# **Planetary Surface Processes**

















Karunatillake et al. (2009)





# Mappable surfaces of the solar system



# **Planetary Surface Processes**

Cratering Gravity **Tectonics** Volcanism Winds Fluvial Glacial Chemical weathering

















# They're everywhere!

# The sky *is* falling!

"I would rather believe that two Yankee professors would lie than believe that stones fall from heaven."

—Thomas Jefferson

# The sky *is* falling!

TABLE 3 Chances of dying from selected causes (USA)

Cause of death	Chances
Motor vehicle accident	1 in 100
Murder	1 in 300
Fire	1 in 800
Firearms accident	1 in 2,500
Asteroid/comet impact (lower limit)	1 in 3,000
Electrocution	1 in 5,000
ASTEROID/COMET IMPACT	1 in 20,000
Passenger aircraft crash	1 in 20,000
Flood	1 in 30,000
Tornado	1 in 60,000
Venomous bite or sting	1 in 100,000
Asteroid/comet impact (upper limit)	1 in 250,000
Fireworks accident	1 in 1 million
Food poisoning by botulism	1 in 3 million
Drinking water with EPA limit of TCE*	1 in 10 million

\* EPA, Environmental Protection Agency; TCE, trichloroethylene.

Chapman & Morrison (1994)

# Terminology





#### 1) meteoroid



2) meteor

3) meteorite

# Meteor (Barringer) Crater, AZ

# Upheaval Dome, UT



# Clearwater Lakes, Quebec

### Simple craters



#### Contact and compression stage

 Most of projectile's energy, momentum transferred to target rocks

- $t_{cc} \approx 2R/v_i$
- Rankine-Hugoniot equations can be solved for pressure

 At few km/s, energy per unit mass ≈ that of TNT





#### Cinder Lake Crater Field, AZ



### Ejection/excavation stage

 Rarefraction wave vaporizes/melts/ fractures rocks

•  $t_{cf} \approx (D/g_p)^{1/2}$ 

~10 s for Meteor crater

~13 min for Mare Imbrium



#### Collapse/modification stage

- Steep rim of transient crater collapses into interior
- $t \approx \text{few x } (D/g_p)^{1/2}$
- Final depth  $d \approx 0.2D$
- Rim height  $h \approx 0.04D$

FOLD

• Diameter  $D \approx 20R$ 

PRE-IMPACT HORIZONTAL SURFACE

Kring (2007,

Po

## Victoria Crater as viewed by Opportunity

Bedrock

Pre-Impact Surface

Squyres et al. (2009)

### Complex craters



#### Simple vs. complex craters





Worthington (1908)



#### Simple vs. complex craters



Kring (2006)

#### Multi-ring basins



### Multi-ring basins



# Multi-ring basins

