




1 2  **Chapter 24 – Planetary Geology**3  **Our Solar System: An Overview**

- The solar system includes:
 - Sun (~99.85 percent of mass of solar system)
 - Eight planets and their satellites
 - Asteroids
 - Comets
 - Meteoroids

4  **Orbits of the Planets**5  **Our Solar System: An Overview**

- Nebular Theory: Formation of the Solar System
 - The nebular theory explains the formation of the solar system
 - The Sun and planets formed from a solar nebula (a cloud of interstellar gases and dust)
 - Contracted due to gravity, most of the material collected in the center to form the hot *protosun*
 - Remaining material formed a thick, flattened rotating disk around the protosun
 - Repeated collisions of particles in the disk formed planetesimals (asteroid-sized objects)

6  **Our Solar System: An Overview**

- Nebular Theory: Formation of the Solar System
 - The solar nebula contracted
 - Repeated collision of planetesimals formed protoplanets
 - Mercury, Venus, Earth, Mars
 - Far from the Sun, ices (water, carbon dioxide, ammonia, methane) also contributed to the formation of planetesimals and protoplanets
 - Jupiter, Saturn, Uranus, Neptune

7  **Our Solar System: An Overview**












- The Planets: Internal Structures and Atmospheres
 - Terrestrial planets
 - “Earth-like,” “inner planets”
 - Mercury, Venus, Earth, Mars
 - Jovian planets
 - “Jupiter-like,” “outer planets”
 - Jupiter, Saturn, Uranus, Neptune

8  **Our Solar System: An Overview**

- The Planets: Internal Structures and Atmospheres
 - Internal Structures
 - Early segregation of material by chemical separation led to layering of planets
 - Terrestrial planets have iron/nickel cores and silicate crusts
 - Jupiter and Saturn have small iron-rich cores and hydrogen and helium outer layers
 - Uranus and Neptune have small iron-rich cores, ammonia and methane mantles, and hydrogen and helium outer layers

9  **Comparing the Internal Structures of the Planets**10  **Our Solar System: An Overview**

- The Planets: Internal Structures and Atmospheres
 - The Atmosphere of Planets
 - Solar heating and gravity affect the thickness of a planet’s atmosphere
 - Jovian planets have a very thick hydrogen- and helium-rich atmosphere
 - » Lesser water, methane, ammonia and other hydrocarbons
 - Terrestrial planets have a thin atmosphere composed of carbon dioxide, nitrogen, and oxygen

- 11  **Planetary Atmospheres**
- 12  **Our Solar System: An Overview**
- Planetary Impacts
 - Impact craters are the result of planetary collisions with massive bodies
 - Meteoroids with masses less than 10 kilograms lose 90 percent of their speed as they pass through Earth's atmosphere
 - Planetary impacts were more common in the early formation of the solar system
 - Period of intense bombardment
 - Craters excavated by objects that are several kilometers across often exhibit a central peak
- 13  **Formation of an Impact Crater**
- 14  **Lunar Crater Euler**
- 15  **Earth's Moon: A Chip Off the Old Block**
- The Moon is the largest satellite relative to its planet in the solar system
 - General characteristics
 - Diameter of 3475 kilometers
 - One-fourth of Earth's diameter
 - Temperature variations of 107°C to –153°C
 - Density is 3.3 times that of water
 - Gravitational attraction is one-sixth of Earth's
- 16  **Earth's Moon: A Chip Off the Old Block**
- How Did the Moon Form?
 - Result of a collision with a Mars-sized asteroid
 - 4.5 billion years ago
 - Earth was semi-molten
 - Debris from collision was ejected into orbit around Earth
 - Particles eventually coalesced into the Moon
- 17  **Earth's Moon: A Chip Off the Old Block**
- The Lunar Surface
 - Two types of terrain
 - Maria
 - Smooth plains of basaltic lava
 - Terrae or Lunar Highlands
 - Breccias elevated several kilometers above the maria
 - Impact Craters
 - Because the moon has no atmosphere, a 3-meter-wide meteoroid can create a 150-meter-wide crater
- 18  **The Moon**
- 19  **Earth's Moon: A Chip Off the Old Block**
- History of the lunar surface
 - Formation of the original crust
 - 4.4 billion years ago, magma ocean began to cool and underwent magmatic differentiation
 - Dense minerals sank
 - Less dense silicates floated to the surface
 - » Most common highland rock is anorthosite
 - Excavation of the large impact basins
 - Lunar crust was bombarded by debris
 - Frequency of bombardment decreased 3.8 billion years ago
- 20  **Large Impact Basins**
- 21  **Earth's Moon: A Chip Off the Old Block**
- History of the lunar surface

- Filling of mare basins
 - Maria basalts are 3.0–3.5 billion years old
- Formation of rayed craters
 - Meteoroid impacts that are younger than maria
 - Rays are lightly colored ejected material
 - Example: Copernicus crater

22 Earth's Moon: A Chip Off the Old Block

- Today's Lunar Surface: weathering and erosion
 - Lack of atmosphere and flowing water on the Moon
 - Tectonic forces no longer active
 - Erosion is dominated by impacts of tiny particles from space (*micrometeorites*)
 - Continually bombard surface and mixed upper layer of lunar crust
 - Crust is covered with soil-like lunar regolith
 - Composed of igneous rocks, breccia, glass beads, and *lunar dust*
 - Regolith is anywhere from 2 to 20 meters thick

23 Sampling the Lunar Surface

24 Terrestrial Planets

- Mercury: The Innermost Planet
 - Innermost and smallest planet
 - Revolves quickly, rotates slowly
 - Greatest temperature extremes in the solar system
 - Absorbs most of the solar radiation it receives
 - Has a magnetic field
 - Hot and fluid core
 - Vast, smooth terrains and heavily cratered terrain
 - Lobate scarps

25 Mercury

26 Terrestrial Planets

- Venus: The Veiled Planet
 - Second to the Moon in brilliance
 - Rotates in the opposite direction as other planets
 - *Retrograde motion*
 - Rotation is incredibly slow
 - Similar to Earth in size
 - Densest atmosphere of terrestrial planets
 - Atmosphere is 97 percent carbon dioxide
 - Extreme greenhouse effect
 - Surface marked by:
 - Lava flows, craters, and highlands

27 Venus

28 Lava Flows on Venus

29 Lava Flows on Venus

30 Terrestrial Planets

- Mars: The Red Planet
 - Half the diameter of Earth
 - Atmosphere
 - 1 percent as dense as Earth's
 - Primarily carbon dioxide
 - Mean surface temperature variations
 - –140°C at the poles in winter
 - 20°C at the equator in summer
 - Topography

- Pitted with impact craters filled with dust
 - Reddish color is due to iron oxide
- Period of extreme cratering ended 3.8 billion years ago
- Two-third of the surface is heavily cratered Martian highlands
- One-third of the surface is younger, lower plains

31 **Two Hemispheres of Mars**

32 **Terrestrial Planets**

- Mars: The Red Planet
 - Volcanoes on Mars
 - Volcanism prevalent throughout Martian history
 - Olympus Mons—largest volcano in the solar system
 - Resembles a shield volcano
 - Volcanoes are large because plate tectonics is absent on Mars
 - Formed by mantle plumes
 - Wind Erosion on Mars
 - Dominant force shaping the Martian surface is wind
 - Dust storms with winds up to 270 kilometer/hour

33 **Olympus Mons**

34 **Terrestrial Planets**

- Mars: The Red Planet
 - Water Ice on Mars
 - Ice is found within a meter of the surface poleward of 30 degrees latitude
 - Permanent ice caps are found on the poles
 - Maximum water ice held there is about 1.5 times the amount covering Greenland
 - Liquid water once flowed on Mars
 - Created stream valleys and related features

35 **Similar Rock Outcrops**

36 **Earth-Like Stream Channels**

37 **Jovian Planets**


- Jupiter: Lord of the Heavens
 - Largest planet
 - 2.5 times more massive than combined mass of all other planets, satellites, and asteroids in the solar system
 - Three main cloud layers
 - Innermost blue-gray layer of water ice
 - Middle orange-brown layer of ammonium hydrosulfide droplets
 - Outermost white layer of ammonia ice
 - Due to immense gravity, Jupiter is shrinking
 - Contraction generates heat that drives atmospheric circulation
 - Dark-colored belts
 - Cool material is sinking and warming
 - Light-colored zones
 - Warm material is ascending and cooling

38 **Jupiter**




39 **Jovian Planets**

- Jupiter: Lord of the Heavens
 - Great Red Spot
 - Enormous storm
 - Twice the size of Earth
 - Observed for over 300 years
 - Magnetic field

- Generated by a liquid metallic hydrogen layer
- Strongest in the solar system
- Bright auroras associated with magnetic field

40  **Jupiter's Aurora**41  **Jovian Planets**


- Jupiter's Moons
 - Jupiter has 67 moons
 - Four largest moons are the Galilean satellites
 - Ganymede
 - Has a dynamic core and magnetic field
 - Callisto
 - Roughly the size of Mercury
 - Io
 - Most volcanically active body in the solar system
 - Europa
 - Covered with ice, possibly liquid water under the ice

42  **Jupiter's Four Largest Moons**43  **Volcanic Eruption on Io**44  **Jovian Planets**



- Jupiter: Lord of the Heavens
 - Jupiter's Rings
 - Composed of fine, dark particles, similar to smoke particles
 - The main ring is composed of particles believed to be from the surfaces of the two small moons Metis and Adrastea

45  **Jovian Planets**

- Saturn: The Elegant Planet
 - Similar to Jupiter in atmosphere, composition, and internal structure
 - Atmosphere is 93 percent H and 3 percent He by volume
 - Saturn's Moons
 - 62 known moons
 - Titan is Saturn's largest moon
 - Larger than Mercury
 - Has a substantial atmosphere
 - Earth like geologic landforms
 - » Caused by methane "rain"

46  **Saturn's Satellites**47  **Jovian Planets**

- Saturn: The Elegant Planet
 - Saturn's Ring System
 - Composed of small particles (water ice and rocky debris) that orbit the planet
 - Most rings fall into one of two categories based on particle density
 - Thought to be debris ejected from moons
 - Origin is still being debated

48  **Saturn's Rings**49  **Saturn's Ring Moons**50  **Jovian Planets**

- Uranus and Neptune: Twins
 - Both equal in diameter and bluish in appearance
 - Result of methane in the atmosphere
 - Mantles are water, ammonia, methane
 - Uranus takes 84 Earth years to complete one revolution around the sun
 - Neptune takes 165 Earth years to complete one revolution around the Sun

51  **Jovian Planets**

- Uranus and Neptune: Twins
 - Uranus: The Sideways Planet
 - Rotates on its side
 - Due to a large impact
 - Uranus' moons
 - Moons have varied terrains
 - Uranus' rings
 - 10 sharp-edged rings orbiting the equatorial region

52  **Uranus**53  **Jovian Planets**


- Uranus and Neptune: Twins
 - Neptune: The Windy Planet
 - Dynamic atmosphere
 - One of the windiest places in the solar system
 - Large dark spots are short-lived storms
 - Neptune's moons
 - 14 known satellites
 - Triton is the largest Neptunian moon
 - » Has an atmosphere
 - » Has cryovolcanism—eruptions of water ice, methane ice, and ammonia ice
 - Neptune's rings
 - Has five rings: two broad and three narrow

54  **Neptune**55  **Triton**56  **Small Solar System Bodies**

- Asteroids: Leftover Planetimals
 - Asteroids are small bodies
 - Left over from the formation of the solar system
 - Irregular shaped, porous bodies
 - » "piles of rubble"
 - Most orbit in the asteroid belt between Mars and Jupiter
 - Only four asteroids with diameters greater than 400 kilometers
 - 1–2 million asteroids with a diameters greater than 1 kilometer
 - Some have very eccentric orbits
 - » 1000–2000 Earth-crossing asteroids

57  **Asteroid Belt**58  **Giant Asteroid Vesta**59  **Small Solar System Bodies**

- Comets: Dirty Snowballs
 - Comets are also leftover material from the formation of the solar system
 - Loose collection of rocky material, dust, water ice, and frozen gases
 - Most reside in the outer reaches of the solar system
 - Take hundreds of thousands of years to orbit the Sun
 - Some short-period comets (orbital period less than 200 years)
 - Halley's Comet
 - Comet Holmes


60  **Comet's Tail**61  **Small Solar System Bodies**

- Comets: Dirty Snowballs

- Structure and composition of comets
 - Small central body called a nucleus
 - Escaping gases and dust around the nucleus is the coma
 - As a comet approaches the Sun, most develop a tail that points away from Sun due to:
 - Radiation pressure
 - Solar wind

62  **Comet Holmes**63  **Small Solar System Bodies**

- Comets: Dirty Snowballs
 - The realm of comets: The Kuiper belt and Oort cloud
 - The Kuiper belt exists beyond Neptune and contains comets in orbit around the Sun
 - Halley's Comet originated in the Kuiper belt
 - The Oort cloud consists of comets distributed in all directions from the Sun
 - Only a tiny fraction of Oort cloud comets come into the inner solar system

64  **Comet Wild 2**65  **Small Solar System Bodies**

- Meteoroids: Visitors to Earth
 - A meteoroid is a small, solid particle
 - Called meteors when they enter Earth's atmosphere
 - Originate from:
 - Interplanetary debris
 - Material ejected from asteroid belt
 - Rocky/metallic remains of a comet
 - Meteor Showers
 - A meteor shower occurs when meteor sightings increase to 60 or more per hour
 - Associated with debris ejected from comets
 - Meteoroids large enough to survive passage through Earth's atmosphere originate from the asteroid belt
 - A few have blasted craters onto Earth's surface

66  **Meteor Crater**67  **Small Solar System Bodies**

- Meteoroids: Visitors to Earth
 - Types of meteorites
 - The remains of meteoroids found on Earth are referred to as meteorites
 - Classified by composition
 - Irons
 - » Aggregates of iron with 5–20 percent nickel
 - Stony (chondrites)
 - » Silicate minerals with inclusions of other minerals
 - » *Carbonaceous chondrite* contains organic compounds
 - Stony-irons
 - » A mixture of stony and iron

68  **Iron Meteorite**69  **Small Solar System Bodies**

- Dwarf Planets
 - Dwarf planets are round and orbit the Sun but are not large enough to sweep debris from their orbital paths
 - Pluto is a dwarf planet
 - Smaller than Earth's Moon
 - Other dwarf planets include Eris (a Kuiper belt object) and Ceres (largest known asteroid)

70  **Pluto's Surface**

- 71  **Swirling Patterns on Pluto**
- 72  **Relative Sizes of Dwarf Planets**
- 73 