Redesigning Introductory College Geology Courses at Arizona State University

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Setting of ASU Geology Redesign

- GLG101 taken by ~2,500 students per year
- Five classes per semester, each with 220-230 students
- Taught by various faculty members
- Laboratory is separate, but related course and generally follows same sequence of topics
- Most students are non-science majors (fulfill science requirement), but some majors

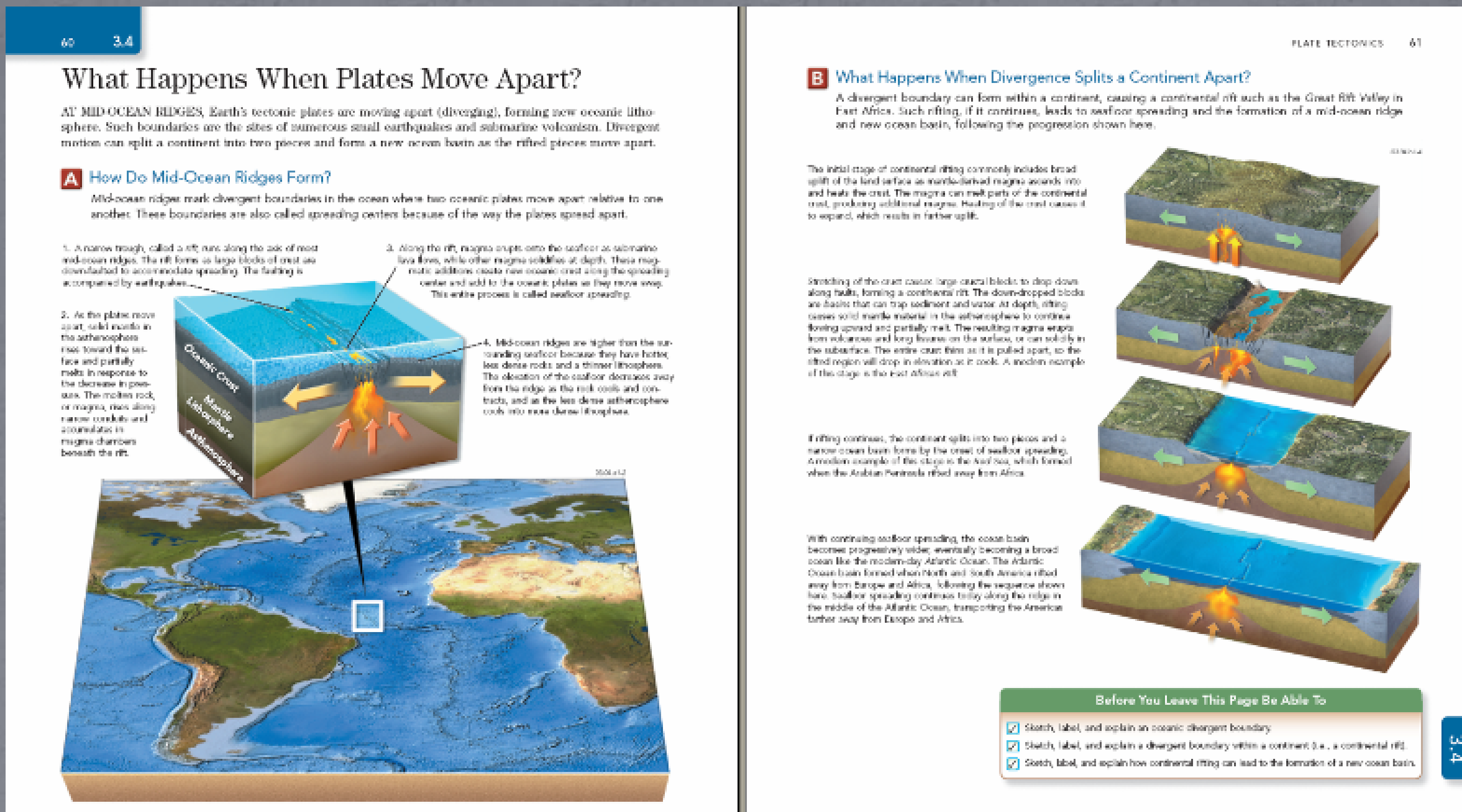
Goals of GLG101

- Teach students about scientific methods
- Improve their observation and critical thinking skills
- Learn key geologic concepts and processes
- Help student understand the relevance of geology to their lives
- Not hate science more as a result of taking the class

Goals of ASU Redesign Effort

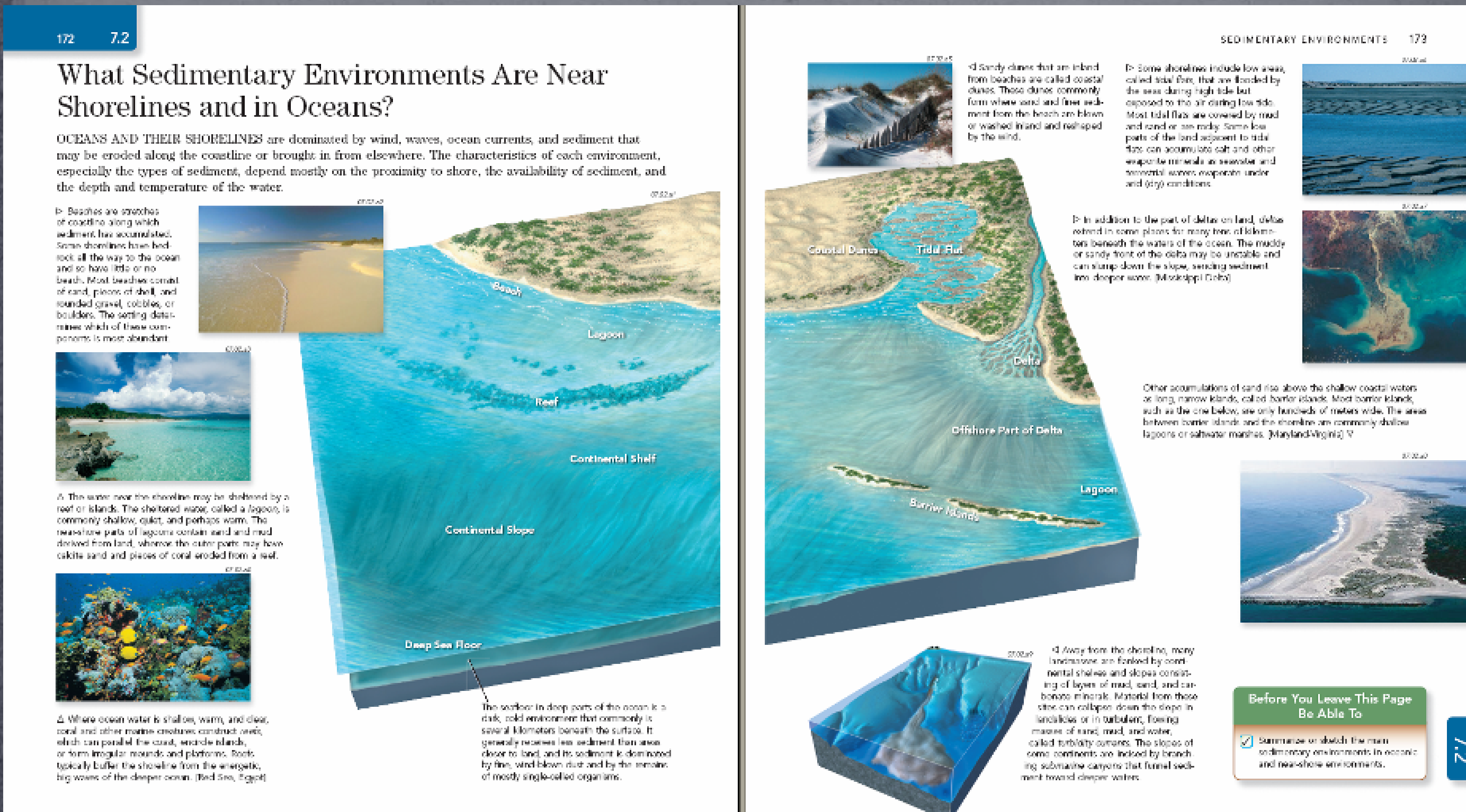
- Free up class time to engage students in active learning
- Allow students to learn in different modes, some asynchronous
- Have students engage in inquiry/problem solving
- Develop authentic methods of assessment that demonstrate mastery of subject
- Allow faculty instructor and teaching assistant to be more efficient, saving time and money

Context of ASU Reform Effort



- Textbook designed from cognitive research allows students to learn on their own (*Exploring Geology*, Reynolds and others, McGraw-Hill)

Integrating Text, Figures, Photos



What Sedimentary Environments Are Near Shorelines and in Oceans?

OCEANS AND THEIR SHORELINES are dominated by wind, waves, ocean currents, and sediment that may be eroded along the coastline or brought in from elsewhere. The characteristics of each environment, especially the types of sediment, depend mostly on the proximity to shore, the availability of sediment, and the depth and temperature of the water.

▷ Beaches are stretches of coastline along which sediment has accumulated. Some shorelines have bedrock all the way to the ocean and so have little or no beach. Most beaches consist of sand, pieces of shell, and rounded gravel, cobbles, or boulders. The setting determines which of these components is most abundant.

△ The water near the shoreline may be sheltered by a reef or islands. The sheltered water, called a *lagoon*, is commonly shallow, quiet, and perhaps warm. The nearshore parts of lagoons contain sand and mud derived from land, whereas the outer parts may have calcite sand and pieces of coral eroded from a reef.

△ Where ocean water is shallow, warm, and clear, coral and other marine creatures construct *reefs*, which can parallel the coast, encircle islands, or form irregular mounds and platforms. Reefs typically buffer the shoreline from the energetic, big waves of the deeper ocean. (Red Sea, Egypt)

The seafloor in deep parts of the ocean is a dark, cold environment that commonly is several kilometers beneath the surface. It generally receives less sediment than areas closer to land, and its sediment is dominated by fine, wind-blown dust and by the remains of mostly single-celled organisms.

◁ Sandy dunes that are inland from beaches are called coastal dunes. These dunes commonly form where sand and finer sediment from the beach are blown or washed inland and reshaped by the wind.

▷ Some shorelines include low areas, called tidal flats, that are flooded by the seas during high tide but exposed to the air during low tide. Most tidal flats are covered by mud and sand or are rocky. Some low parts of the land adjacent to tidal flats can accumulate salt and other evaporite minerals as seawater and terrestrial waters evaporate under arid (dry) conditions.

▷ In addition to the part of deltas on land, deltas extend in some places for many tens of kilometers beneath the waters of the ocean. The muddy or sandy front of the delta may be unstable and can slump down the slope, sending sediment into deeper water. (Mississippi Delta)

Other accumulations of sand rise above the shallow coastal waters as long, narrow islands, called *barrier islands*. Most barrier islands, such as the one below, are only hundreds of meters wide. The areas between barrier islands and the shoreline are commonly shallow lagoons or saltwater marshes. (Maryland-Virginia) ▽

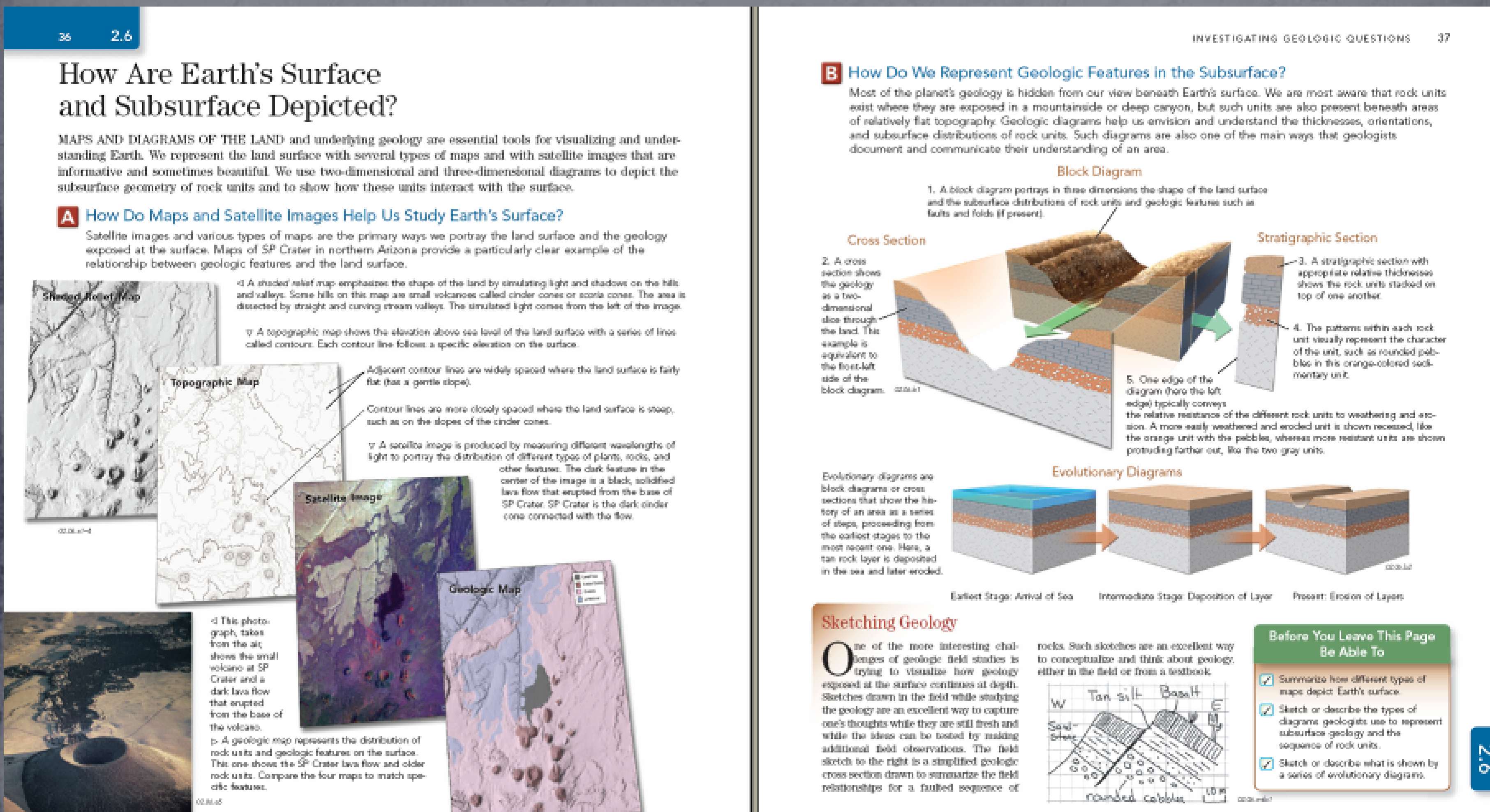
◁ Away from the shoreline, many landmasses are flanked by continental shelves and slopes consisting of layers of mud, sand, and carbonate minerals. Material from these sites can collapse down the slope in landslides or in turbulent, flowing masses of sand, mud, and water, called turbidity currents. The slopes of some continents are incised by branching submarine canyons that funnel sediment toward deeper waters.

Before You Leave This Page Be Able To

- ✓ Summarize or sketch the main sedimentary environments in oceanic and near-shore environments.

7.2

Two-Page Spreads Reduce Cognitive Load



36 2.6

How Are Earth's Surface and Subsurface Depicted?

MAPS AND DIAGRAMS OF THE LAND and underlying geology are essential tools for visualizing and understanding Earth. We represent the land surface with several types of maps and with satellite images that are informative and sometimes beautiful. We use two-dimensional and three-dimensional diagrams to depict the subsurface geometry of rock units and to show how these units interact with the surface.

A How Do Maps and Satellite Images Help Us Study Earth's Surface?

Satellite images and various types of maps are the primary ways we portray the land surface and the geology exposed at the surface. Maps of SP Crater in northern Arizona provide a particularly clear example of the relationship between geologic features and the land surface.

◁ A shaded relief map emphasizes the shape of the land by simulating light and shadows on the hills and valleys. Some hills on this map are small volcanoes called cinder cones or scoria cones. The area is dissected by straight and curving stream valleys. The simulated light comes from the left of the image.

▽ A topographic map shows the elevation above sea level of the land surface with a series of lines called contours. Each contour line follows a specific elevation on the surface.

Adjacent contour lines are widely spaced where the land surface is fairly flat (has a gentle slope).

Contour lines are more closely spaced where the land surface is steep, such as on the slopes of the cinder cones.

▽ A satellite image is produced by measuring different wavelengths of light to portray the distribution of different types of plants, rocks, and other features. The dark feature in the center of the image is a black, solidified lava flow that erupted from the base of SP Crater. SP Crater is the dark cinder cone connected with the flow.

◁ This photograph, taken from the air, shows the small volcano at SP Crater and a dark lava flow that erupted from the base of the volcano.

▷ A geologic map represents the distribution of rock units and geologic features on the surface. This one shows the SP Crater lava flow and older rock units. Compare the four maps to match specific features.

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B How Do We Represent Geologic Features in the Subsurface?

Most of the planet's geology is hidden from our view beneath Earth's surface. We are most aware that rock units exist where they are exposed in a mountainside or deep canyon, but such units are also present beneath areas of relatively flat topography. Geologic diagrams help us envision and understand the thicknesses, orientations, and subsurface distributions of rock units. Such diagrams are also one of the main ways that geologists document and communicate their understanding of an area.

1. A block diagram portrays in three dimensions the shape of the land surface and the subsurface distributions of rock units and geologic features such as faults and folds (if present).

2. A cross section shows the geology as a two-dimensional slice through the land. This example is equivalent to the front-left side of the block diagram.

3. A stratigraphic section with appropriate relative thicknesses shows the rock units stacked on top of one another.

4. The patterns within each rock unit visually represent the character of the unit, such as rounded pebbles in this orange-colored sedimentary unit.

5. One edge of the diagram (here the left edge) typically conveys the relative resistance of the different rock units to weathering and erosion. A more easily weathered and eroded unit is shown recessed, like the orange unit with the pebbles, whereas more resistant units are shown protruding farther out, like the two gray units.

Evolutionary diagrams are block diagrams or cross sections that show the history of an area as a series of steps, proceeding from the earliest stages to the most recent one. Here, a tan rock layer is deposited in the sea and later eroded.

Sketching Geology

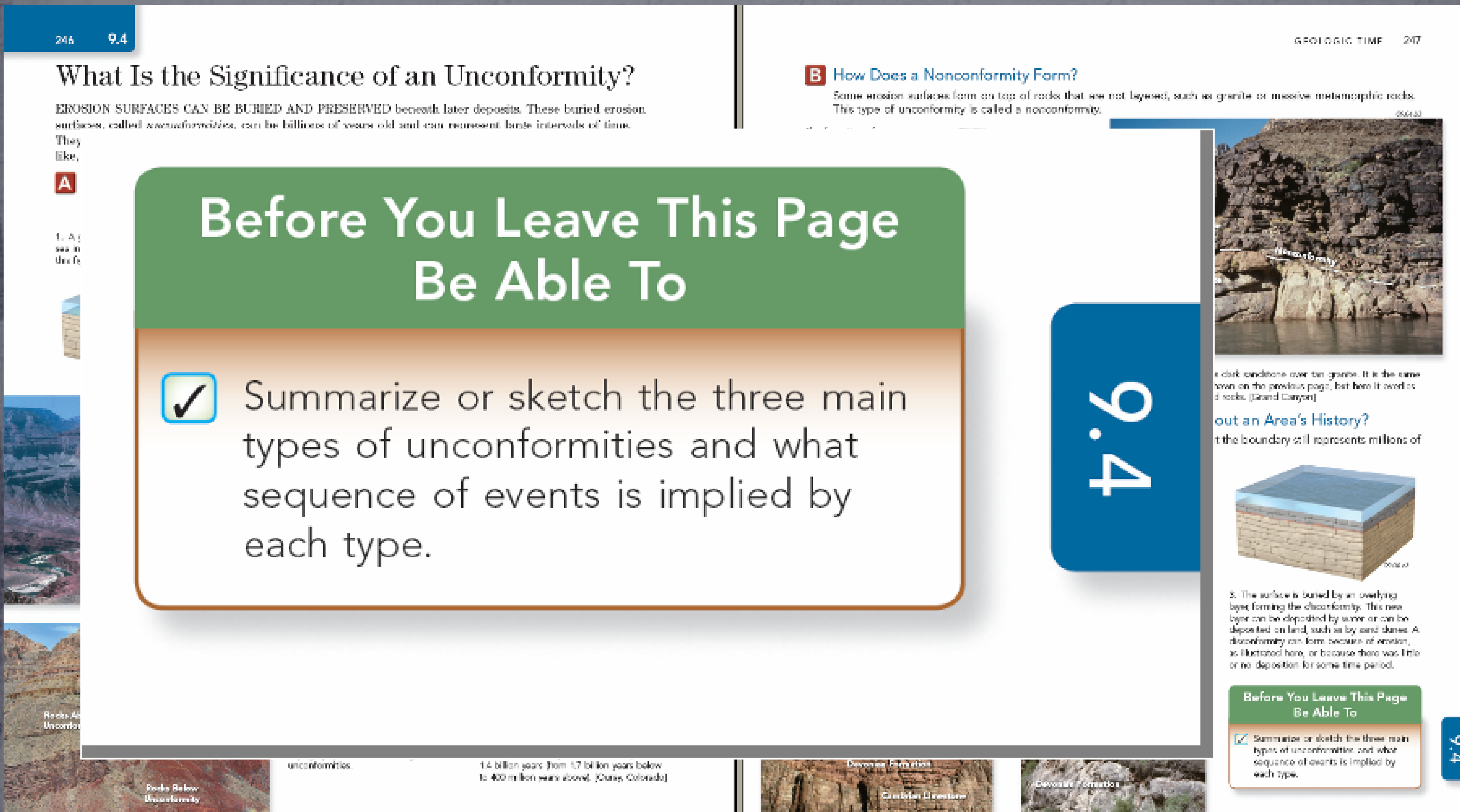
One of the more interesting challenges of geologic field studies is trying to visualize how geology exposed at the surface continues at depth. Sketches drawn in the field while studying the geology are an excellent way to capture one's thoughts while they are still fresh and while the ideas can be tested by making additional field observations. The field sketch to the right is a simplified geologic cross section drawn to summarize the field relationships for a faulted sequence of rocks. Such sketches are an excellent way to conceptualize and think about geology, either in the field or from a textbook.

Before You Leave This Page Be Able To

- Summarize how different types of maps depict Earth's surface.
- Sketch or describe the types of diagrams geologists use to represent subsurface geology and the sequence of rock units.
- Sketch or describe what is shown by a series of evolutionary diagrams.

2.6

Built-In What-to-Know List in Textbook



- Master list handed out at start of semester and guides all assessment

Investigation Spread: Authentic Inquiry

Who Polluted Surface and Groundwater in This Place?

SURFACE WATER AND GROUNDWATER IN THIS AREA are contaminated. You will use the geology of the area, along with elevations of the water table and chemical analyses of the contaminated water, to determine where the contamination is, where it came from, and where it is going. From your conclusions, you will decide where to drill new wells for uncontaminated groundwater.

Goals of This Exercise:

- Observe the landscape to interpret the area's geologic setting.
- Read descriptions of various natural and constructed features.
- Use well data and water chemistry to draw a map showing where contamination is and which way groundwater is flowing.
- Use the map and other information to interpret where contamination originated, which facilities might be responsible, and where the contamination is headed.
- Determine a well location that is unlikely to be contaminated.
- Suggest a way to remediate some of the contamination.

Procedures

Use the available information to complete the following steps, entering your answers in appropriate places on the worksheet.

1. This figure shows geologic features, rivers, springs, and human-constructed features, including a series of wells (lettered A through P). Observe the distribution of rock units, sediment, rivers, springs, and other features on the landscape. Compare these observations with the cross sections on the sides of the terrain to interpret how the geology is expressed in different areas.
2. Read the descriptions of key features and consider how this information relates to the geologic setting, to the flow of surface water and groundwater, and to the contamination.
3. The data table on the next page shows elevation of the water table in each lettered well. Use these data and the base map on the worksheet to construct a groundwater map with contours of the water table at the following elevations: 100, 110, 120, 130, and 140 meters. On the contoured map, draw arrows pointing down the slope of the water table to show the direction of groundwater flow.
4. Use the data table showing concentrations of a contaminant, purposely unnamed here, in groundwater to shade in areas where there is contamination. Use darker shades for higher levels of contamination.
5. Use the groundwater map to interpret where the contamination most likely originated and which facilities were probably responsible. Mark a large X over these facilities on the map and explain your reasons in the worksheet.
6. Determine which of the lettered well sites will most likely remain free of contamination, and draw circles around two such wells.
7. Devise a plan to remediate the groundwater contamination by drilling wells in front of the plume of contamination; mark these on the map with the letter R.

1. The region contains a series of ridges to the east and a broad, gentle valley to the west. Small towns are scattered across the ridges and valleys. There are also several farms, a dairy, and a number of industrial sites, each of which is labeled with a unique name.

2. A main river, called the Black River for its unusual dark, cloudy color, flows westward (right to left) through the center of the valley. The river contains water all year, even when it has not rained in quite a while. Both sides of the valley slope inward, north and south, toward the river.

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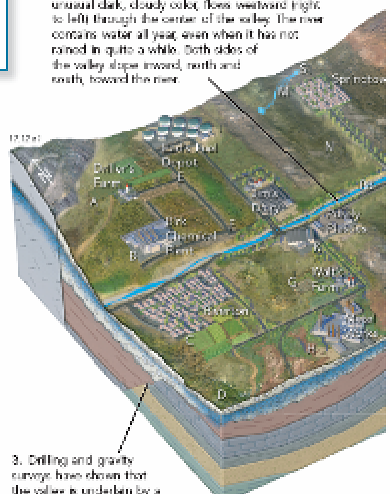

3. Drilling and gravity surveys have shown that the valley is underlain by a thick sequence of relatively unconsolidated and weakly cemented sand and gravel. The deepest part of the basin has been downdropped by normal faults, one of which is buried beneath the gravel.

6. Bedrock units cross the landscape in a series of north-south stripes, parallel to the strike of the rock layers. One of the north-south valleys is named Coal Mine Valley because it contains several large coal mines and a coal-burning, electrical generating plant. An unsubstantiated rumor says that one of the mines had some sort of chemical spill that was never reported. Activity at the mines and power plant has caused fine coal dust to be blown around by the wind and washed into the smaller rivers that flow along the valley.

7. A north-south ridge is composed of sandstone, which geologists call the *lower sandstone*. A few nice-tasting, freshwater springs issue from the sandstone where it is cut by small streams.

Stratigraphic Section

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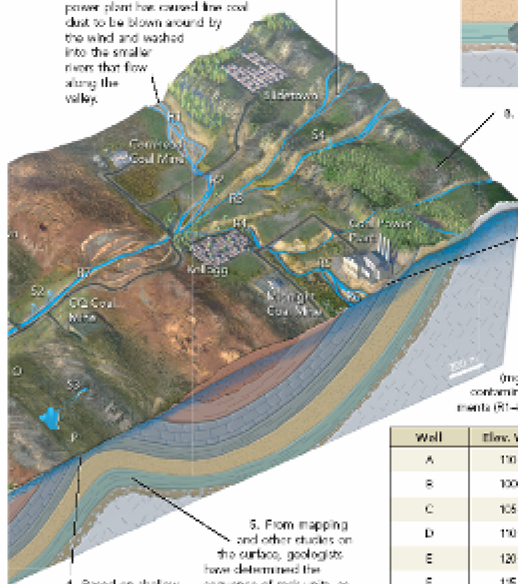


8. The highest part of the region is a ridge of granite and sedimentary rocks along the east edge of the area. This ridge receives quite a bit of rain during the summer and snow in the winter. Several clear streams begin in the ridge and flow westward toward the lowlands.

9. A coal-burning power plant was built over tilted beds of a unit named the *Sinkerton Limestone*, so-called because it is associated with many sinkholes, caves, and karst topography. The limestone is so permeable that the power plant has had difficulty keeping water in ponds built to dispose waste waters that are rich in the chemical substances that are naturally present in coal.

4. Based on shallow drilling, the water table (the top of the blue shading) mimics the topography, being higher beneath the ridges than beneath the valleys. Overall, the water table slopes from east to west (right to left), parallel to the regional slope of the land.

5. From mapping and other studies on the surface, geologists have determined the sequence of rock units, as summarized in the stratigraphic section in the upper right corner of this page. These studies also document a broad anticline and syncline beneath the eastern part of the region.

10. The tables below list water-table elevations in meters and concentrations of contamination in milligrams per liter (mg/L) for each of the lettered wells (A–P), and the concentration of contamination in samples from four springs (S1–S4) and eight river segments (R1–R8). The location of each sample site is marked on the figure.

Well	Elev. WT	mg/L
A	110	0
B	100	0
C	105	0
D	110	20
E	120	10
F	115	0
G	120	0
H	120	50

Well	Elev. WT	mg/L
I	130	30
J	125	0
K	120	0
L	130	0
M	140	50
N	140	0
O	140	0
P	140	0

Spring	mg/L
S1	50
S2	0
S3	0
S4	0

River	mg/L
R1	0
R2	20
R3	0
R4	0

River	mg/L
R5	0
R6	0
R7	5
R8	5

17.12

Online Content

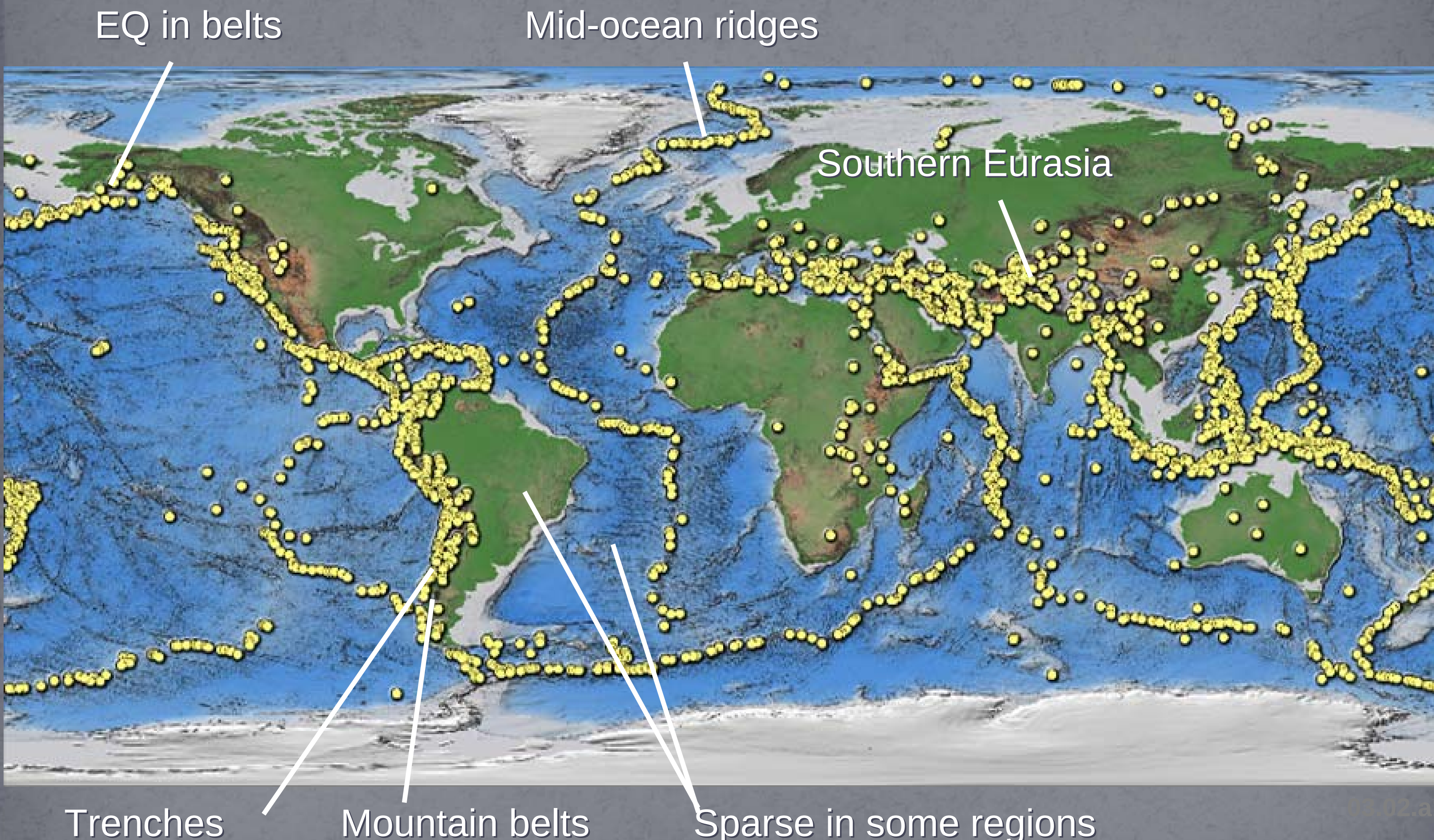
- Truly multimedia – images and narration
  - Photos
  - Illustrations
  - Animations
  - Video clips
  - Audio
  - Embedded assessment
- Graduate-student designed and produced media
- Formative and final assessment via online surveys and in-person interviews

Activites During Class

- Less covering of content (more time for activities consistent with goals)
- Time for student observations, interpretations, problem solving (critical thinking)
- PowerPoint with interactive media
- Think-Pair-Share, small-group discussions, and whole-class discussions
- Meaningful demonstrations
- CPS questions, including from online quizzes

Observe the location of cities with respect to mountains and valleys

Observe the pattern of earthquakes (yellow dots)



Assessment: Online Quizzes and Investigations

Which Areas Have the Highest Risk of Slope Failure?

THIS GEOLOGICALLY DIVERSE PLACE has stylized and exaggerated features that appear to be related to slope failure. Large angular blocks occur in several different settings, and some of the hills may not be stable or safe. You will use descriptions and images of these features to determine what hillslope processes are occurring in different areas, and how they impact where people may live safely.

Goals of This Exercise:

- Observe the landscape to investigate the geologic setting of different areas, and interpret the geologic setting from descriptions of each location.
- Assess the hazards in different areas.
- Construct a map that shows areas that have a high risk for different types of slope failure.
- Identify locations that you think are most safe, moderately safe, and least safe on which to build.

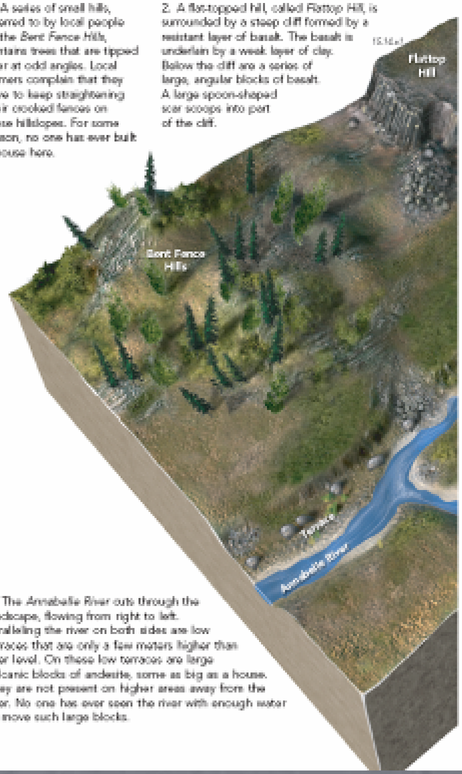
Procedures

Use the available information to complete the following steps, entering your answers in the appropriate places on the worksheet.

1. Observe the features shown on this landscape. Read the text boxes associated with each feature and decide what that statement implies about the geologic setting of the area and how the landscape reflects the underlying geology.
2. Think about the description of each area and consider possible types of slope failure that could have occurred there. Provide a reasonable interpretation of what types of slope processes are occurring and what key observations led you to that conclusion.
3. On the figure in the worksheet, draw approximate boundaries around areas that you interpret as having the highest risk for each type of slope failure. Label each area with a few words to identify the main hazard you interpret to be present.
4. Draw the letters S, M, and L on the map for sites where you think it would be relatively safe to live. Write an (S) for one or more relatively safe places, an (M) for a moderately safe place, and an (L) for each place you think is less safe to live. There is not a single best choice for any of these sites, so be prepared to describe your reasoning and defend your choice.

1. A series of small hills, referred to by local people as the *Bent Fence Hills*, contains trees that are tipped over at odd angles. Local farmers complain that they have to keep straightening their crooked fences on these hillslopes. For some reason, no one has ever built a house here.

2. A flat-topped hill, called *Flattop Hill*, is surrounded by a steep cliff formed by a resistant layer of basalt. The basalt is underlain by a weak layer of clay. Below the cliff are a series of large, angular blocks of basalt. A large spoon-shaped scar scoops into part of the cliff.



9. The *Annabelle River* cuts through the landscape, flowing from right to left. Paralleling the river on both sides are low terraces that are only a few meters higher than river level. On these low terraces are large volcanic blocks of andesite, some as big as a house. They are not present on higher areas away from the river. No one has ever seen the river with enough water to move such large blocks.

3. The highest mountain, called *Snow Mountain*, is an ice-capped volcano. The volcano has not erupted since people settled here, but steam occasionally rises from the central crater. Next to the volcano are huge blocks of andesite, some of which have a partially preserved coating of mud.

4. On the lower flanks of the volcano is a place named *Rock Valley*, which contains a mass of large rocks and other debris with hummocky topography. This mass can be followed back upslope to a huge, bare scar on the side of the volcano. This debris cuts across the paths of smaller streams that originated in adjacent hills. The area has no soil.

5. *Gray Mountain* contains a gray granite cut by widely spaced fractures that dip back into the mountain.

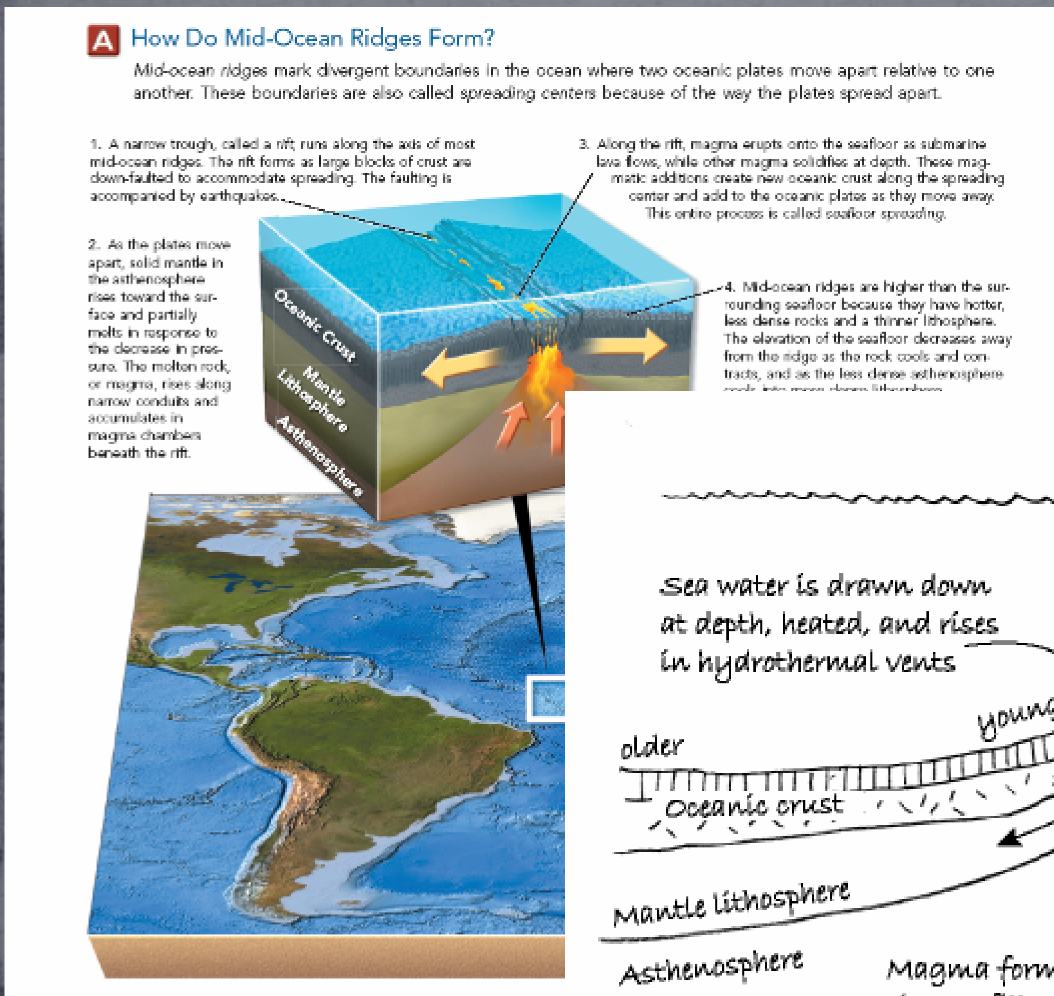
6. In *Wild Ride Valley*, a layer of volcanic ash has been altered and weathered into sticky clays. Roads crossing this area, such as shown in the photograph below, are very bumpy, have visible cracks and are in constant need of repair, especially when the weather changes back and forth between the rainy season and dry season.

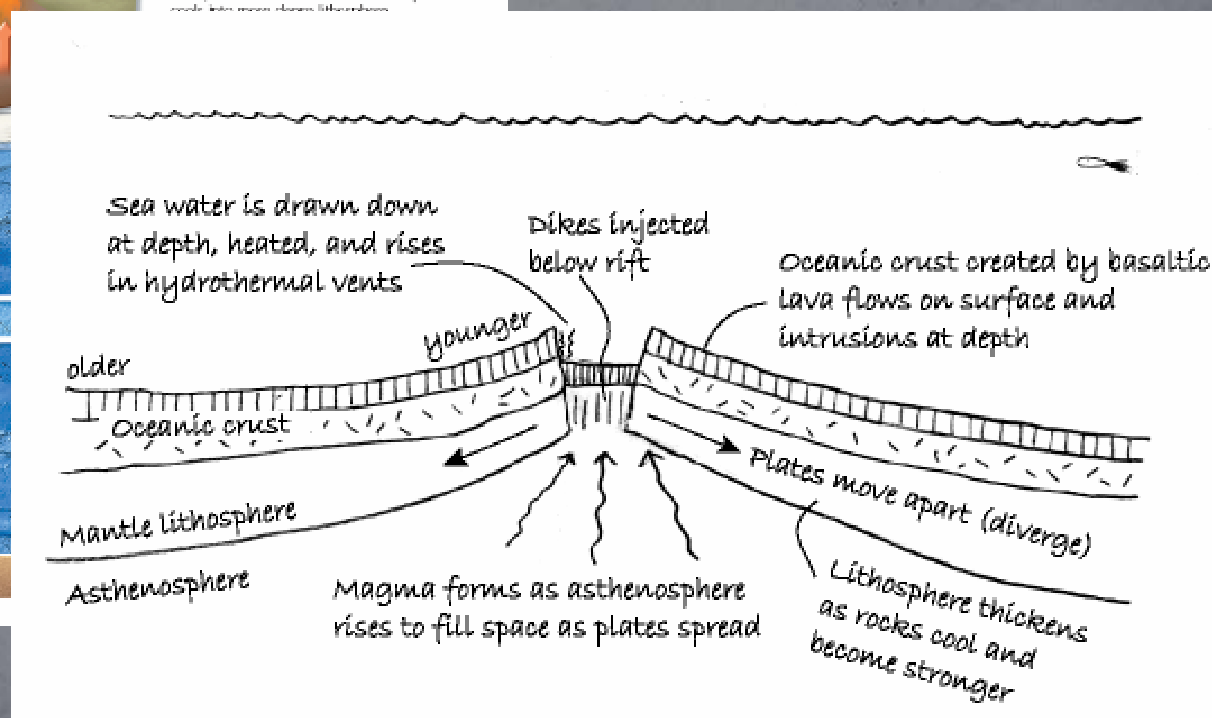
7. A mountain is called *Tilted Mountain* by the local people because of the way the tilted limestone layers are expressed on the mountain's sides. Cutting across the center of the mountain are some open fissures, which some people claim have become wider over the past several years.

8. The base of Tilted Mountain is a cliff exposing a shale layer beneath the limestone layers. Downhill from the cliff are huge blocks of limestone identical to the limestone that makes up the top of the mountain. These blocks are chaotically strewn about and not part of the underlying bedrock. Near an adjacent creek, the blocks are smooth and partially worn away.

15.14

Assessment: Concept-Sketch Exams

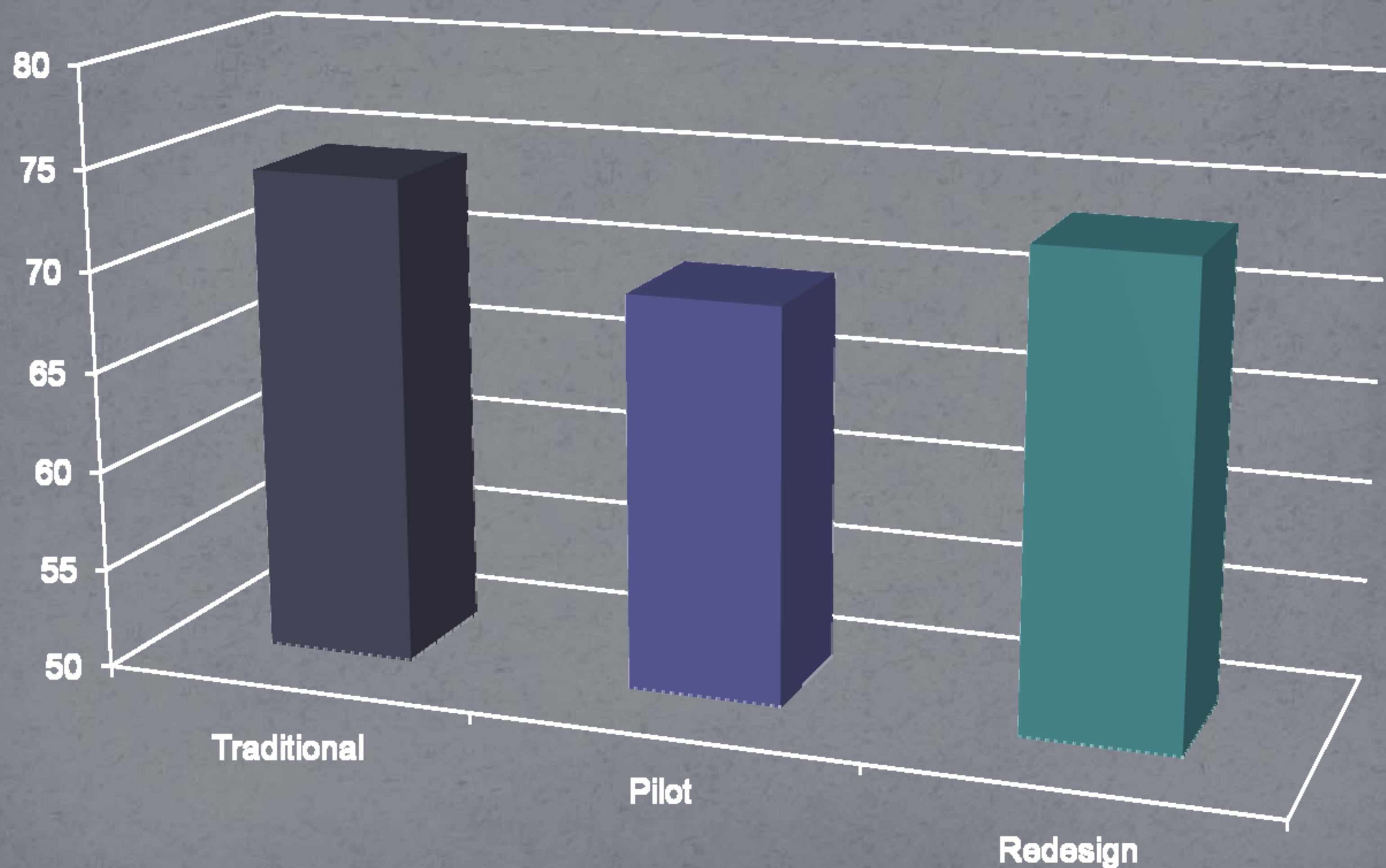




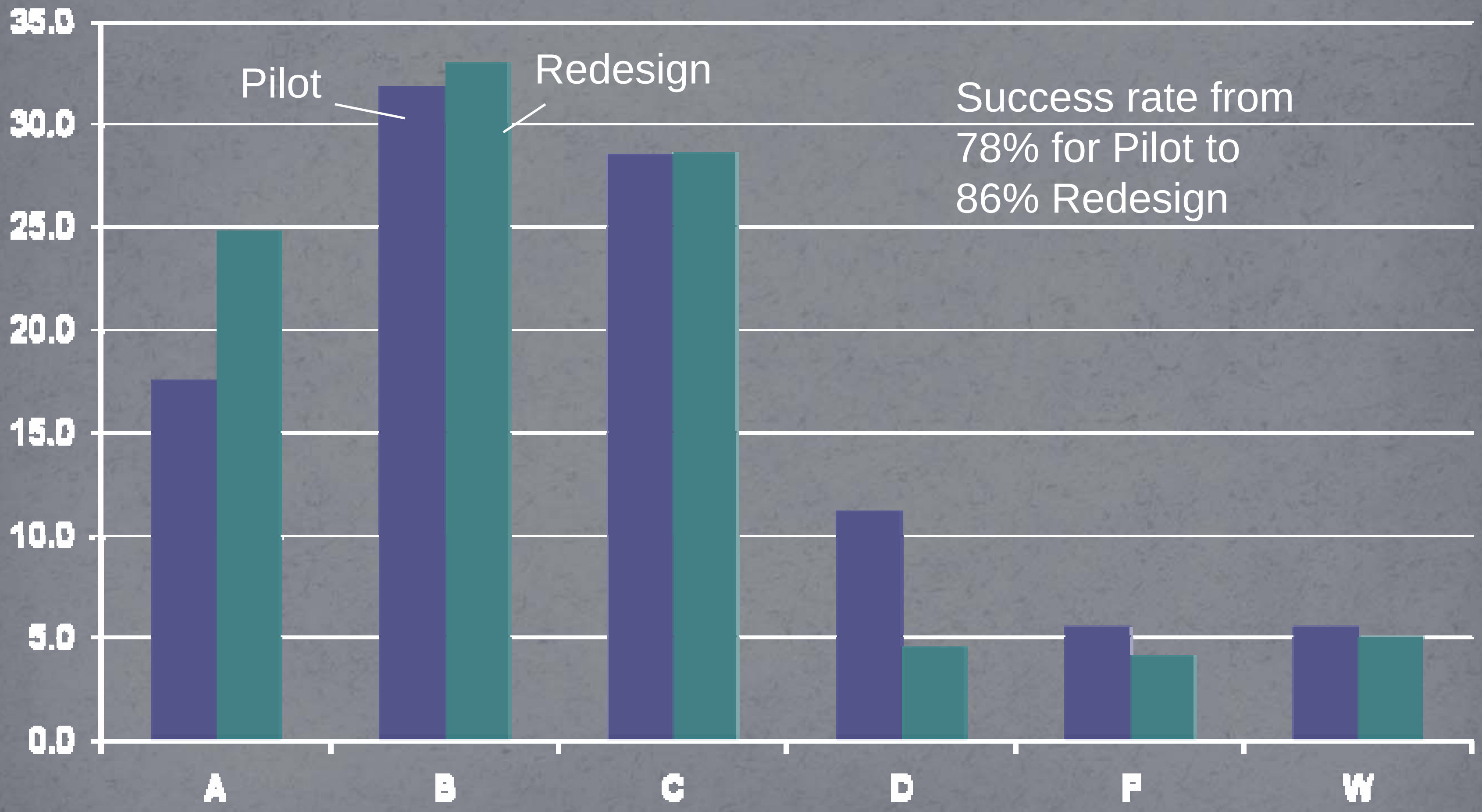
Redesign Experiment

- Quasi-experimental (intact sections)
- Traditional and Pilot taught by same instructor during same semester (Spring 2008) – same exams but pilot used online materials
- Compared Pilot versus fully Redesigned, which shared balance of in-class versus online
- Drastic revision of type of exams in summer 2008 (after pilot), moving to concept sketches only -- greatly improved class but made comparisons to traditional difficult

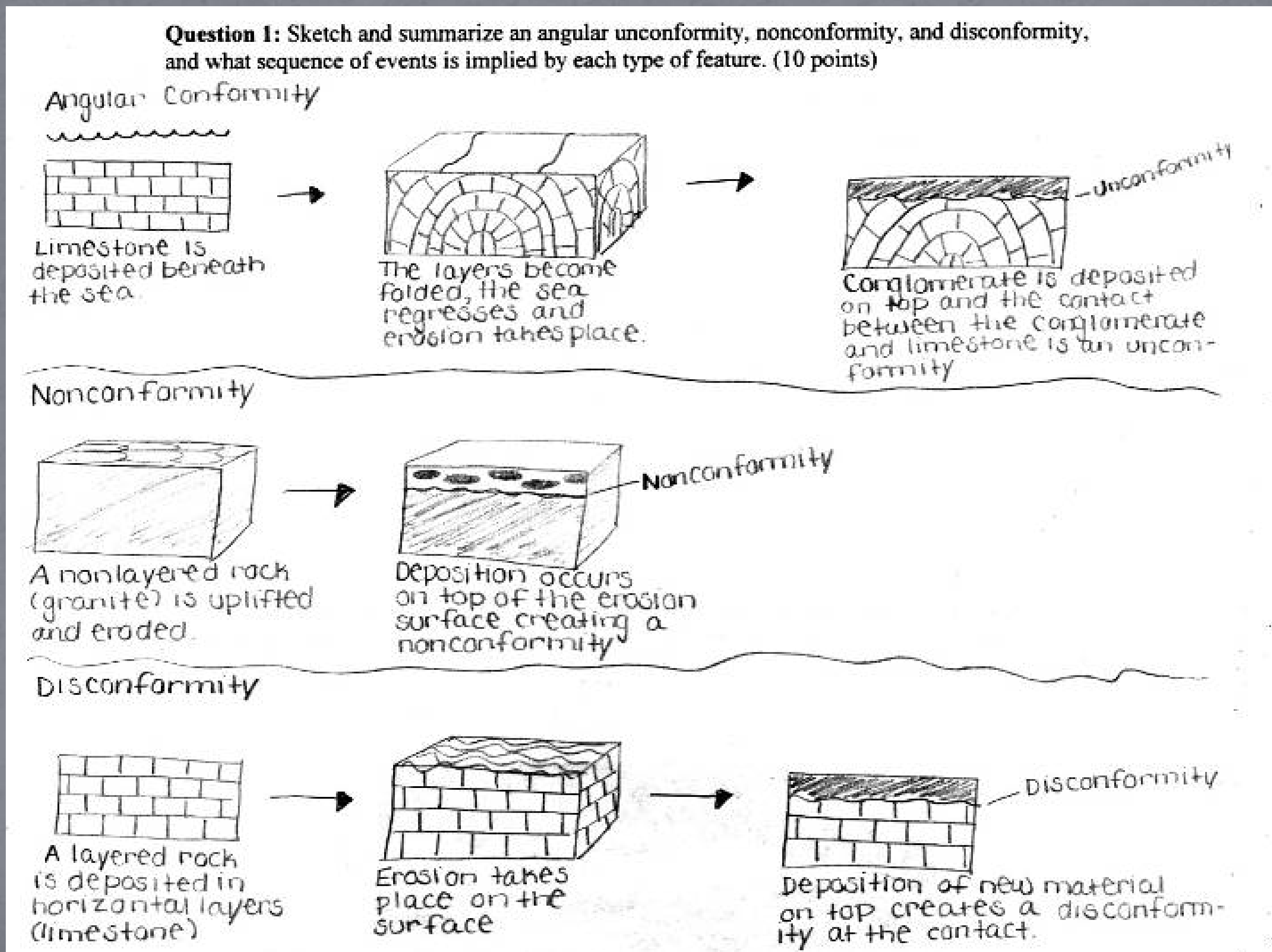
Results: Final Class Percentage



Results: Student Success (Grades)

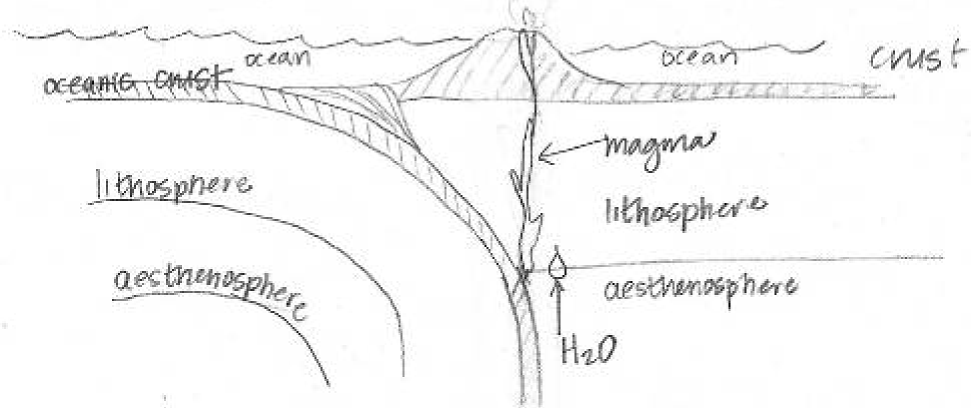


Results: Improved Concept Sketches



Results: Improved Concept Sketches

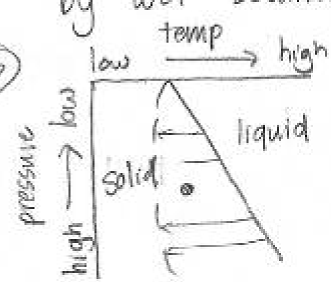
Question 2: • Sketch and describe how magma is generated in a subduction zone.



(1) in an ocean-ocean convergence (depicted above) one plate is subducted under another plate. As the depth of the plate increases, so does temperature & pressure

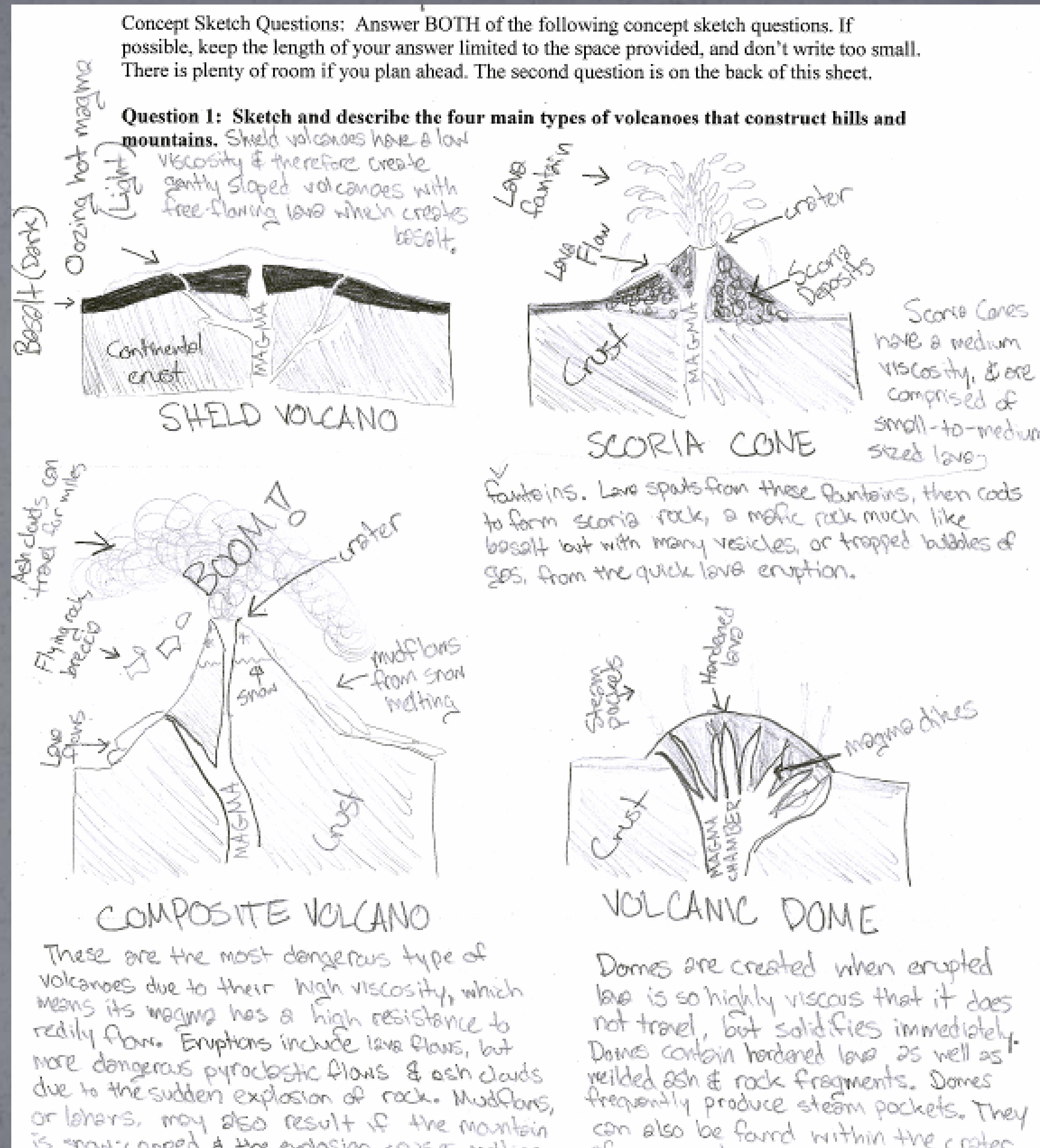
(2) changes in existing minerals occur b/c of the changes in temperature & pressure. This is called metamorphisiom. Minerals that contain water release it. H_2O is also introducted by wet sediments.

(3)



the introduction of water causes the environment to change from dry to wet. This causes a change in the melting point. Mantle melts easier. Mantle derived magma rises into the overlying plate.

Results: Improved Concept Sketches


Concept Sketch Questions: Answer BOTH of the following concept sketch questions. If possible, keep the length of your answer limited to the space provided, and don't write too small. There is plenty of room if you plan ahead. The second question is on the back of this sheet.

Question 1: Sketch and describe the four main types of volcanoes that construct hills and mountains. Sheld volcanoes have a low viscosity & therefore create gently sloped volcanoes with free-flowing lava which creates basalt.

Scoria Cones have a medium viscosity, & are comprised of small-to-medium sized lava fountains. Lava spouts from these fountains, then cools to form scoria rock, a mafic rock much like basalt but with many vesicles, or trapped bubbles of gas, from the quick lava eruption.

These are the most dangerous type of volcanoes due to their high viscosity, which means its magma has a high resistance to redily flow. Eruptions include lava flows, but more dangerous pyroclastic flows & ash clouds due to the sudden explosion of rock. Mudflows, or lahars, may also result if the mountain is snow-capped & the explosion causes melting

Domes are created when erupted lava is so highly viscous that it does not travel, but solidifies immediately. Domes contain hardened lava as well as welded ash & rock fragments. Domes frequently produce steam pockets. They can also be found within the crater

Cost and Time Savings

- Estimate 30% savings for instructors and more than 35% for teaching assistant
- Sources of savings
  - Less meetings per week (50% - 66% of original)
  - Less class preparation, exam preparation, and grading
  - Automation of quizzes and investigations (Blackboard)
  - Shared Resources
  - Photocopying
- Savings offset by
  - Increase in email traffic and issues with Blackboard

Implementation Issues

- Development of online materials
  - Involvement of students in process
  - Refinement of online materials using surveys, interviews, and degree of difficulty
  - Issues translating in-class or paper-based activities to Blackboard
- Buy-in of faculty members