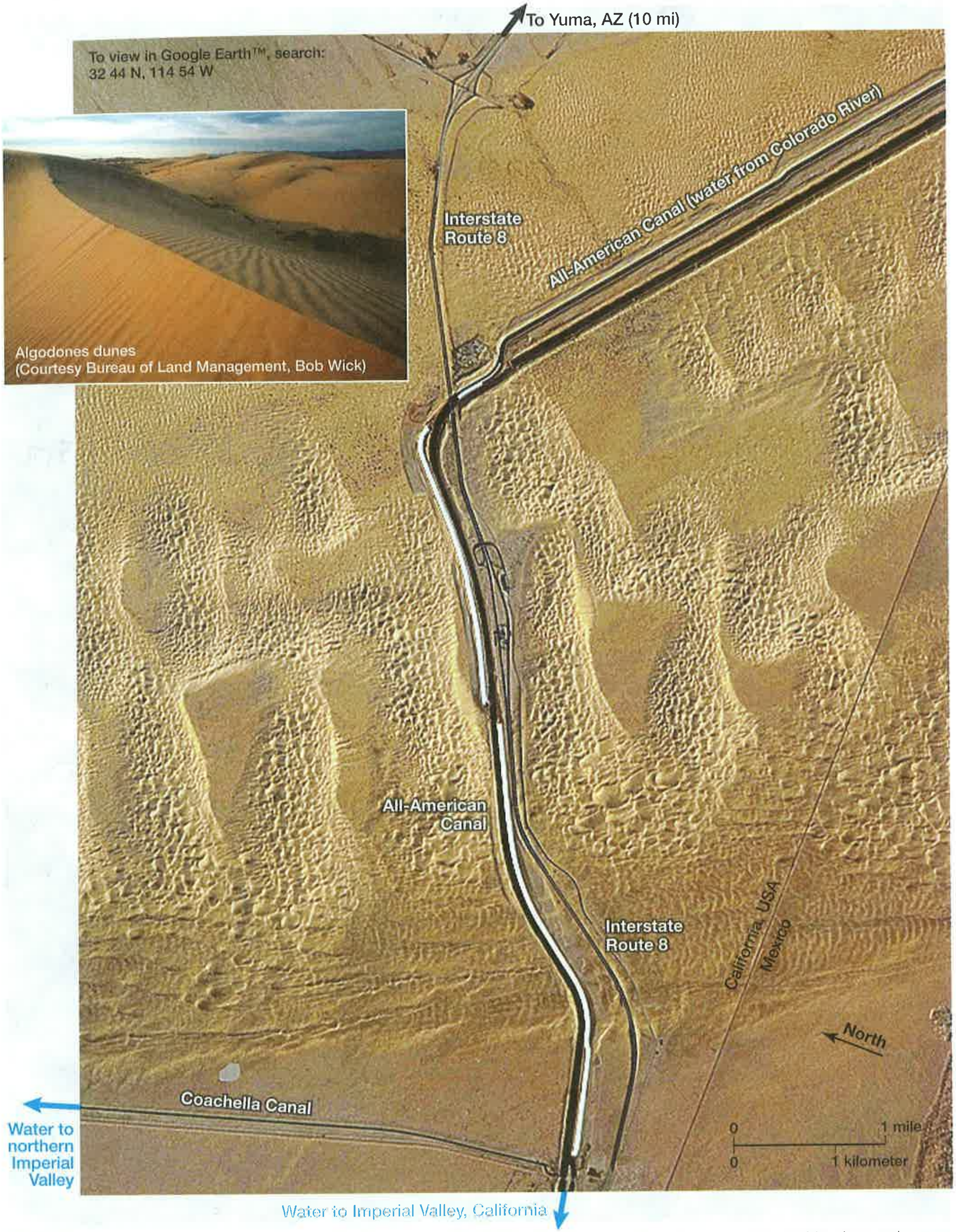


FIGURE 14.1 Algodones Dune Field, Sonoran Desert, near the California-Mexico border. Algodones Dune Field is about 10 km (6 mi) wide and 70 km (45 miles long). The long axis of the dune field is oriented northwest-southeast, along the direction of the prevailing northwest winds. Notice in this astronaut photograph how Interstate Route 8 and the All-American Canal cross the dune field. The 85-mile (53-km) canal and its branches carry water westward, from the Colorado River (at 26,000 cubic feet per second) to homes and farms of California's Imperial Valley. It is the largest irrigation canal in the world. Runoff from land irrigated by the canal system drains into the Salton Sea. (Astronaut photograph ISS018-E-24949, acquired 1-31-2009, courtesy of Image Science & Analysis Laboratory, NASA Johnson Space Center.)

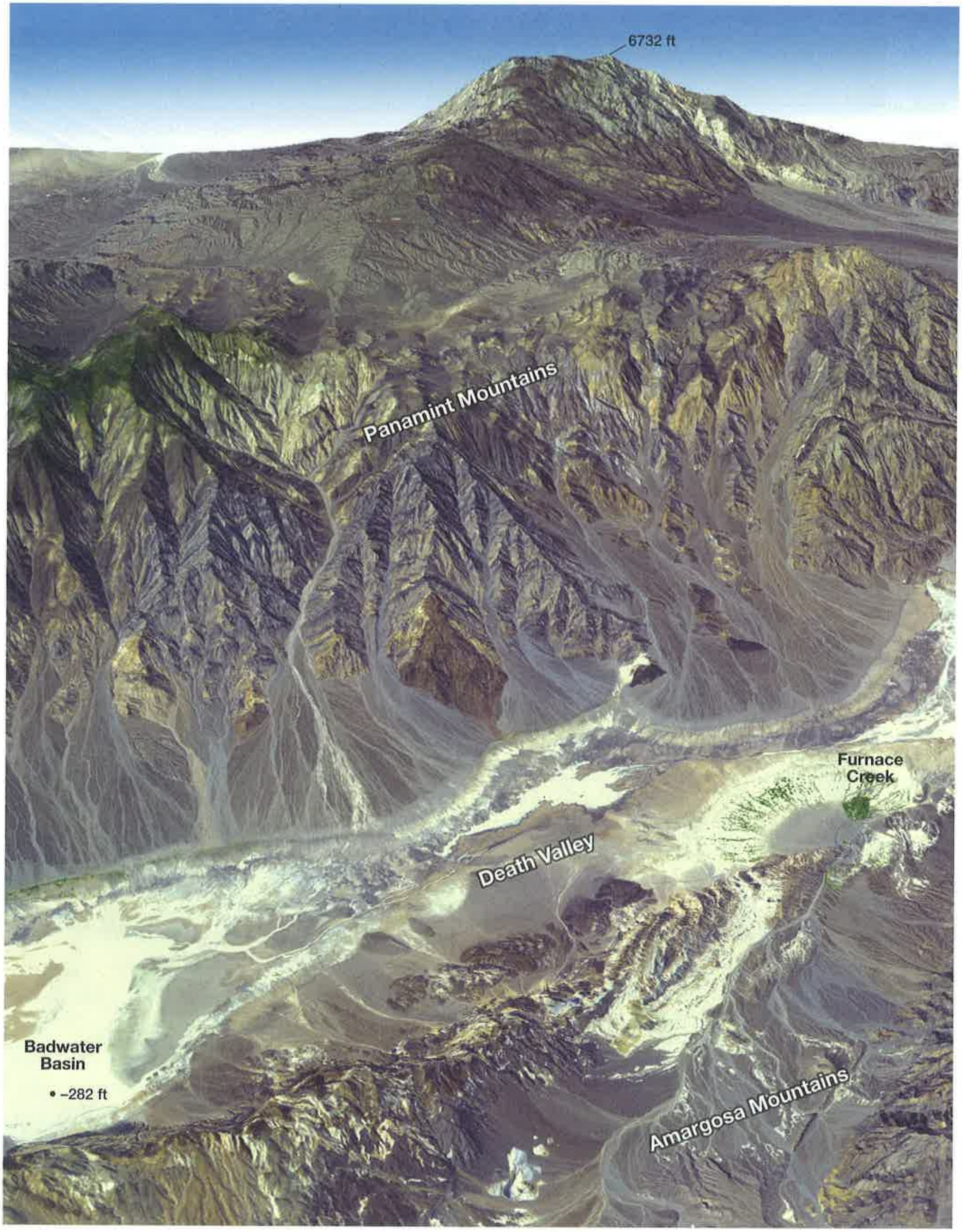


FIGURE 14.2 Perspective view of Mojave Desert, Death Valley, California, looking northwest. Width of view is about 20 km (12.5 miles). The lowest point in North America (282 feet below sea level) is labeled in Badwater Basin at the bottom of the image. Tucki Mountain, at the top of the image, is 6732 feet above sea level. Death Valley is also the driest and hottest location in North America. Note the lack of vegetation. (ASTER true-color satellite image draped over an ASTER elevation model. Courtesy of NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.)

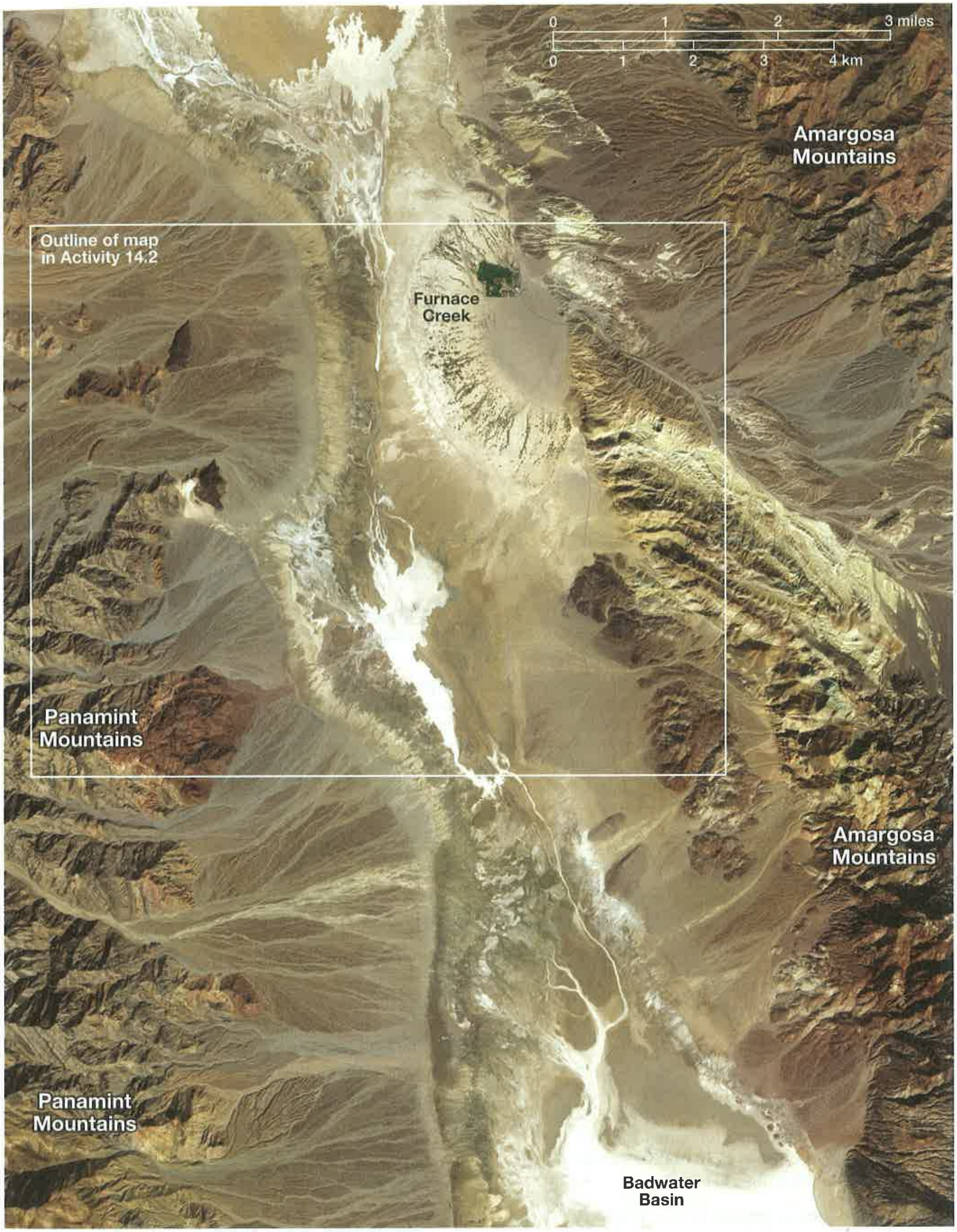


FIGURE 14.3 Overhead satellite view of Mojave Desert, Death Valley, California. Notice Badwater Basin at the bottom of the image. The water is very alkaline there, when present. Furnace Creek is the only location in the valley with potable water and significant vegetation. View in Google Earth™ by searching: 36 22 N, 116 53 W. (NASA Earth Observatory image processed by Jesse Allen and Robert Simmon using NASA EO-1 data.)

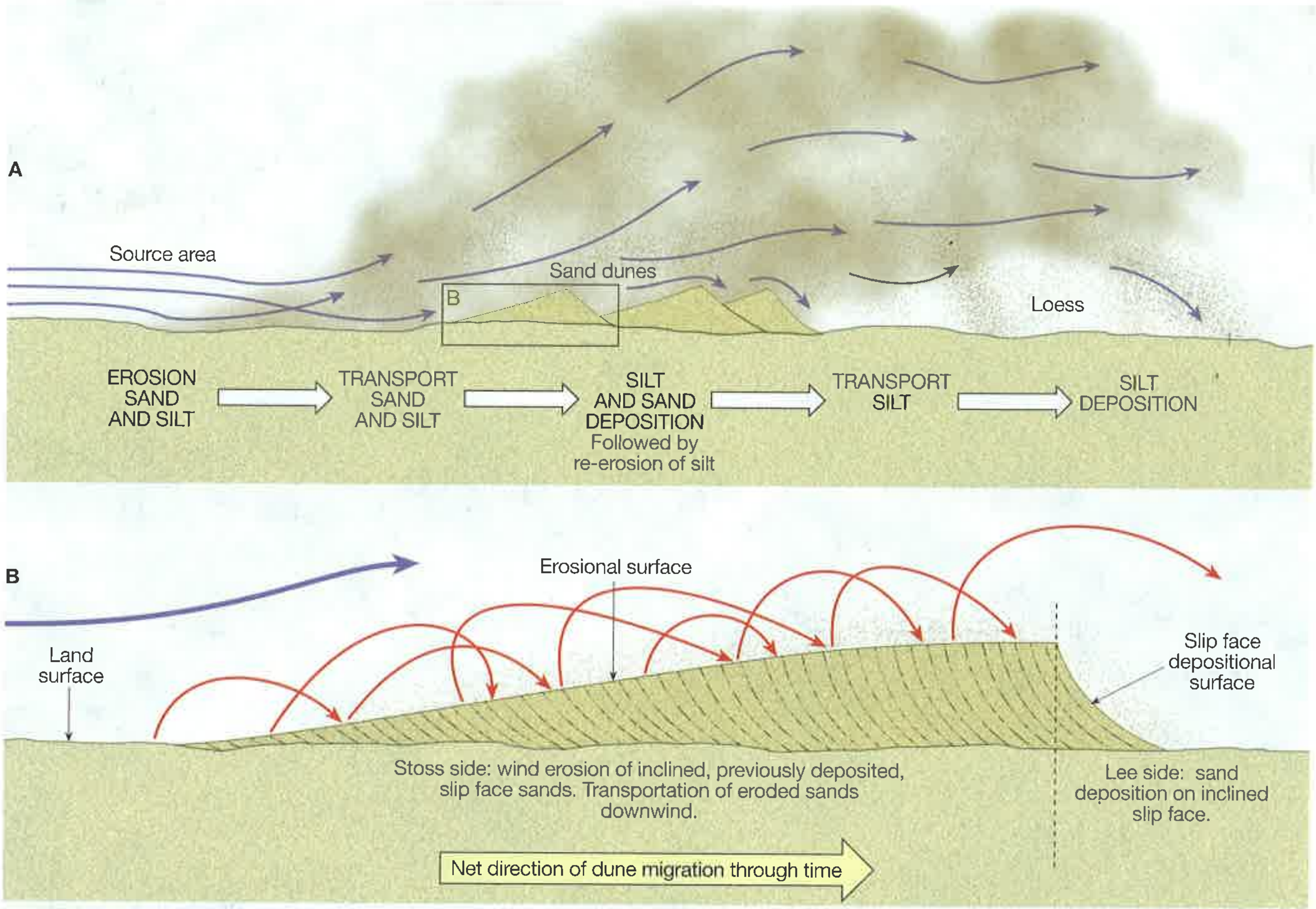


FIGURE 14.4 Eolian (wind-related) erosion, transportation, and deposition. A. Strong winds erode sand and silt from a source area and transport them to new areas. As the wind velocity decreases, the sand accumulates first (closest to the source) and the silt (loess) is carried further downwind. B. Hypothetical cross section through a sand dune. Wind erodes and transports sand up the *stoss side* (upwind side) of the dune. Sand bounces onto the slip face and accumulates, forming the *lee side* (downwind side) of the dune. This continuing process of wind erosion and transportation of sand on the stoss side of the dune, and simultaneous deposition of sand on the slip face of the dune, results in net downwind migration of the dune.

resemble sinkholes (depressions formed where caves have collapsed), or kettles (depressions formed where sediment-covered blocks of glacial ice have melted), but you can distinguish these different types of depressions in the context of other features observable on the map. Unlike sinkholes and kettles, blowouts usually have an adjacent sand dune or dunes that formed where sand-sized grains were deposited after being removed from the blowout. Blowouts also range in size from a few meters to a few kilometers in diameter.

Sand Dunes

When wind-blown (eolian) sediment accumulates, it forms sand dunes and silty loess deposits (see FIGURE 14.5). The process of dune and loess formation is shown in FIGURE 14.4. Some common types of dunes are illustrated in FIGURE 14.6 and described below:

- **Barchan dunes** are crescent shaped. They occur where sand supply is limited and wind direction is fairly constant. Barchans generally form around shrubs or large rocks, which serve as minor barriers to sand transportation. The *horns* (tips) of barchans point downwind.
- **Transverse dunes** occur where sand supply is greater. They form as long ridges perpendicular to the prevailing wind direction. The crests of transverse dunes generally are linear to sinuous.
- **Bachanoid ridge dunes** form when barchan dunes are numerous and the horns of adjacent barchan dunes merge into transverse ridges. The crests of barchanoid ridge dunes are chains of the short crescent-shaped segments that are the crests of individual barchan dunes. They can easily be distinguished from true transverse dunes that have long sinuous to very sinuous (like a snake) crests.
- **Parabolic dunes** somewhat resemble barchans. However, their horns point in the opposite direction—upwind. Parabolic dunes always form adjacent to blowouts, oval depressions from which come the sandy sediments that form the parabolic dunes.
- **Longitudinal (linear) dunes** occur in some modern deserts where sand is abundant and crosswinds merge to form these high, elongated dunes. They can be quite large, up to 200 km long and up to 100 m high. The crests of longitudinal dunes generally are straight to slightly sinuous.

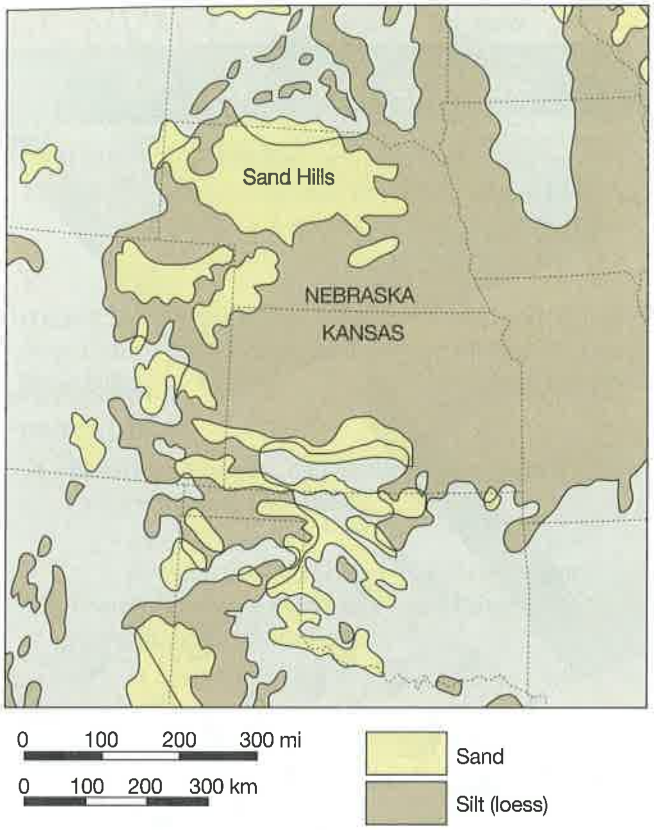


FIGURE 14.5 The Sand Hils of Nebraska. Map of part of the midwestern United States showing the location of Nebraska's Sand Hills, sand deposits, and silt (loess) deposits.

Dunes tend to migrate slowly in the direction of the prevailing wind (FIGURES 14.4 and 14.6). However, revegetation of exposed areas, due to changes in climate or mitigation, may stabilize them.

Water Erodes Drylands

Two characteristics of dryland precipitation combine to create some of the most characteristic dryland landforms other than blowouts and dunes. First, rainfall in drylands is minimal, so there are few plants to trap and bind loose rocks among their roots or aid in the development of soil that would absorb rainwater. Second, when rainfall does occur, it generally is in the form of violent thunderstorms. The high volume of water falling from such storms causes flash floods over dry ground. These floods develop suddenly, have high discharge, and last briefly. They carve steep-walled canyons, often floored with gravel that is deposited as the flow decreases and ends. Such steep-walled canyons with gravel floors commonly are called **arroyos** (or **wadis,** or **dry washes**).

Flash flooding in arid regions also erodes vertical cliffs along the edges of hills. When bedrock lies roughly horizontal, such erosion creates broad, flat-topped **mesas** bounded by cliffs. In time, the mesas can erode to stout, barrel-like rock columns, called **buttes.**

Mountainous Drylands

A variety of landforms are characteristic of drylands (FIGURE 14.7). They are primarily formed by the action of infrequent rain storms and flash floods that erode the landscape and transport and deposit sediment. However, these effects are enhanced in tectonically active regions, where there is greater relief of the land.

When it rains in mountainous drylands, the water simply runs off of the rocks because there is no soil to absorb it. This leads to development of severe flash floods, which have the cutting power to erode rock and transport sediment. These flash floods often develop into *mudflows* (sediment liquified with water, and having the consistency and density of concrete being poured from a "cement mixer" truck). Flash floods and mudflows do millions of dollars worth of damage to human properties each year and claim many lives. They also lead to development of **alluvial fans** (fan-shaped, delta-like deposits of sediment that develop where the flash floods and mudflows empty into a valley).

The southwestern United States (Great Basin) is one of many arid regions of the world where Earth's crust is being lengthened by tensional forces (pulled apart). This leads to **block faulting**—a type of regional rock deformation where Earth's crust is broken into fault-bounded blocks of different elevations. The higher blocks are called *horsts* and the lower blocks are *grabens* (see FIGURE 14.7). Steep slopes develop along faults, between the blocks. After severe thunderstorms, flash floods and mudflows commonly flow from the horsts into the graben valleys. Huge alluvial fans develop where the stream valleys of the flash floods and mudflows empty into the grabens, much as deltas develop where rivers empty into a lake or the ocean. In a humid climate, these basins might collect water in permanent lakes. But in a desert, precipitation usually is insufficient to fill and maintain permanent lakes. Many of the graben valleys are also closed basins, meaning that water has no outlet to flow from them. The only way that water can escape from such graben basins is by evaporation. Such ephemeral bodies of water are called **playas.** Chemicals

ACTIVITY 14.3 Sand Seas of Nebraska and the Arabian Peninsula

THINK About It **What can we learn from topographic maps and satellite images about dryland processes and landforms?**

OBJECTIVE Identify landforms, including types of sand dunes, in drylands and analyze drylands to determine their risk of desertification.

PROCEDURES

1. **Before you begin,** read Sand Seas of Nebraska and the Arabian Peninsula below. Also, this is **what you will need:**
   ____ colored pencils
   ____ Activity 14.3 Worksheet (p. 371) and pencil
2. **Then follow your instructor's directions** for completing the worksheets.

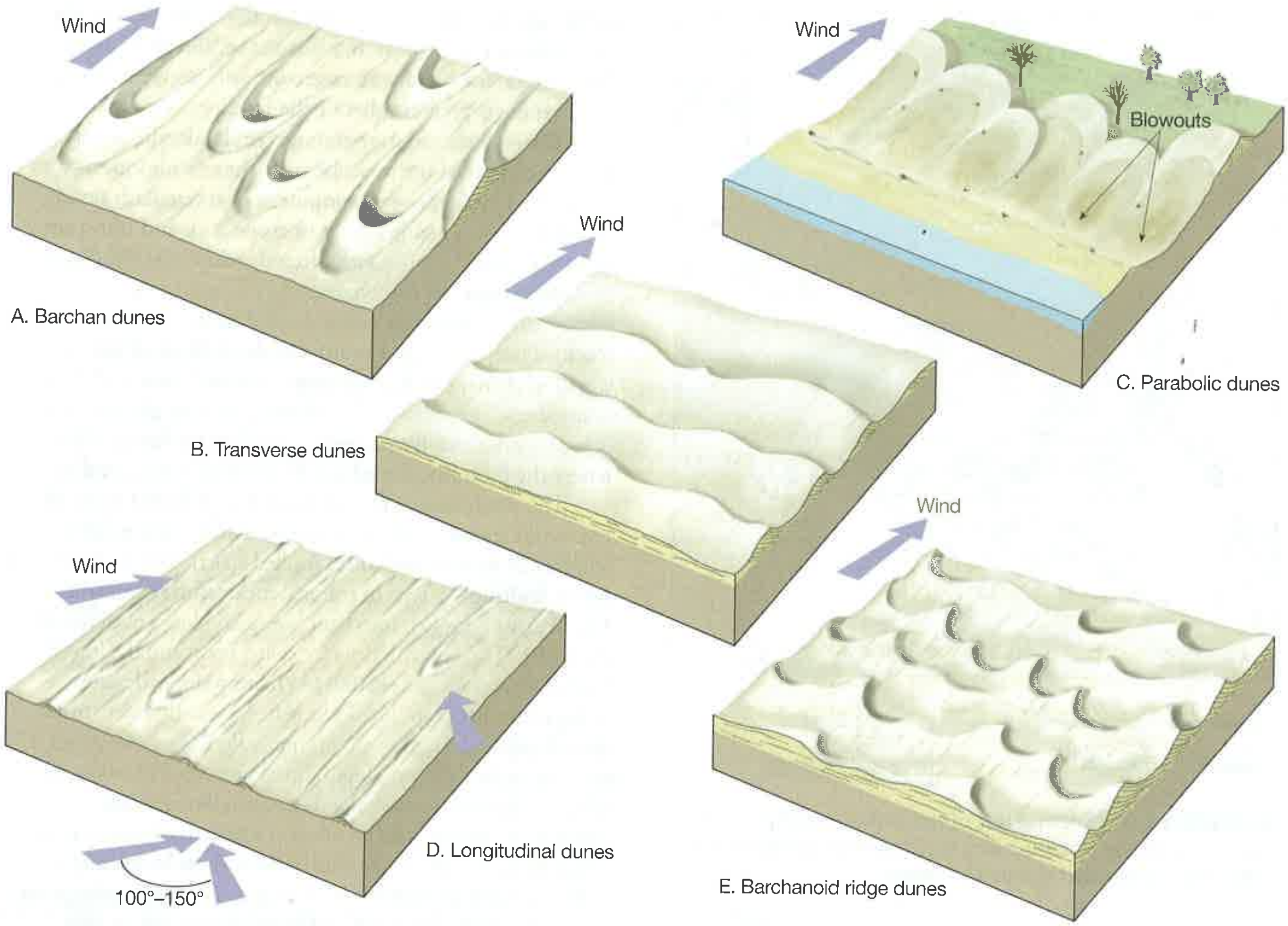


FIGURE 14.6 Common types of sand dunes. Note their basic morphology and internal stratification relative to wind direction.

dissolved in playa water become more and more concentrated as the water evaporates. Eventually, evaporite minerals (salts) precipitate from the water, and all that is left is a white, soggy or dry, **salt flat** (a level patch of land that is encrusted with salt).

Sand Seas of Nebraska and the Arabian Peninsula

Deserts can be rocky or sandy. An extensive sandy desert is called a sand sea, or **erg.** The largest erg on Earth is the Rub' al Khali (rūb al ka'lē), Arab for "the Empty Quarter," of the Arabian Peninsula. It covers an area of about 250,000 square kilometers (nearly the size of Oregon). Many kinds of active dunes occur there, and some reach heights of more than 200 meters. Rub' al Khali is a true desert (supports no agriculture) with rainfall less than 35 mm per year.

The Sand Hills of Nebraska (**FIGURES 14.5**) is only one-fifth the size of the Empty Quarter, or about 50,000 square kilometers of land, but it is the largest erg in the Western Hemisphere. This sand sea was active in Late Pleistocene and early Holocene time, but it has been inactive (i.e., the dunes are not actively forming or moving) for about the past 8000 years. This was determined by dating the radioactive carbon of organic materials that have been covered up by the large dunes. The large dunes are now covered with grass (short-grass prairie) that is suitable for limited ranching. About 17,000 people (mostly ranchers) now live in the Sand Hills.

Dryland Lakes

The amount of rain that falls on a particular dryland normally fluctuates over periods of several months, years, decades, centuries, or even millennia. Therefore, a dryland may actually switch back and forth between arid and semi-arid conditions, semi-arid and dry-subhumid conditions, arid and dry-subhumid conditions, and so on. Where lakes persist in the midst of drylands, their water levels fluctuate up and down in relation to such periodic changes in precipitation and climate. Periods of higher rainfall (or snow that eventually melts) and reduced aridity and evaporation create lakes that dry up during intervening periods of less rain and greater aridity and evaporation. Great Salt Lake, Utah, is an example.

Great Salt Lake is a closed basin, so water can escape from the lake only by evaporation. When it rains, or when snow melts in the surrounding hills, the water

ACTIVITY

14.4 Dryland Lakes of Utah

THINK About It **How can topographic maps and aerial photographs of drylands be used to interpret how their environments have changed?**

OBJECTIVE Analyze a stereogram and topographic map of the Utah desert to evaluate the history of Lake Bonneville.

PROCEDURES

1. **Before you begin**, read Dryland Lakes below. Also, this is **what you will need:**
   ____ colored pencils
   ____ Activity 14.4 Worksheet (p. 373) and pencil
2. **Then follow your instructor's directions** for completing the worksheets.

raises the level of the lake. Therefore, the level of Great Salt Lake has varied significantly in historic times over periods of months, years, and decades. During one dry period of many years, people ignored the dryland hazard of fluctuating lake levels and constructed homes, roads, farms, and even a 2.5-million-dollar resort, the Saltair, near the shores of Great Salt Lake. When a wet period occurred from 1982–87, many of these structures (including the resort) were submerged. The State of Utah installed huge pumps in 1987 to pump lake water into another valley, but the pumps were left high and dry during a brief dry period that lasted for 2 years (1988–89) after they were installed.

Geologic studies now suggest that the historic fluctuations of Great Salt Lake are minor in comparison to those that have occurred over millennia. Great Salt Lake is actually all that remains of a much larger lake that covered 20,000 square miles of Utah—Lake Bonneville. Lake Bonneville reached its maximum depth and geographic extent about 17,000 years ago as glaciers were melting near the end of the last Ice Age. One arm of the lake at that time extended into Wah Wah Valley, Utah, which is now a dryland (**FIGURE 14.8**).

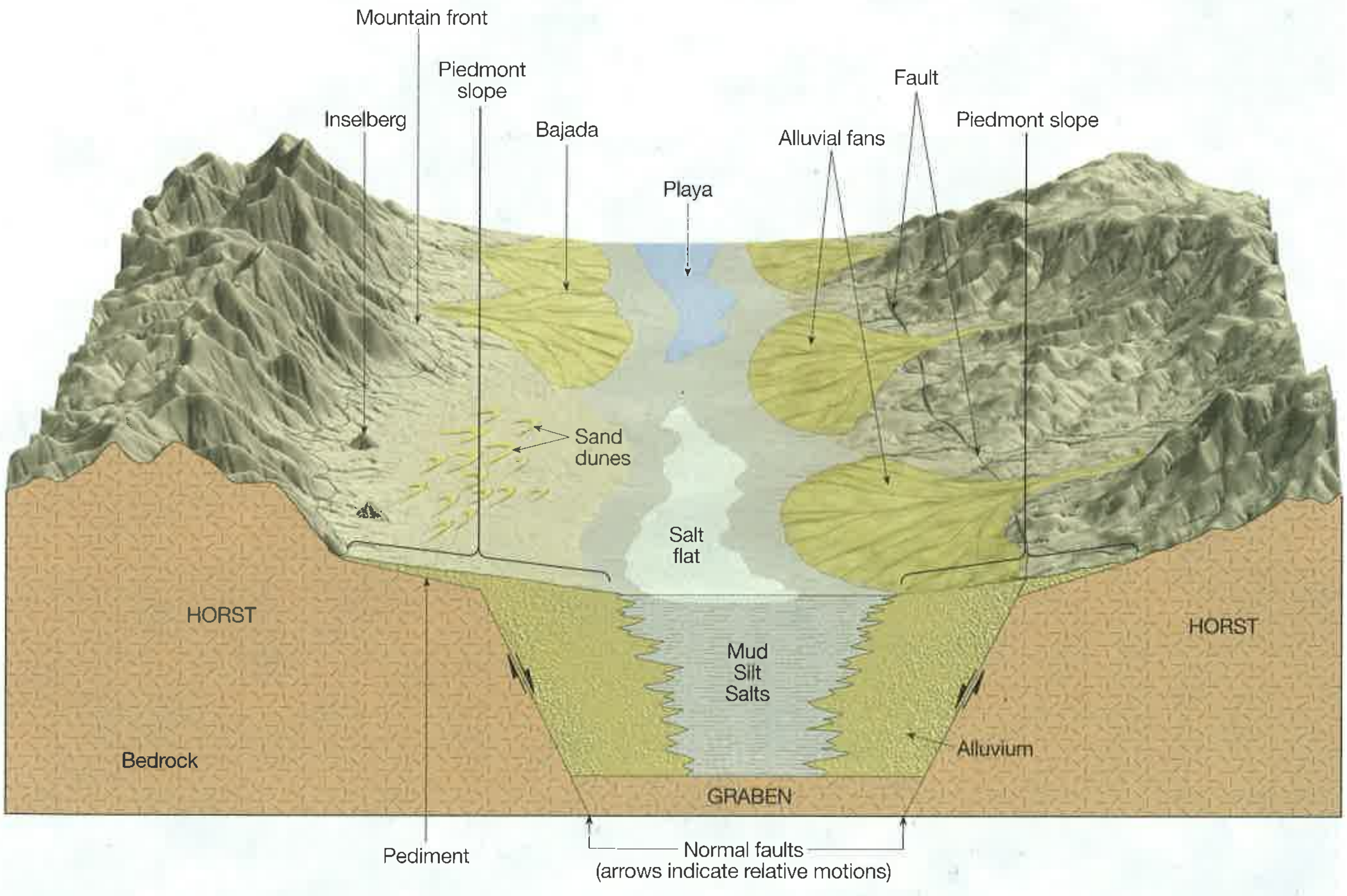


FIGURE 14.7 Landforms of mountainous drylands. These landforms are typical of arid mountainous deserts in regions of the southewestern United States, where Earth's crust has been lengthened by tensional forces (pulled apart). Mountain ranges and basins develop by **block faulting**—a type of regional rock deformation where Earth's crust is broken into fault-bounded blocks of different elevations. The higher blocks form mountains called *horsts* and the lower blocks form valleys called *grabens*. Note that the boundaries between horsts and grabens are typically normal faults. Sediment eroded from the horsts is transported into the grabens by wind and water. **Alluvial fans** develop from the mountain fronts to the valley floors. They may surround outlying portions of the **mountain fronts** to create **inselbergs** (island-mountains). The fans may also coalesce to form a **bajada.** In cases where there is no drainage outlet from the valley, the valley is a closed basin from which water can escape only by evaporation. Because rain is infrequent in drylands, the lakes that form are temporary (**playas**). When they evaporate, all that is left is a **salt flat** (a patch of level land that is encrusted with salt.). Wind blowing over the valleys can form **sand dunes** made of salt crystals or muineral grains eroded from bedrock (usually quartz sand).

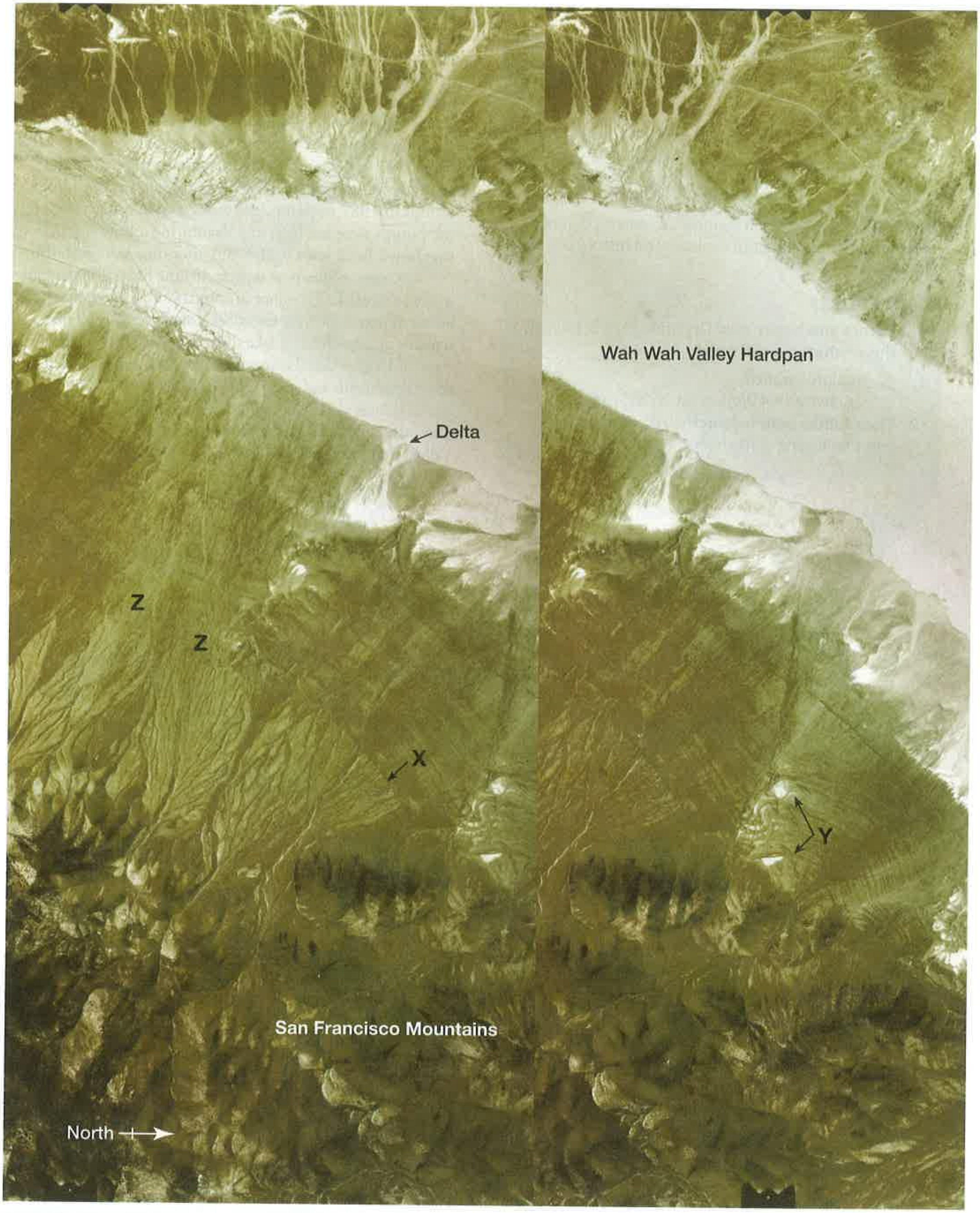


FIGURE 14.8 Stereogram of the Wah Wah Valley, Utah, area: 1:58,000 scale. The stereogram is constructed with two 1991, National high-altitude photograph (NHAP) aerial photographs (Courtesy of U.S. Geological Survey). View this stereogram using a pocket stereoscope (FIGURE 9.9, page 241) or by crossing your eyes. Hold the stereogram at a comfortable distance (one foot or so) from your eyes with your nose facing the line between the images. Cross your eyes until you see four photographs (two stereograms), then relax your eyes to let the two center photographs merge into one stereo image.

ACTIVITY 14.1 Dryland Inquiry

Name: ______________________ **Course/Section:** ______________________ **Date:** ____________

A. When most people think of drylands and deserts, they imagine hot sandy landscapes. Most of the southwestern United States is desert, including the Sonoran Desert of southern California and Arizona. However, most of the Sonoran Desert is rocky landscapes. Sandy areas are present, but limited, like the Algodones Dune Field in FIGURE 14.1. This is the location where Star Wars producers filmed desert scenes of the film's planet Tatooine.

1. Notice the sand dunes of the Algodones Dune Field in FIGURE 14.1. Why do you think there are no plants growing on the dunes?

2. Winds in the Algodones Dune Field can reach velocities up to 60 miles per hour. This can create hazardous conditions and the need for maintanence on the canal and Interstate Route 8. What would be the hazard, and what maintenance would be needed periodically on the canal and Interstate Route 8 as a result of the hazard?

3. This region is managed by the U.S. Bureau of Land Management as Imperial Sand Dunes Recreation Area. Portions of the dunes are available for operating off-road vehicles. What effect do you think the operation of off-road vehicles here would have on plant growth and the hazards you described above?

B. Death Valley, occurs in the Mojave Desert. Analyze the images of the Death Valley region in FIGURES 14.2 and 14.3.

1. Notice in FIGURE 14.2 that steep mountainous slopes occur on both sides of Death Valley. Also notice that there is almost no soil or vegetation on the slopes. Describe what you think conditions would be like in the river valleys on these mountain slopes when a heavy rain falls on them.

2. Notice the delta-like landforms that form at the mouths of the rivers in FIGURES 14.2 and 14.3, where the rivers enter the valley. Explain how you think these landforms form.

3. Notice that there is no standing water in Death Valley, even though you can see that water sometimes flows into the valley from the mountains. It is a closed basin (meaning that water has no way to drain from it). It is also the hottest and driest place in North America. When there is water on the floor of the vally, it is alkaline to salty and not potable (drinkable). How do you think the water gets so alkaline and salty?

4. Suppose you could walk down to the white patches on the floor of Death Valley in FIGURES 14.2 and 14.3 and examine them. Predict what materials and conditions you would find there.

5. Residents of Furnace Creek have grassy lawns, trees, and potable water to drink. Why do you think their water is potable?

C. Open Google Earth™. Type coordinates "33 44 15 N, 116 25 W" into the search box and press enter to go to the location. You should arrive at Rancho Mirage, California, a resort community located in a desert region.

1. Notice that Rancho Mirage has a triangular shape. Based on your work in part **B**, how was the landform beneath Rancho Mirage formed?

2. Using your mouse, hover over the icons at the top of the Google Earth™ screen to find and select the "Show historical imagery" feature. Use the slider to go back in time and view how Rancho Mirage has changed. Describe how it has changed since 1996.

3. In July of 1979, a violent storm developed here and nearly six inches of rain fell on the San Jacinto Mountains, uphill from Rancho Mirage. At that time, flood control at Rancho Mirage included a system of earthen channels and concrete walls that were overwhelmed by a flash flood. Many homes were damaged and two lives were lost in the event. Analyze, recent images of Rancho Mirage in Google Earth™ and describe any evidence of flood control measures.

4. Would you feel safe living at Rancho Mirage? Explain.

D. **REFLECT & DISCUSS** The United Nations Convention to Combat Desertification (UNCCD) points out that many people live in drylands, and that more than half of the world's productive land is dryland. The challenge is to manage the land so that it does not degrade to useless desert that supports no agriculture, and to live safely. Based on your work above, make a list of challenges that people face when they live in drylands, and some ways that the land could be managed to make it safer and more productive.

ACTIVITY 14.2 Mojave Desert, Death Valley, California

Name: ______________________________ **Course/Section:** ______________________________ **Date:** ______________

Death Valley is located in the USGS 15-minute Furnace Creek, California quadrangle (provided on the back of this activity sheet). It is the large valley (graben) in the middle of the map and the lowest valley in the United States (**FIGURES 14.2**, **14.3**). The mountains on each side of the valley are *horsts* (**FIGURE 14.7**).

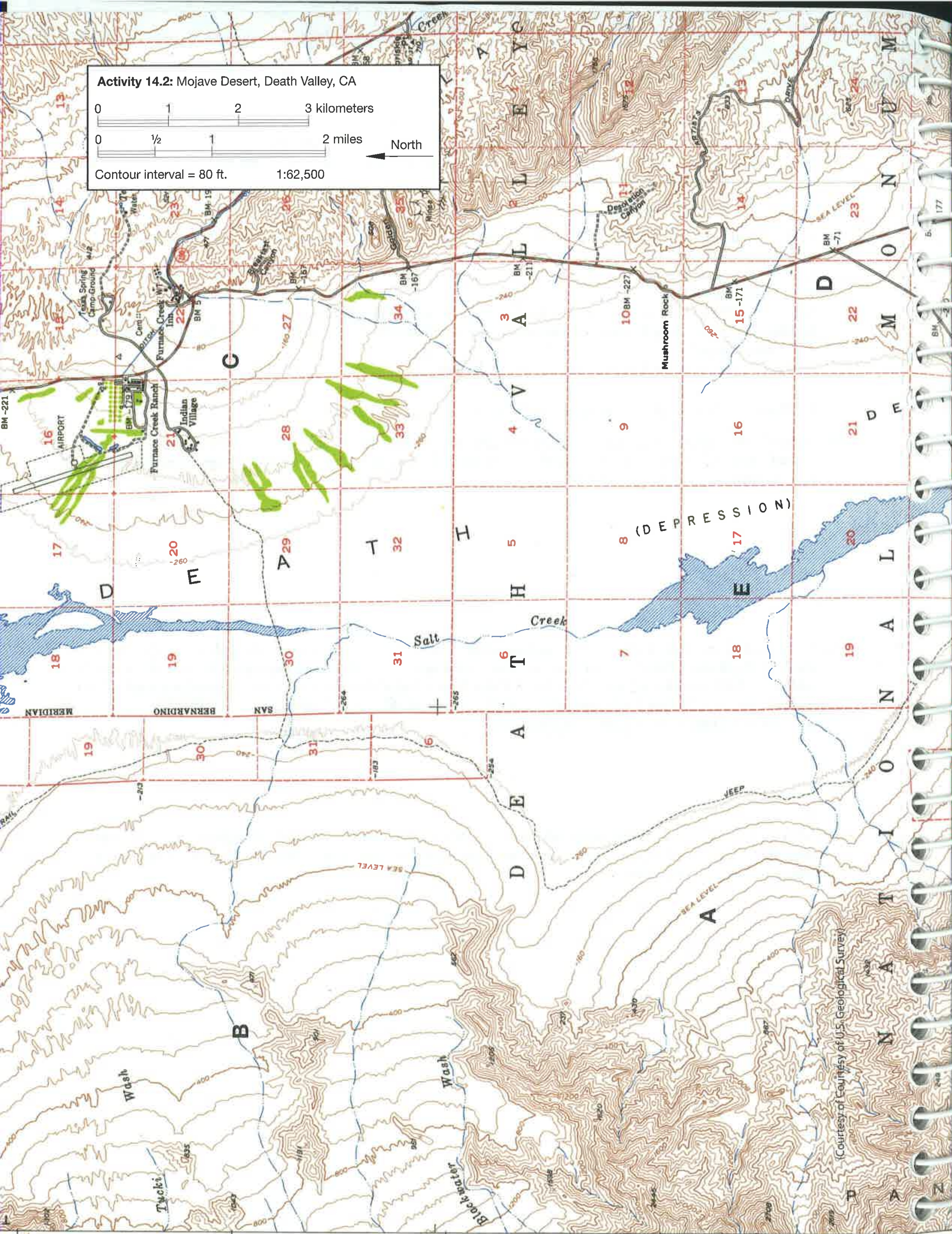
A. Obtain your set of colored pencils and do the following on the topographic map on the back of this page.

1. Neatly and precisely color alluvial fan **A** yellow, including the two arroyos at the top (upslope end) of the fan.
2. Color the inselbergs red in the vicinity of location **B**.
3. Color alluvial fan **C** yellow.
4. Color alluvial fan **D** yellow.
5. Color the 00 (sea level) topographic contours blue on both sides of the valley.
6. Make a green line along the downhill edge of the *mountain front* (**FIGURE 14.7**) on both sides of the valley and label it "mountain front."
7. What is the elevation of the lowest contour line on the map? ______________ feet
8. What is the elevation of the lowest point on the map? ______________ feet

B. Notice the intermittent stream that drains from the upstream end of the alluvial fan/arroyo system **A** (that you have already colored yellow) to the playa at **E**. How would the grain size of the sediments along this stream change as you walk downslope from the high arroyo to the playa (**E**)? Why?

C. The floor of most grabens is tilted, because fault movement is usually greater on one side of the graben than the other. There are also half grabens, valleys developed along only one normal fault. Carefully examine the map on the back of this page for evidence of faults on either or both sides of Death Valley. Draw a dark dashed line (with a normal pencil or a black colored pencil or pen) wherever you think a normal fault may be present on either or both sides of the valley. Based on your work, do you think that Death Valley is a graben or a half graben?

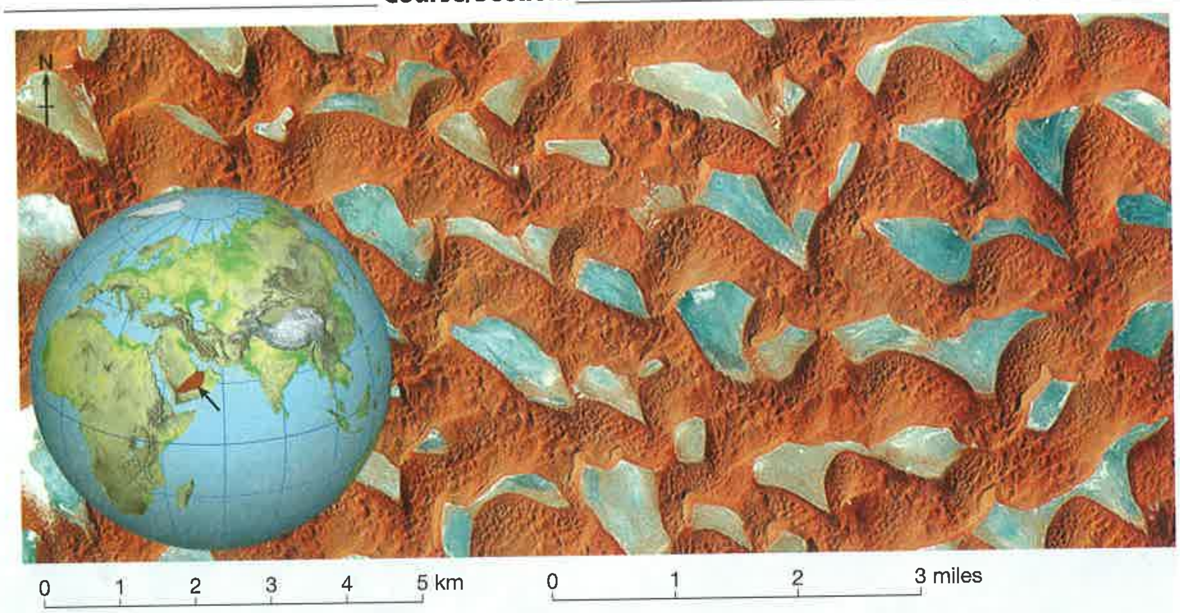
D. **REFLECT & DISCUSS** Notice that people chose to build a ranch on alluvial fan **C**, even though this entire region is dryland. What do you think was the single most important reason why those people chose alluvial fan **C** for their ranch instead of one of the other fans?



(Courtesy of U.S. Geological Survey)

ACTIVITY 14.3 Sand Seas of Nebraska and the Arabian Peninsula

Name: ______________________ **Course/Section:** ______________________ **Date:** ______________



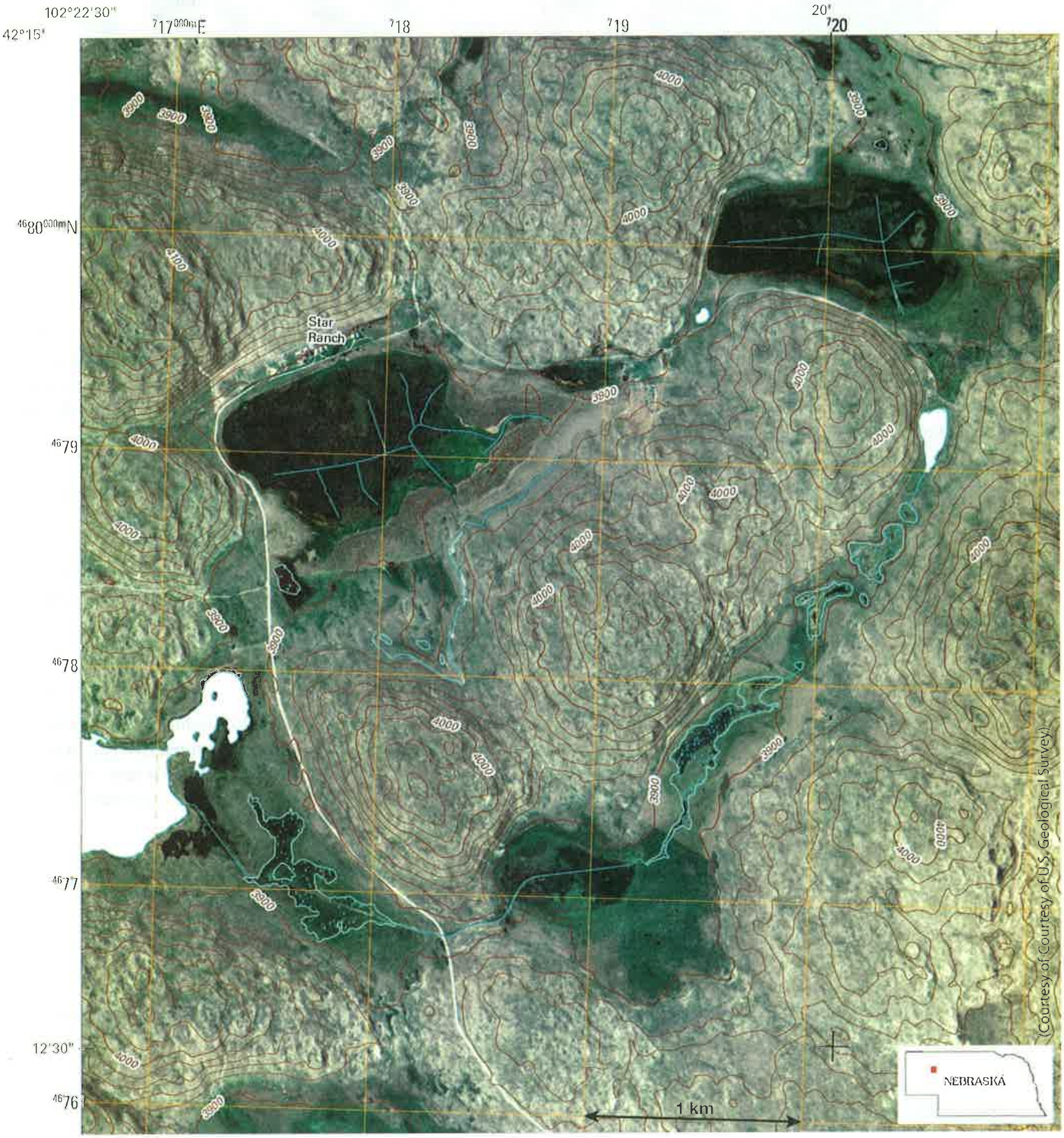
A. Analyze the satellite image above of the Empty Quarter Desert. This is a sandy desert. The sand is mostly quartz (with a reddish hematite coating) transported south by strong winds from Jordan, Syria, and Iraq. These winds, called *shamals*, can reach speeds of nearly 50 mph that last for days. The dunes sit on gray and brown clay (ancient lake beds). White patches are salt flats (mostly gypsum).

1. What kind of dunes are developed in this image?
2. The dominant winds here are northerly (i.e., come from the north and blow south). How can you tell?

B. Analyze the USGS orthoimage of part of Nebraska's semi-arid Sand Hills region on the next page. Rainwater quickly drains through the porous sand, so the hilltops are dry and support only sparse grass. There is a shallow water table, so there are lakes, marshes, and moist fields between the hills.

1. How are the Sand Hills sand dunes similar to the sand dunes of the Barren Quarter?
2. Locate Star Ranch in the northwest corner of the orthoimage. This ranch was present in the 1930s during the famous Dust Bowl days, when dry windy conditions persisted for years and dust storm after dust storm scoured the land here. Star Ranch was not covered by any advancing dunes during the Dust Bowl. What does this suggest about how much desertification must occur here in order for the large dunes of the Sand Hills to once again become an active sand sea?
3. The hills (Sand Hills) in the orthoimage are either large barchan dunes (called *megabarchans*) or barchanoid ridges (**FIGURE 14.6**). Using a highlighter or colored pencil color an isolated megabarchan yellow and a barchanoid ridge green (color it from one side of the map to the other). What is the relief, in feet, of the megabarchan that you colored?
4. According to the orientations of the megabarchans and the barchanoid ridges, the winds that made these dunes were coming *from* what direction?
5. What evidence is there in **FIGURE 14.5** that the source of sand for the Sand Hills was located northwest of Nebraska and the Sand Hills? Explain your reasoning.

D. The Sand Hills region now receives an average of 580 mm (about 2 in.) of rain per year, and large active dunes tend to occur in regions that receive less than 250 mm of rain per year (less than an inch). Winds capable of moving sand already occur in this region, but the rainfall and moisture from evapotranspiration is presently enough to sustain grasses that hold the sand in place in the dunes. If you were a rancher in the Sand Hills, what grazing practices would you follow to decrease the risk of desertification there?



E. **REFLECT & DISCUSS** Many cities in central and eastern Nebraska rely on groundwater for consumption, industry, and pleasure. As these cities continue to grow, and their use of groundwater increases, what effect might this have on the environments and people of the Sand Hills?

ACTIVITY 14.4 Dryland Lakes of Utah

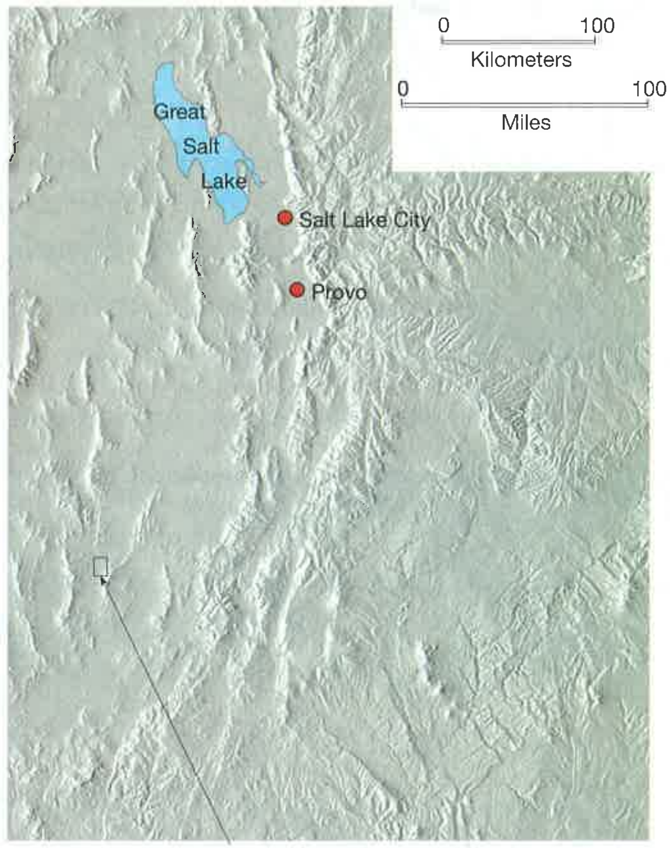
Name: ______________________________ **Course/Section:** ______________ **Date:** __________

Refer to **FIGURE 14.8** (stereogram) and the Frisco Peak topographic map on the back of this page.

A. What specific type of feature is the Wah Wah Valley Hardpan?

B. If the Wah Wah Valley Hardpan were to fill with water, then how deep could the lake become before it overflows to the northeast (along the jeep trail, near the red number 27)? Show your work.

C. On **FIGURE 14.8**, notice the lines beneath the letters **X** and **Y**. They are low, steplike terraces that go all around the valley (like bathtub rings). How do you think these terraces formed?



Frisco Peak Quadrangle: Figure 14.8 (stereogram) and map on back of this page

D. Also on **FIGURE 14.8**, notice that there is a line of small deltas upslope and downslope from letter **Y**. They are also visible on the topographic map. How did they form in a line from upslope to downslope?

E. On the stereogram (**FIGURE 14.8**) and topographic map, what evidence can you identify for a former deeper lake (an arm of Lake Bonneville) in Wah Wah Valley (deeper than your answer in part D) at location **X** and what was its elevation?

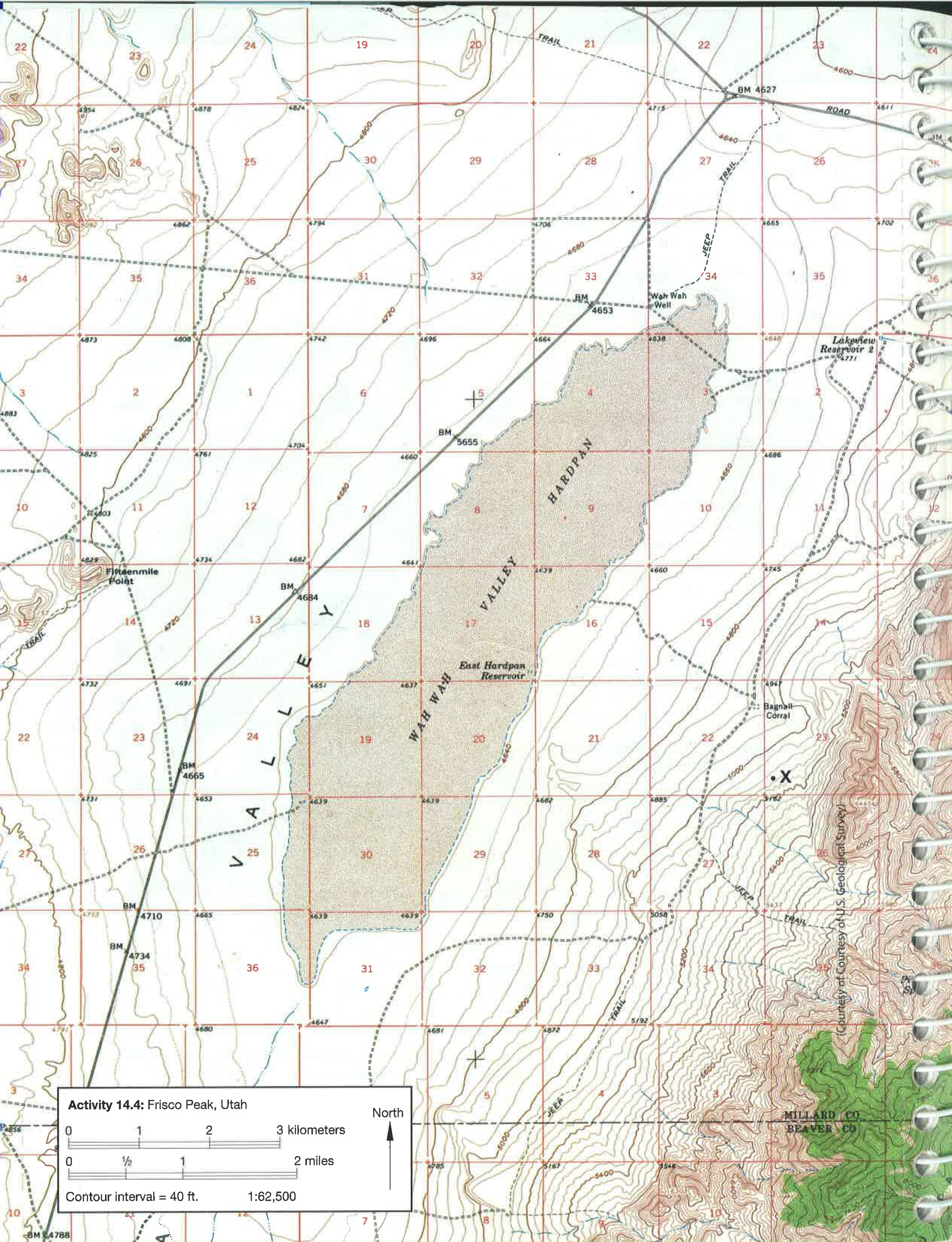
F. Are the alluvial fans at **Z** in **FIGURE 14.8** older or younger than the shoreline you identified in **B**? Why?

G. On the topographic map, use a blue colored pencil to draw the position (line) of the shoreline of ancient Lake Bonneville where it reached its highest elevation (answer **G**). Then shade (blue) the area that was submerged (i.e., color in the area that was the lake).

H. Studies by geologists of the Utah Geologic Survey and U.S. Geological Survey indicate that ancient Lake Bonneville stabilized in elevation at least three times before present: 5100 ft about 17,000 years ago, 4800 ft about 16,000 years ago, and 4300 ft about 12,000 years ago.

1. What is the age of the lake level that you identified in **G**?
2. Modern Great Salt Lake has an elevation of about 4200 ft and is 30 ft deep. How deep was the Great Salt Lake location at the time you identified above (part **J1**)?

I. **REFLECT & DISCUSS** Explain how the climate must have changed in Utah over the past 17,000 years to explain the fluctuations in levels of Lake Bonneville investigated above. In your answer, consider the times identified in part **H** and conditions in Utah today.



Activity 14.4: Frisco Peak, Utah

Contour interval = 40 ft. 1:62,500