

2. del

# **NARAVNA TVEGANJA**

## 6. Poglavje

# PADEC IZVENZEMELJSKIH (EKSTRATERESTIČNIH) OBJEKTOV



# Tunguska



# Tunguska

- 30. junija 1908 nad dolino reke Tunguska raznese modro-belo ognjeno kroglo.
- Udarna moč piša je bila enaka 10 Mt TNT ali 10 vodikovim bombam.
- Zravnane in požgane je bilo 2,000 km<sup>2</sup> gozda.
- Eksplozijo se je slišalo na najmanj 1,000,000 km<sup>2</sup>.
- Premer asteroida ocenjujejo na 20 to 50 m.
- Na srečo se je dogodek zgodil na izredno redko poseljenem območju.
- Podoben dogodek bi se skoraj zgodil 2004 in se lahko zgodi v bodočnosti.

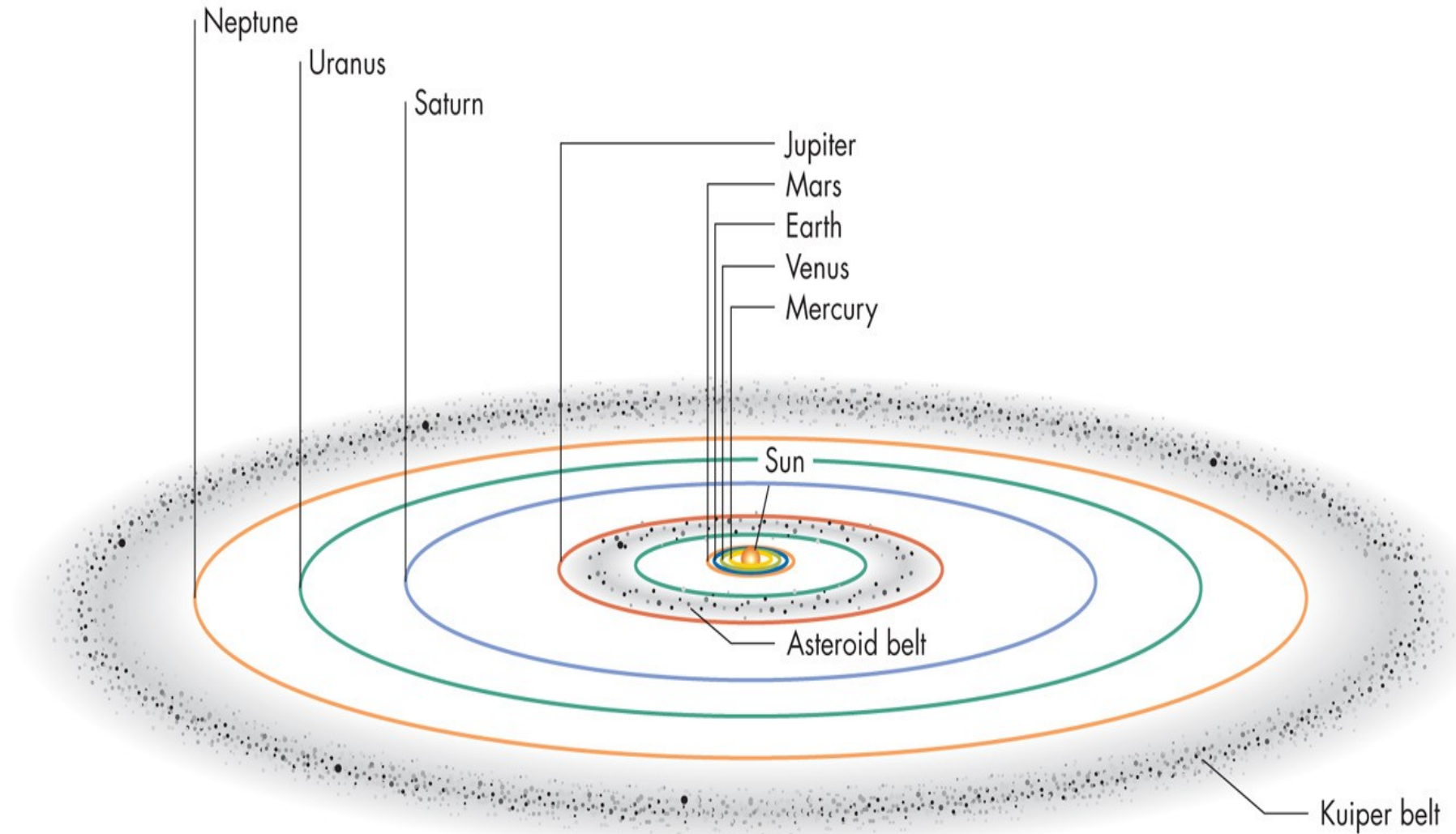
# 34. naloga

- Poišči več podatkov in razlag o dogodku Tunguska.
- Kaj veš o dogodku leta 2004?
- Kaj veš o podobnih dogodkih v Evropi in Sloveniji?

# Položaj Zemlje v Vesolju

- Edini planet v Sončnem sistemu, na katerem je življenje.
- Edini planet, ki ga je življenje preoblikovalo.
- Stalni udarci materiala iz vesolja – trilijoni delcev v našem osončju – od prahu do asteroidov, meteoroidov in kometov.
- Meteoroidi in asteroidi so iz asteroidnega pasu med Marsom in Jupitrom, kometi iz Kuiperjevega pasu ali Oortovega oblaka.

# Sončni sistem





**TABLE 11.1** Meteorites and related objects

Type	Diameter	Composition	Comments
Asteroid	10 m–1000 km	Metallic or rocky	Strong and hard, if metallic, or solid rock. Some hard types may impact Earth. If they are friable or weak, they likely will break up in atmosphere of Earth at elevations of several km to hundreds of kilometers. Most originate in the asteroid belt between Mars and Jupiter.
Comet	Few meters to few hundred kilometers	Frozen water and/or carbon dioxide plus small rock fragments and dust; “dirty snowball”; core is ice surrounded by rock particles.	Weak, porous; will often explode in atmosphere of earth at elevations of several kilometers to several hundreds of kilometers. Most originate in the outer solar system, such as the Oort Cloud 50,000 kilometersAU <sup>1</sup> from the Sun or from the Kuiper belt of comets. The comet tail is produced as ices sublimate (vaporize) and gases and dust particles are shed from the object.
Meteoroid	Less than 10 m to more than dust size	Stony, metallic, or carbonaceous (contains carbon)	Most originate from collisions of asteroids or comets. May be strong or very weak.
Meteor	Centimeter to dust size	Stony, metallic, carbonaceous, or icy	Are destroyed in Earth’s atmosphere. “Shooting star” light produced by frictional heating in the atmosphere.
Meteorite	Variably larger than dust to asteroid size	Stony or metallic	Actually impact Earth’s surface. Most abundant type of stony meteorite is called chondrite. <sup>2</sup>

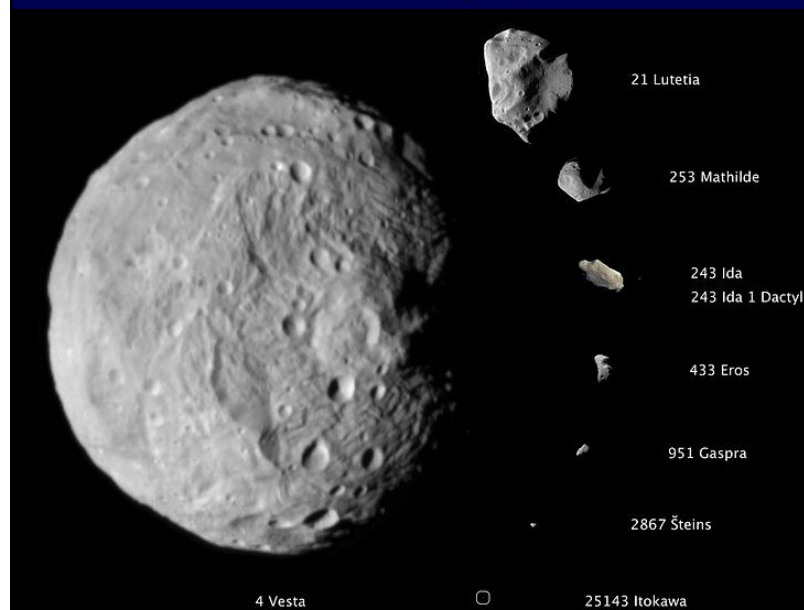
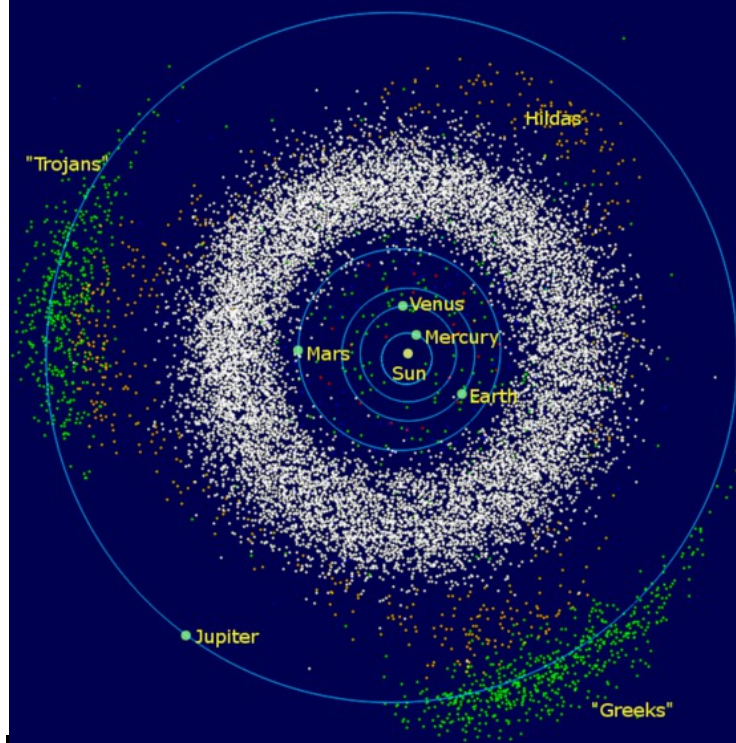
<sup>1</sup> 1 AU is the distance from Earth to the Sun, about 93 million miles (150 million km).

<sup>2</sup> There are many types of chondrites. They contain chondrules, which are small (less than 1 mm) spheroidal inclusions that are glassy or crystalline. It is the chondrite meteorites (asteroids) from which planets are constructed.

Source: Data from Rubin, A. F., 2002, *Disturbing the Solar System*, Princeton, NJ: Princeton University Press.

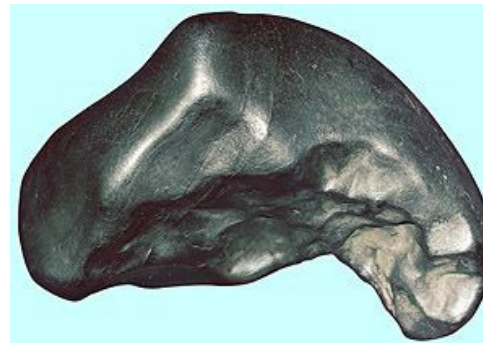
# Asteroidi

- Veliki od 10 m do 1000 km.
- Kamniti, kovinski in kamnito-kovinski.
- Večinoma prihajajo iz asteroidnega pasu med Marsom in Jupitrom.
- Zaradi medsebojnih trkov se jim spremeni krožnica in lahko sekajo Zemljino orbito.

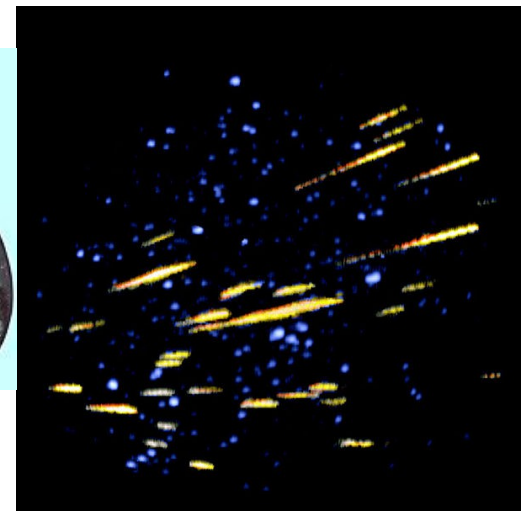


# Meteoroidi, meteorji in meteorit

- Velikost od prahu do nekaj metrov.
- Nastanejo, če se asteroid razbije v manjše dele.
- Ko meteorid vstopi v Zemljino atmosfero, ga imenujemo meteor.
- Delci, ki padejo na površje Zemlje so meteoriti.
- Meteorski dež – veliko število meteorjev.



Avče, 1908



# Kometi

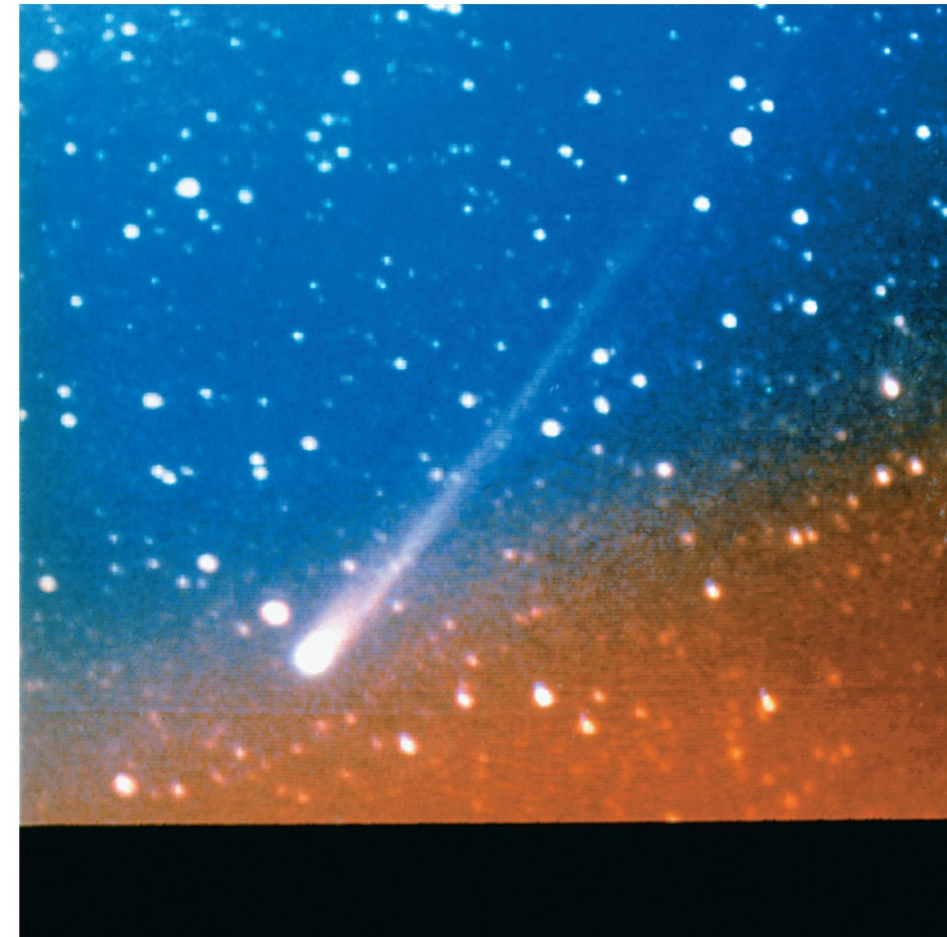
- Veliki so od nekaj metrov do nekaj sto kilometrov.
- Sestavljeni so iz kamnitega jedra, obdanega z ledom ter prekrita z ogljikom bogatim prahom.
- Izvirajo zelo daleč (50.000x razdalja med Zemljo in Soncem) v sončnem sistemu, za Neptunom, v Kuiperjevem pasu in Oortovem oblaku.
- Včasih sekajo Zemljino krožnico.
- Značilen rep kometa nastane zaradi prahu in plinov, ki uhajajo, ko ga ogreva Sonce in se potijejo po vesolju.

- Komet Hale – Bopp  
1997



ion, Inc.

- Halleyev komet

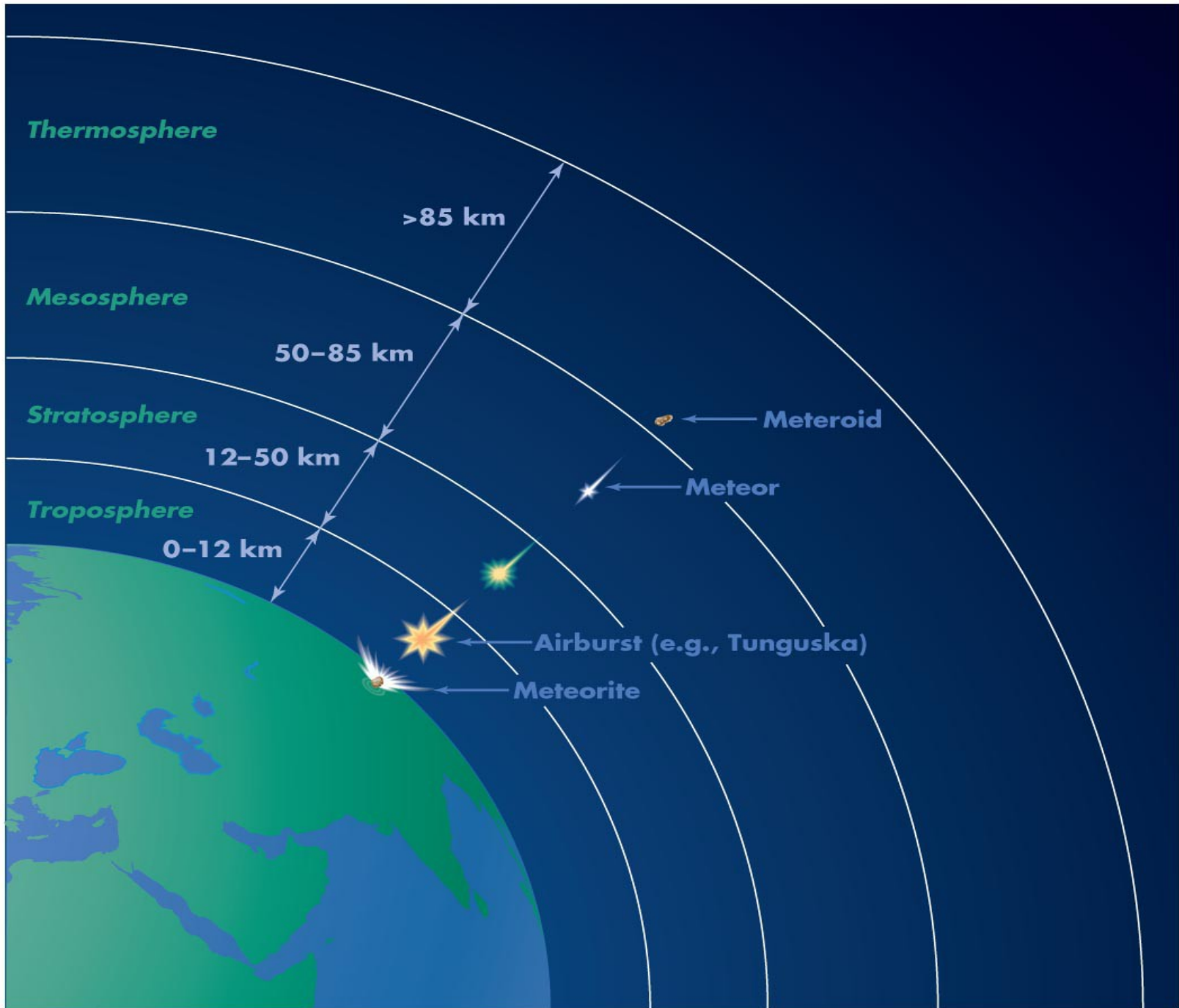


# Zgodnji razvoj Zemlje

- Bombardiranje meteoroidov, asteroidov ali kometov (MAC).
- K nastanku in razvoju Zemlje so prispevali tudi MAC.
- Njihovi udarci so imeli konstruktivni in destruktivni učinek.
- Asteroidi in kometi vsebujejo vodo, kakršna je prispevala tudi k nastanku Zemljine vode.

# Eksplozije in udarci

- Hitrosti, ki jih dosežejo MAC ob vstopu v Zemljino atmosfero so približno 12 do 72 km/s.
- Zaradi vročine, ki nastane ob trenju ob vstopu s Zemljino atmosfero na višini ~85 km nad površjem Zemlje, zažarijo.
- Žareče telo imenujemo meteor.
- V atmosferi lahko na višini 12 – 50 km eksplodirajo (airburst) ali trčijo na površino - meteor.





# 35. naloga

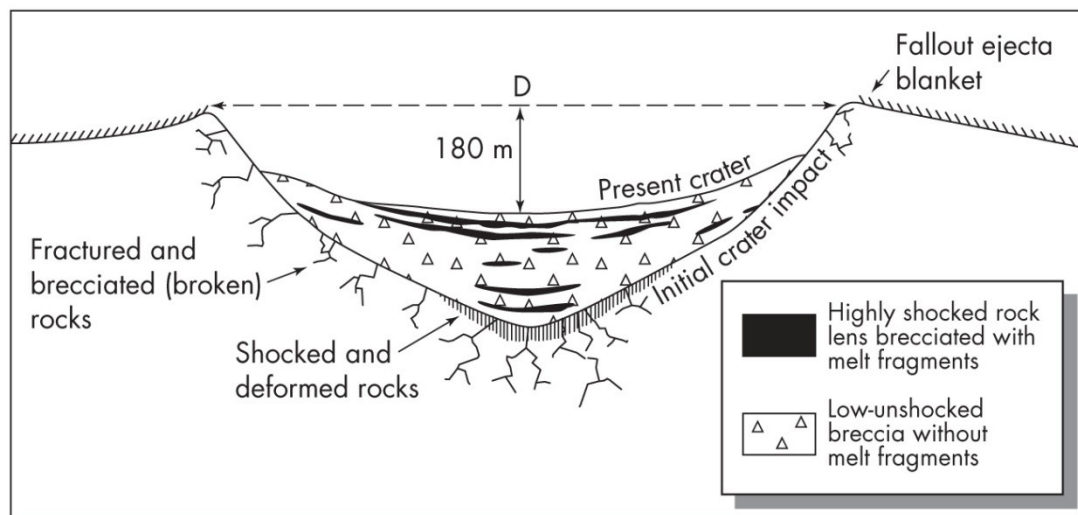
- Zakaj je na Luni in Marsu vidnih bistveno več udarnih kraterjev kot na Zemlji?

# Udarni kraterji

- So neposreden in najbolj očitni dokaz padcev meteoritov.
- So popolnoma drugačni od kraterjev, ki nastanejo z drugimi geološkimi procesi, ker so povezani z izredno visokimi temperaturami,



(a)

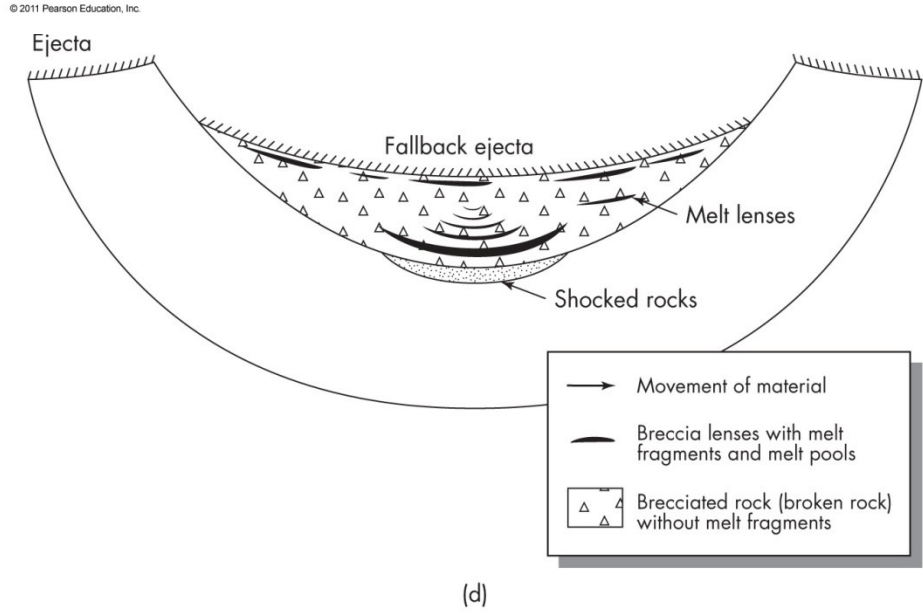
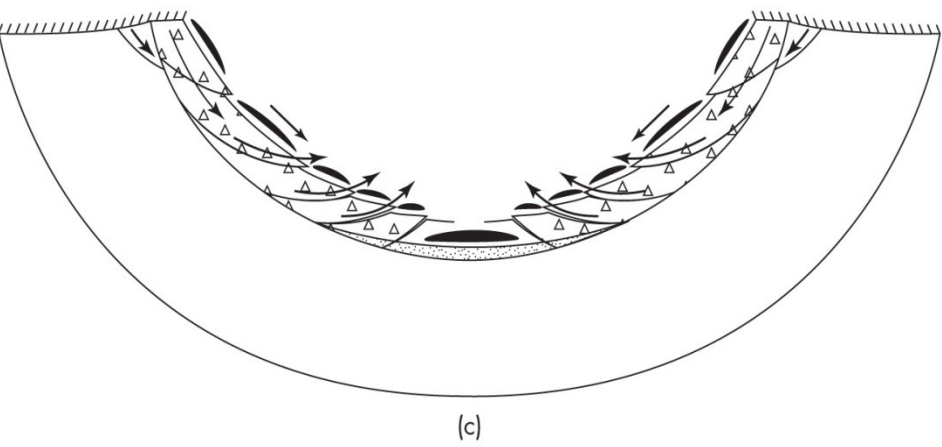
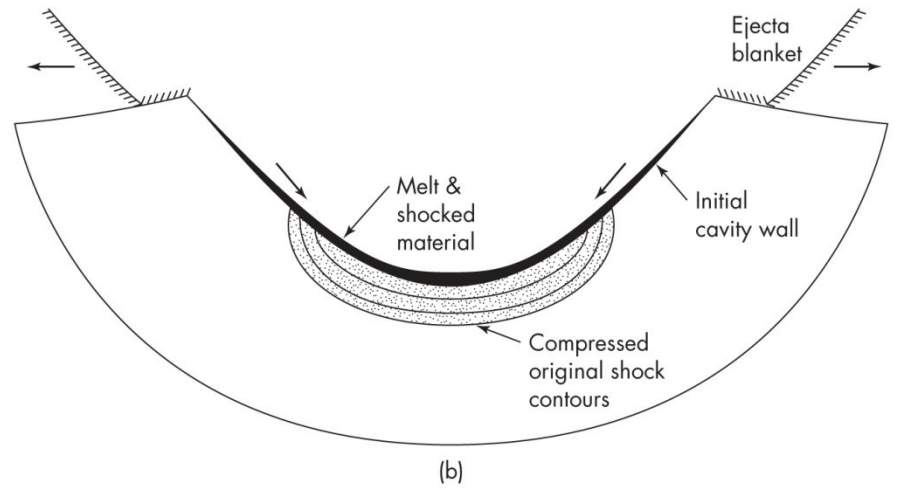
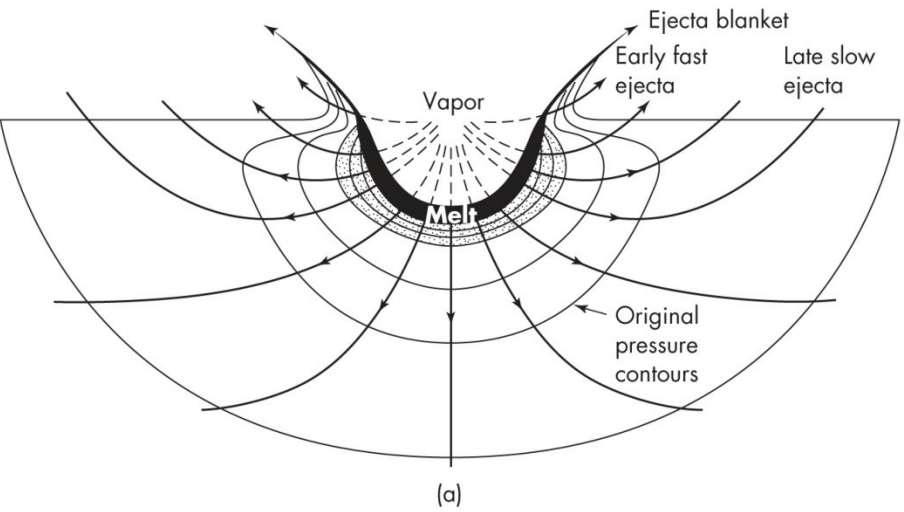


(b)

# Udarni kraterji

- Večina energije ob udarcu je kinetične, ki se ob udarcu prenese v Zemljino površje kot udarni val.
- Ta stisne, segreje, stali in izvrže material na površju Zemlje – nastane krater.
- Ob udarcu manjših teles nastanejo manjši do nekaj km veliki enostavni kraterji, ob udarcu večjih, kraterji s premerom preko 100 km in bolj kompleksni.
- Udarec lahko metamorfozira kamnine na področju udarca, ali pa jih stali in upari.
  - Nastanek visokotlačnih modifikacij mineralov.

# Enostavni krater



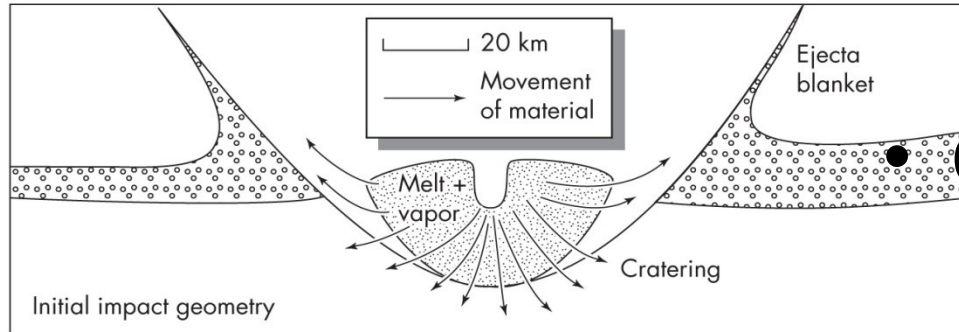
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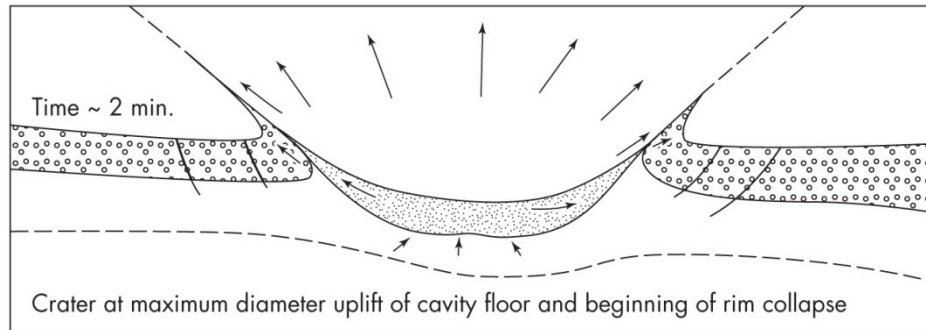
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# Kompleksni krater



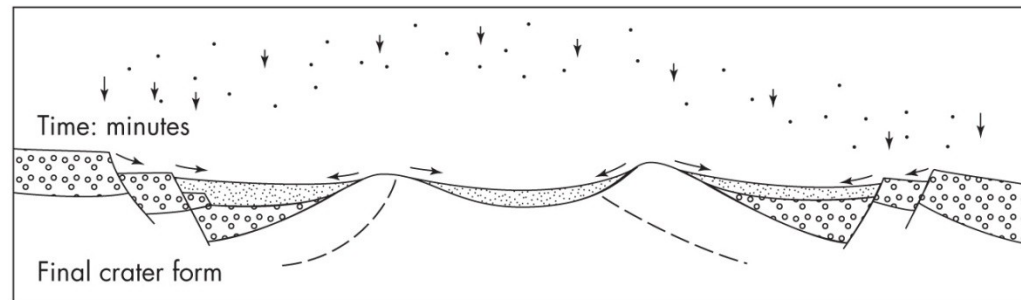
(a)

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(c)

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(e)

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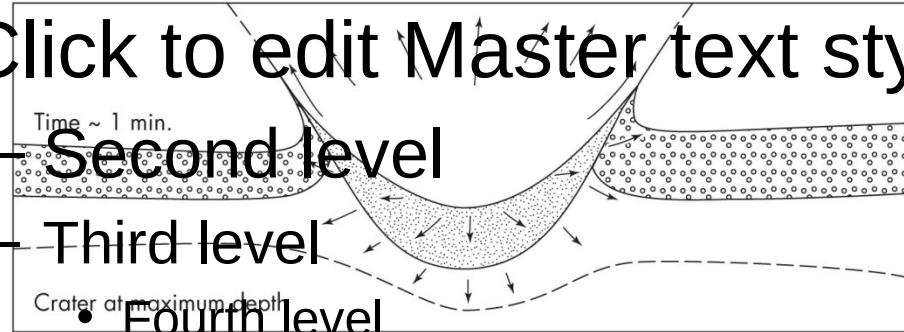
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Time ~ 1 min.  
— Second level

— Third level

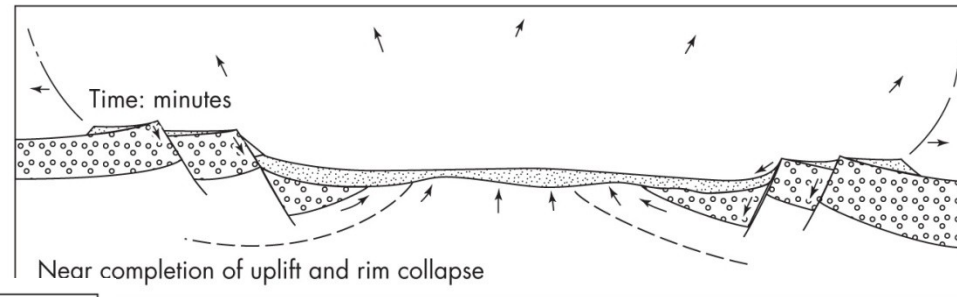
• Fourth level

— Fifth level



(b)

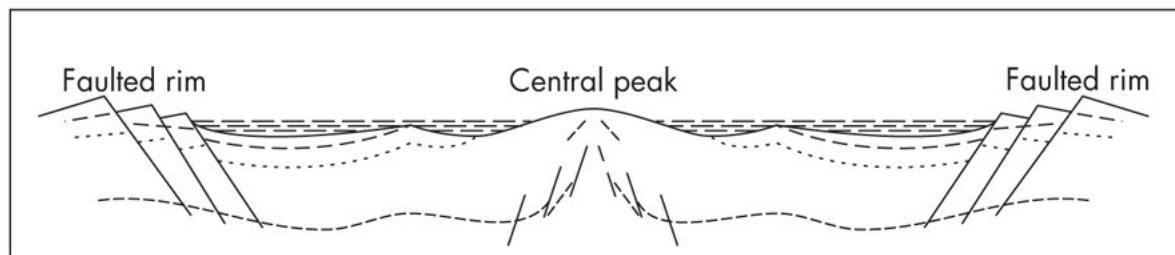
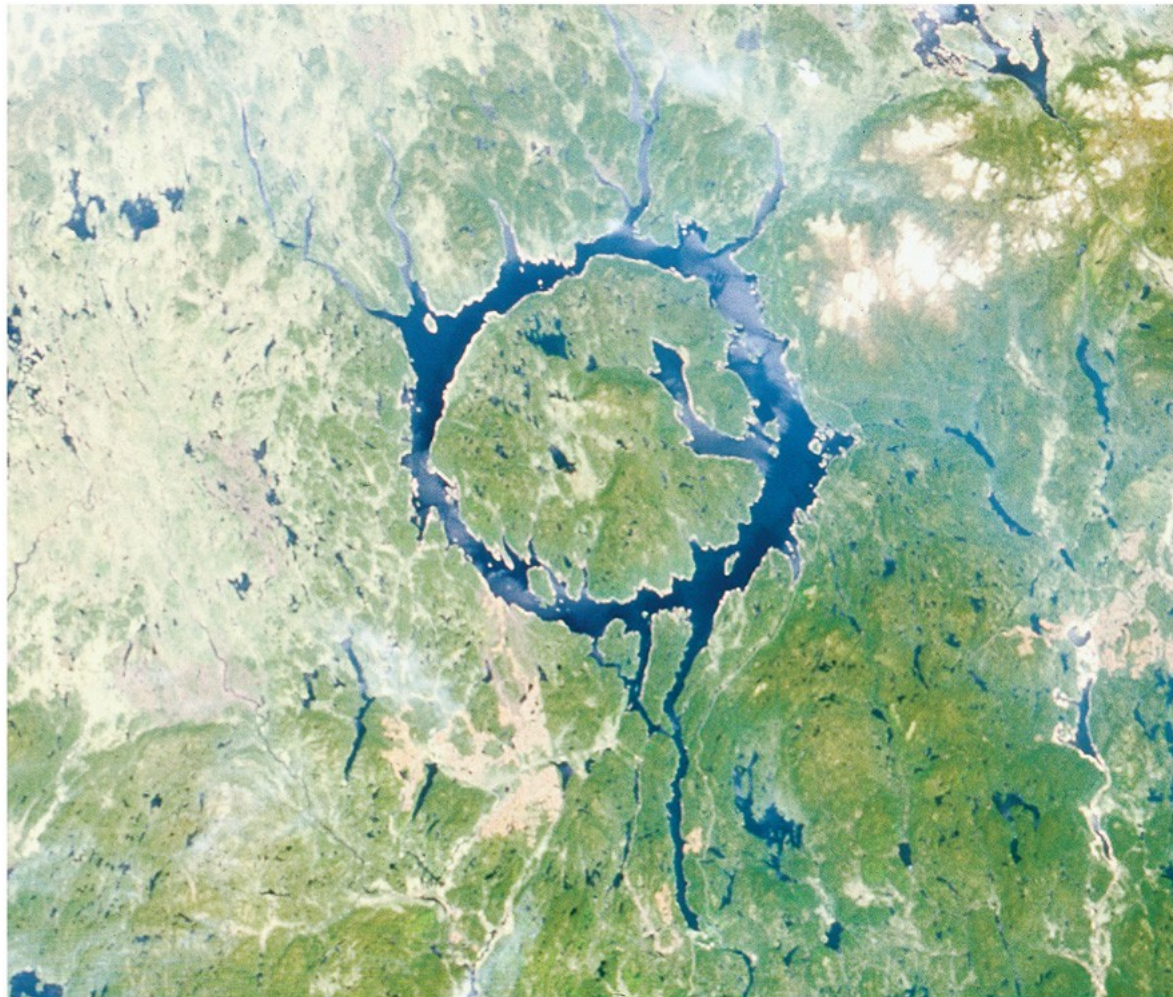
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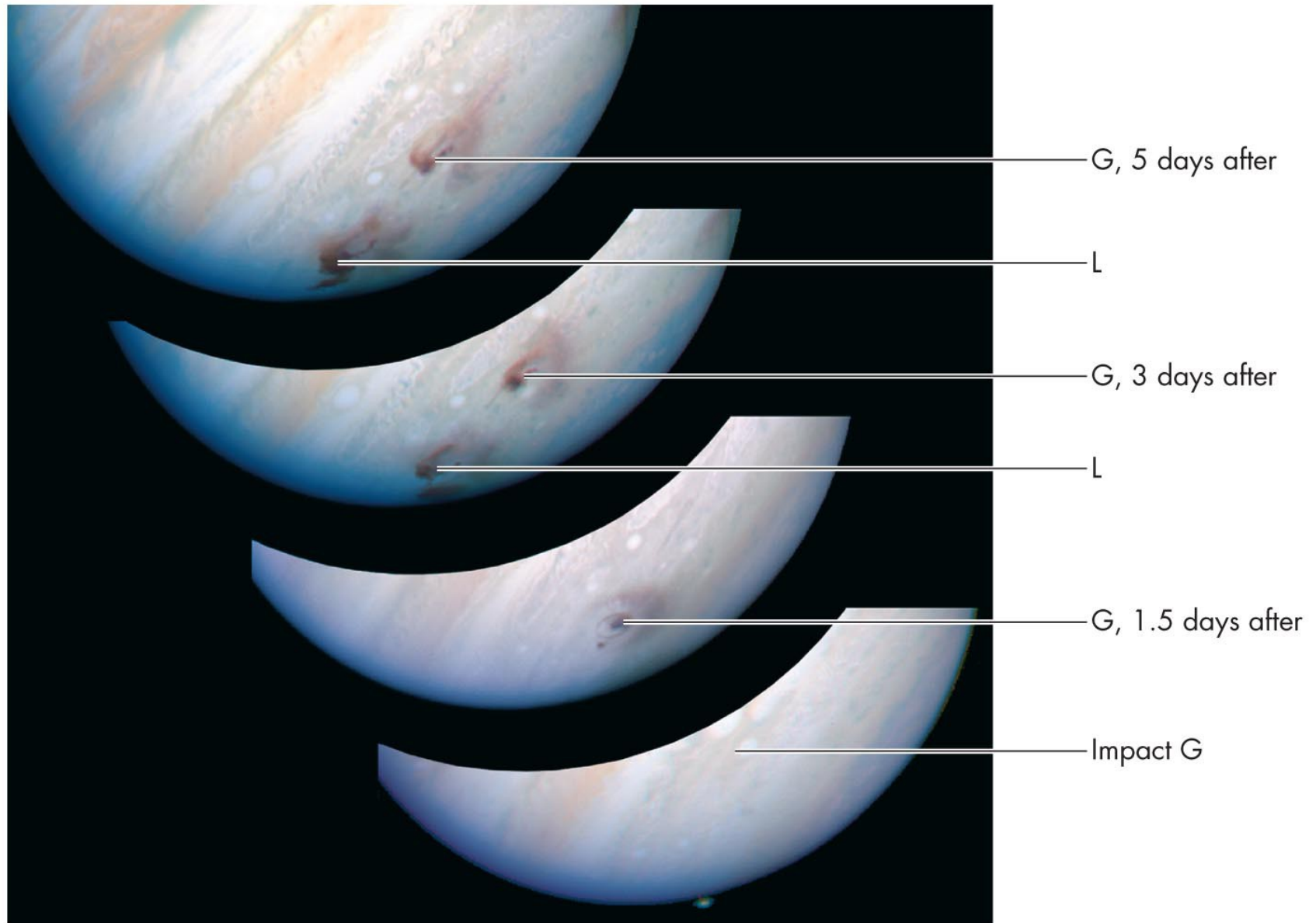
(d)

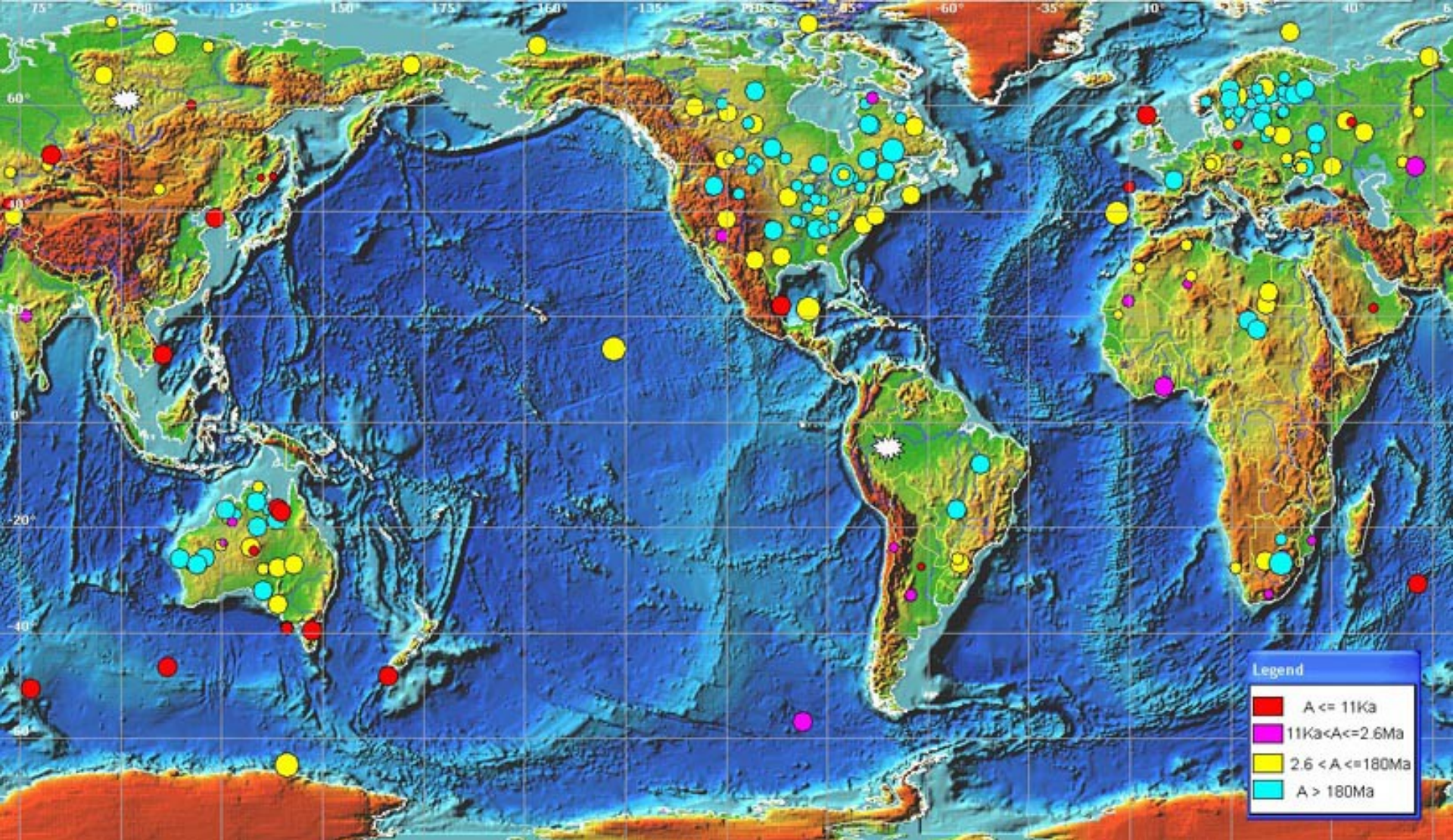
tion, Inc.

# Manicougan udarni krater v Kanadi



# Jupiter: udarec Shoemaker – Levy 9G



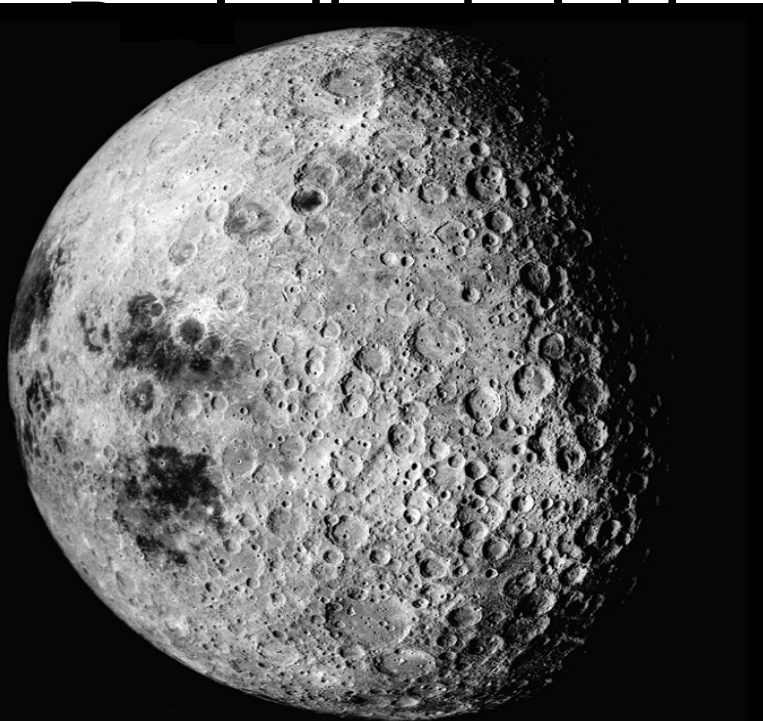


Map of confirmed impact structures on the Earth surface (180 structures) and on the oceanic bottom (24 structures). Size of circles is proportional to the crater diameter. Color shows the age of formation divided into four groups. White stars depict the epicenters of two largest air blasts of the XX century - Tunguska (1908) and Brasil (1930). Density of land impacts basically reflects the quality of geological mapping of the territory rather than actual spatial distribution of the impact structures. It should be noted that 16 of 24 known oceanic craters were discovered during just two years (2005-2006) after beginning of systematic search of submarine impact structures.



# Udarci meteorjev

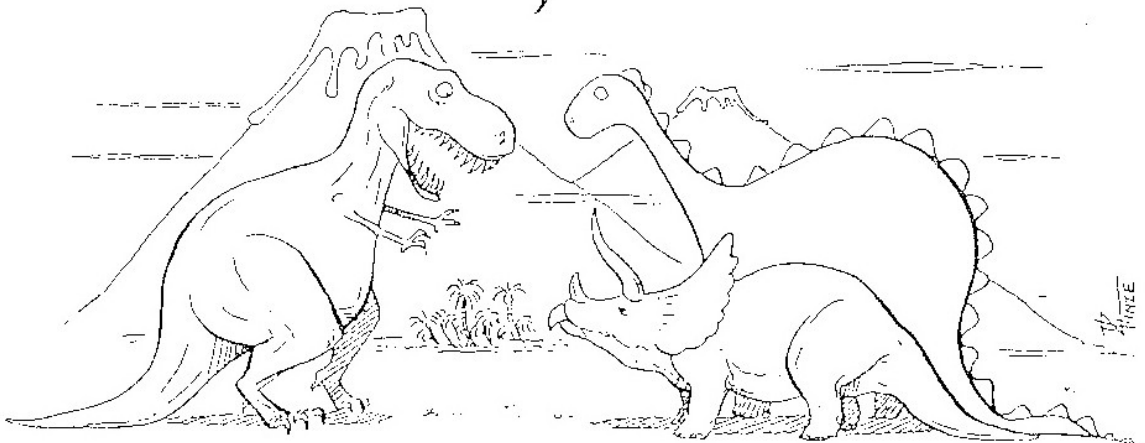
- So se in se bodo dogajali na Zemlji in drugih nebesnih telesih.
  - Dokazi – številni udarni kraterji na Zemlji, Luni, Marsu...



# Masovna izumrtja

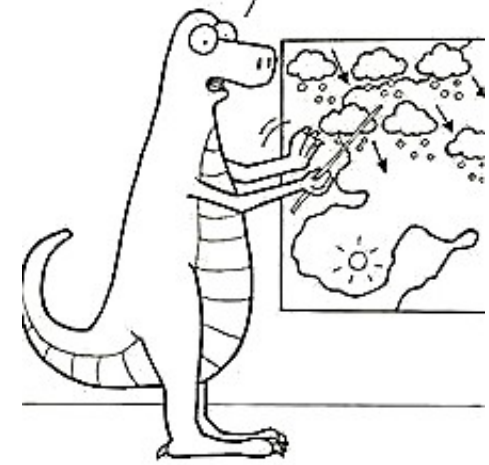
- Številno in nenadno izumrtje rastlin in živali glede na število novo nastalih vrst.
- Več hipotez
  - Hitra sprememba podnebja
  - Tektonika plošč
  - Ekstremni vulkanski izbruhi
  - Udarci meteoritov
- V zadnjih 540 milijonih let šest večjih masovnih izumiranja:
  - Konec ordovicija (540 mio let)
  - Konec devonija (350 mio let)
  - Konec permija (245 mio let)
  - Konec krede (65 mio let)
  - Konec eocena (35 mio let)
  - Konec pleistocena (2 mio let)

LET'S DIVIDE INTO CLASSES,  
FORM NATION-STATES  
AND COMPETE FOR GLOBAL RESOURCES!

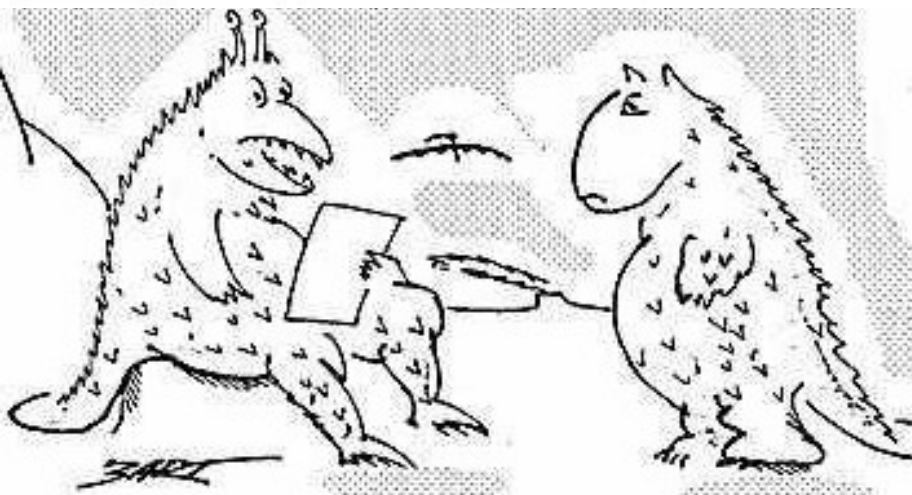


HOW DINOSAURS BECAME EXTINCT

OOH, TOMORROW LOOKS LIKE  
A BIG COLD FRONT MOVING IN  
BRINGING WITH IT AN ICE AGE AND  
MASS EXTINCTION...



JURASSIC WEATHER



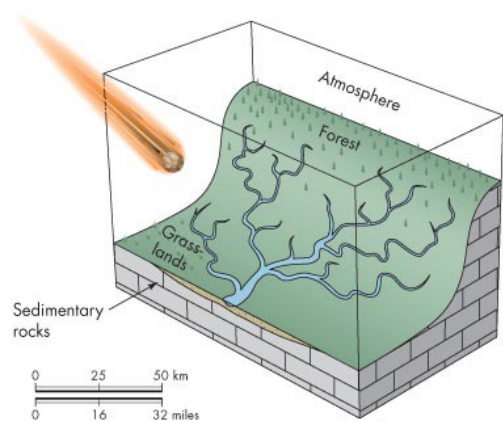
*"It's from our tax consultant. We forgot  
to beef up our pension scheme, so now  
we're going to be extinct."*



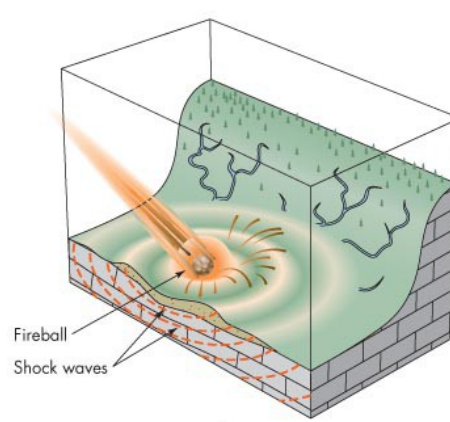
# 36. naloga

- Za vsako od masovnih izumrtij navedi najbolj verjeten razlog.

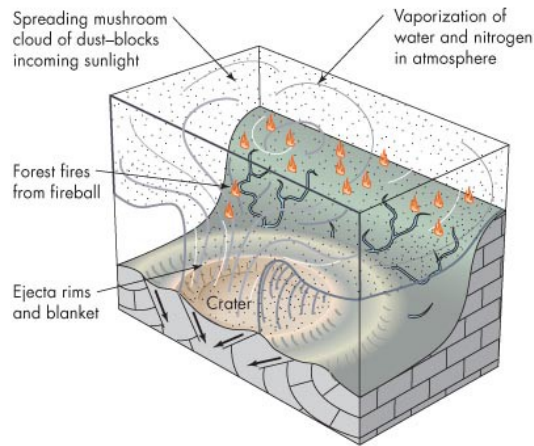
# Izumrtje na meji K - Tc



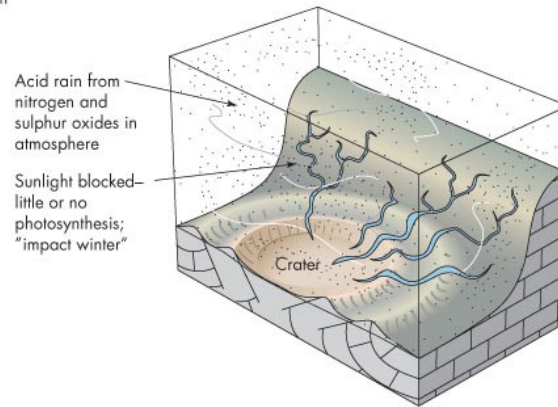
(a) Incoming asteroid



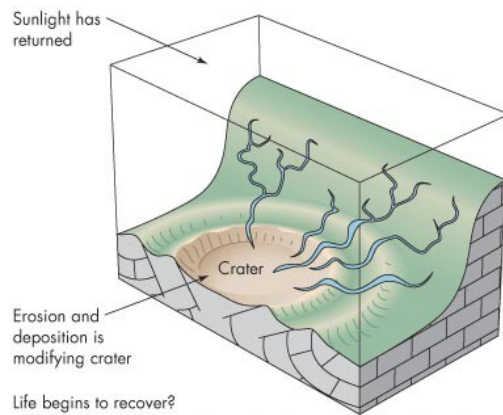
(b) On impact



(c) Minutes after impact



(d) Month later



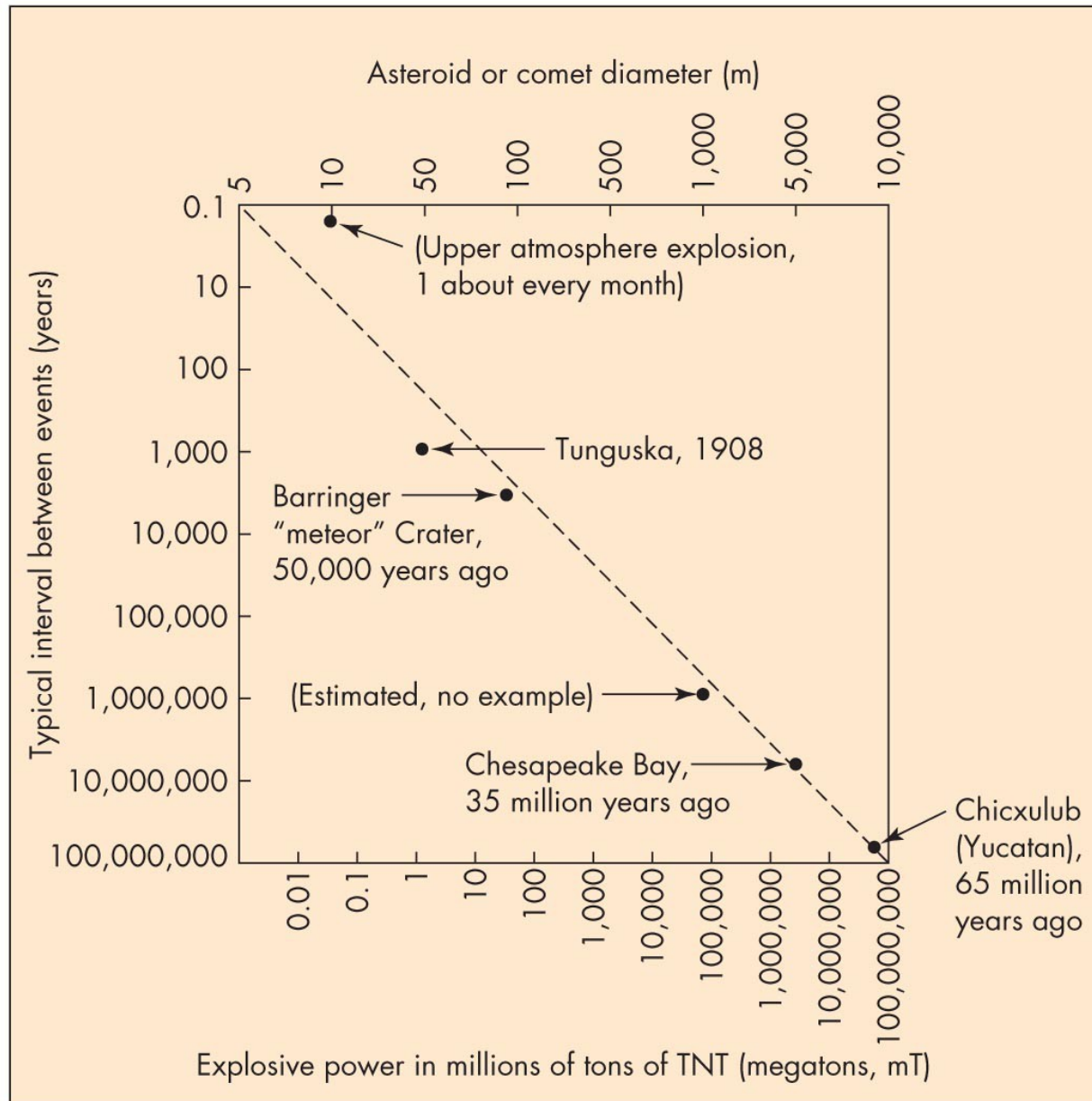
(e) After dust and acid rains out (several months)



# Tveganja povezana s padci meteoritov

- Odvisna od verjetnosti ter posledic udarca.
- Zračna eksplozija in neposredni udarec telesa s premerom nekaj km bi bila katastrofalna.
- Glede na mesto dogodka – lokalno ali globalno.
  - 7/10 dogodkov verjetno v morju
  - Masovno izumrtje
- Manjši dogodki se pojavijo na približno 1000 let, večji na 40 – 100 milijonov let.

# Tveganja povezana s padci meteoritov



# Zmanjševanje tveganja

- Identifikacija vseh potencialno nevarnih objektov v bližini Zemlje (near-Earth objects - NEO).
- Kategorizacija kometov in asteroidov, ki sekajo Zemljino krožnico.
- Programi opazovanja vesolja
  - V ZDA Spacewatch program, 1981.
  - NEAT (near-Earth asteroid tracking) sistem, ki ga podpira NASA, je namenjen ugotavljanju velikosti i porazdelitvi NEO.



# Zmanjševanje tveganja

- Približno 135.000 asteroidov premera  $\leq 100$  m seka Zemljino orbito.
- 20 milijonov NEO; 40% bi lahko vstopilo v atmosfero in predstavljalo grožnjo, 4% bi lahko dejansko povzročilo nastanek udarnega kraterja.
- Razvijanje sistemov za preusmerjanje velikih objektov.
- Razvijanje načrtov za pravočasno evakuacijo ob manjših dogodkih, če bi uspeli določiti mesto udarca.