




1  **Planetary "Geology"****Earth 12<sup>th</sup> Edition - Chapter 24**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  **Orbits of the Planets**6  **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)

7  **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

8  **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


9  **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

10  **Comparing the Internal Structures of the Planets**11  **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


12  **Planetary Atmospheres**

13  **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

14  **Formation of an Impact Crater**


15  **Lunar Crater Euler**

16  **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

17  **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

18  **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

19  **The Moon**

20  **Lunar Surface Features**

21  **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

22 **Formation of lunar maria, stage one:**

23 **Formation of lunar maria**

24 **Large Impact Basins**

25 **20-km wide crater Euler**

26 **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

27 **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

28 **Harrison Schmitt**

29 **Footprint in the Lunar "soil"**

30 **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

31 **Mercury**

32 **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

33 **Computer generated view of Venus**


34 **Venus**

35 **Lava Flows on Venus**

36 **Lava Flows on Venus**

37  **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

38  **Two Hemispheres of Mars**39  **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

40  **Olympus Mons**41  ***Pathfinder: first geologist on Mars***42  ***The Valles Marineris canyon system on Mars***43  **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

44  **Similar Rock Outcrops**45  **Earth-Like Stream Channels**46  ***Crater wall, water gullies***47  ***Streamlined islands in Ares Valles***48  ***Terraces and stream channel***49  ***Patterned ground: permafrost?***50  **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

51  **Jupiter**52  ***Artist's view of Jupiter with the Great Red Spot visible***53  ***Atmospheric structure***54  **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

55  **Jupiter's Aurora**56  **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


57  **Jupiter's Four Largest Moons**58  ***Io***59  ***Europa***60  ***Ganymede***61  ***Callisto***62  **Volcanic Eruption on Io**63  **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



64  **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"

65  **The ring system of Saturn**66  **Saturn & moons**67  **Saturn's Satellites**68  **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

69  **Saturn's Rings**70  **Saturn's Ring Moons**71  **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

72  **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

73  **Uranus**74  **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

75  **Neptune**76  **Triton**77  **Small Solar System Bodies**

- Asteroids: Leftover Planetesimals
  - 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

78  **Asteroid Belt**79  **Giant Asteroid Vesta**80  ***Eros***81  ***Eros***82  **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

83  **Comet’s Tail**84  **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

85  **Comet Holmes**86  **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



87  **Comet Wild 2**88  ***Orbits of Kuiper Belt Objects***89  **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

90  **Meteor Crater**91  **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

92  **Iron Meteorite**93  ***Iron meteorite found near Meteor Crater, Arizona***94  ***Meteor Crater, Arizona***95  **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)

96  **Pluto’s Surface**97  **Swirling Patterns on Pluto**98  **Relative Sizes of Dwarf Planets**99  ***The End !!!***