McFadden, Weissman, and Johnson, *Encyclopedia of the Solar System*, chap. 4.

Shu, *The Physical Universe*, chaps. 5–6.

Wilson, *Astronomy through the Ages*, chap. 11.

Questions to Consider:

1. Before nuclear fusion was discovered, what would astronomers have thought powered the Sun? What important problems would those hypotheses have in terms of generating energy and sustaining output for billions of years?
2. What types of telescopes are best suited to studying the Sun? Why has the space age revolutionized solar research?
3. What do you think will happen when a main-sequence star starts to run out of hydrogen in its core?

Lecture Nine

Planetary Surfaces and Natural Wonders

Scope: The natural wonders of the world are magnificent surface features of Earth. Yet almost all of them are duplicated and exceeded elsewhere in the solar system. Our highest mountains are surpassed and even dwarfed by those of our neighbors. Our deepest canyons can seem but a minor scar by comparison. Our fiercest volcanic activity appears relatively tame. Many similar features are found on other planets and moons, albeit with intriguing variations. From an interplanetary perspective, it is Earth's oceans that are its signature characteristic—a characteristic that is directly related to its primary unique feature: life.

Outline

I. The study of other places in the solar system is best viewed in the context of comparative planetology.

- **A.** We will look at the rocky planets and the larger moons.
- **B.** We learn about other worlds by comparing their features to those on Earth.
- **C.** We learn about Earth by seeing the range of possibilities and where our planet fits in.

II. A tour of rocky surface features reveals many natural wonders of the solar system.

- **A.** Mountains are found on several worlds but are formed in different ways on each.
  1. Earth features long chains of mountains that are the result of plate tectonics.
  2. Mountains exist on the Moon; some of them are similar in height to those on Earth and are the result of impacts.
  3. Venus has several large mountain chains, probably formed by compressional tectonics.
- **B.** Volcanic activity is abundant in the solar system.
  1. Volcanoes on Earth form when oceanic plates meet continental or other oceanic plates.

2. Venus has more than 1000 volcanoes, and about 85% of its surface is covered by volcanic plains.
3. Venus has a unique volcanic feature called coronae, which are oval-shaped volcanic uplifts.
4. Mars has several very large shield volcanoes, including Olympus Mons—by far the largest volcano in the solar system.
5. Io, a small moon of Jupiter's, is covered with volcanoes that are constantly erupting.

C. Canyons have been carved both by water and by geologic forces.
1. The Grand Canyon of the Colorado River on Earth is about 150 kilometers long and about 2 kilometers deep.
2. Venus features deep, narrow canyons called chasmata (singular: chasma) that are hundreds of kilometers long and show abundant geologic faulting.
3. Valles Marineris on Mars is up to 7 kilometers deep and roughly 4000 miles long. Its walls show attributes of both fault scarps and water erosion.

III. Hydrology on Earth is based on water, but elsewhere it shows remarkable diversity.

A. Features resembling riverbeds provide evidence of flowing liquids on many worlds.
1. Rivers on Earth create distinctive and recognizable patterns.
2. Mars shows ample evidence of water flows in the past, although liquid water cannot exist on its surface today.
3. Saturn's giant moon Titan shows river channels probably carved by liquid methane, as well as strong evidence of methane lakes.
4. Sinuous channels on Mars and the Moon were created by lava flows.

B. Geysers in the solar system spew a variety of substances.
1. Earth's geysers release heated water from beneath its surface.
2. Towering methane geysers have been observed on Neptune's large moon Triton.
3. Jets of icy particles spewing from Saturn's moon Enceladus contribute to one of its rings.

C. Polar ice caps on Earth and Mars grow and shrink with the seasons.
1. Large portions of Earth's polar ice caps melt and refreeze each year.
2. The polar caps of Mars can nearly vanish in the summer as the carbon dioxide sublimes into the atmosphere.

D. Earth's most distinguishing feature is the oceans that cover nearly 70% of its surface.

IV. While it is natural to marvel at the diversity of surface features, one learns more by identifying their similarities.

A. Each of the rocky planets shows a dichotomy between rougher upland regions and smoother lowland plains.

B. Similar features indicate that similar geologic and hydrologic forces are at work.

Suggested Readings:

Beatty, Petersen, and Chaikin, *The New Solar System*, chaps. 7–12, 17–22.

Bell, *Postcards from Mars*.

Bennett, Donahue, Schneider, and Voit, *The Cosmic Perspective*, chap. 9.

Benson, *Beyond: Visions of Interplanetary Probes*.

De Pater and Lissauer, *Planetary Sciences*, chap. 5.

Hey, *Solar System*.

McFadden, Weissman, and Johnson, *Encyclopedia of the Solar System*, chaps. 6, 8, 10, 12, 16, 22–26, 44.

Questions to Consider:

1. How is it that Mars, a smaller planet, could have a volcano 10 times taller than any on Earth?
2. Would you expect all of the material in the volcanic plumes above Io to fall back to its surface? If not, what would happen to the excess material?
3. Could biology have developed in the methane lakes of Titan?