Astrobiology
우주생물학

J. Hwang
cnu 2005.08.25

우리 우주의 역사

- 팽창중
- 유한한 과거에 팽창시작
- 간접 추정 나이 ~140억년
  그 전에는?
- 처음 40만년은 빛의 시대
- 그 후 물질시대->은하,별,행성 형성
- 우리은하 원반의 나이 ~110억년
  별들은 지금도 계속 만들어지고 있음.
  오래된 천체 (globular cluster) <150억년
- 태양계의 나이 ~46억년

우리우주의 규모

- 은하들의 분포가 큰 영역(~3억광년 이상)에서 대략 균일
- 볼 수 있는 영역 ~140억 광년

  그 너머는?
- 볼 수 있는 영역 안에 ~천억개 은하
- 우리은하 안에 ~천억개 별

  우리은하 크기 ~지름 10만광년인 원반
- 태양계 안에 수십개의 행성급 천체


NGC4013, HST
http://hubblesite.org/gallery/
JH

Sombrero Galaxy • M104

Hubble Heritage

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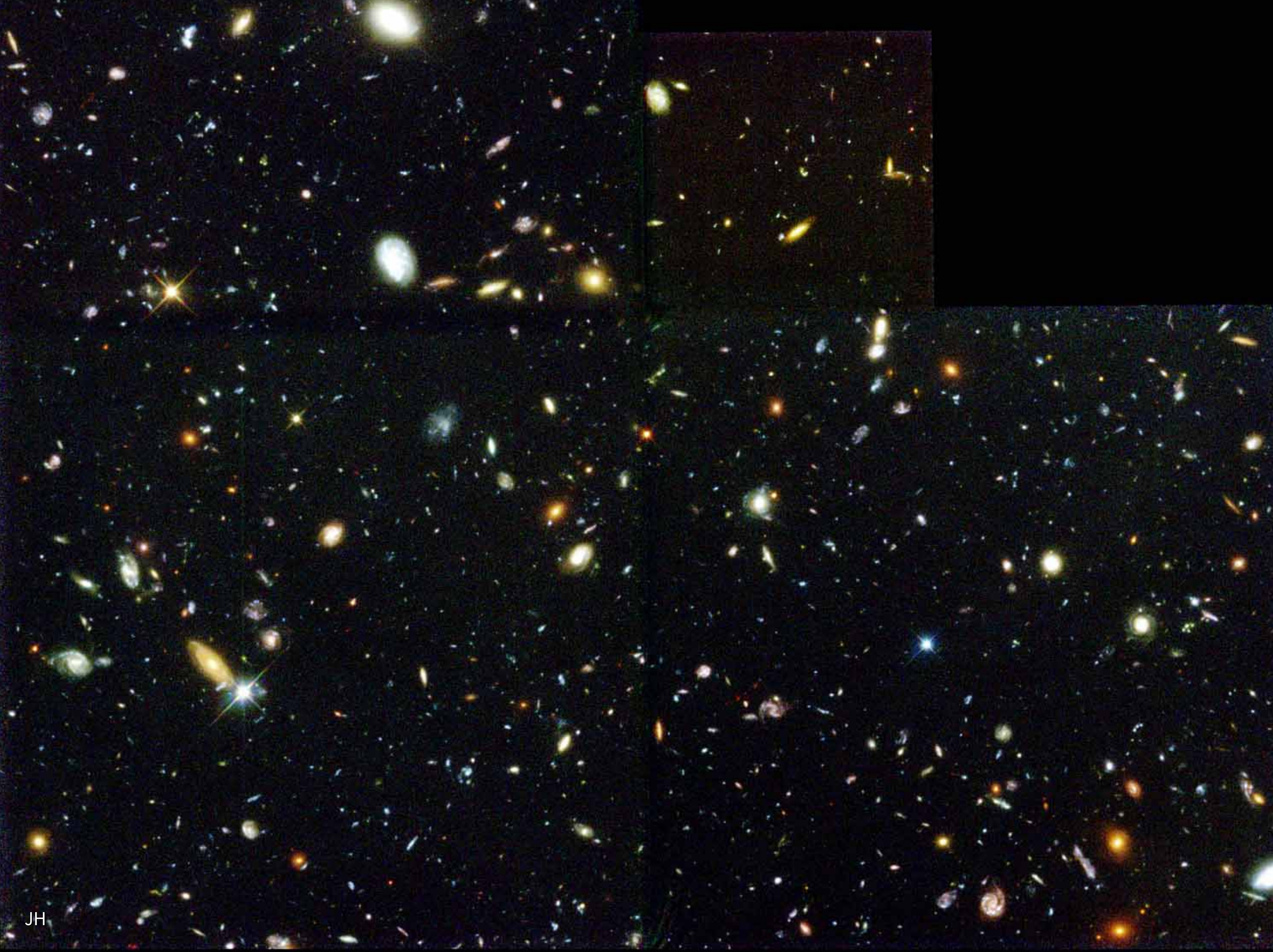
NASA and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope ACS • STScI-PRC03-28

Globular Star Clusters

Hubble Space Telescope • WFPC2

JH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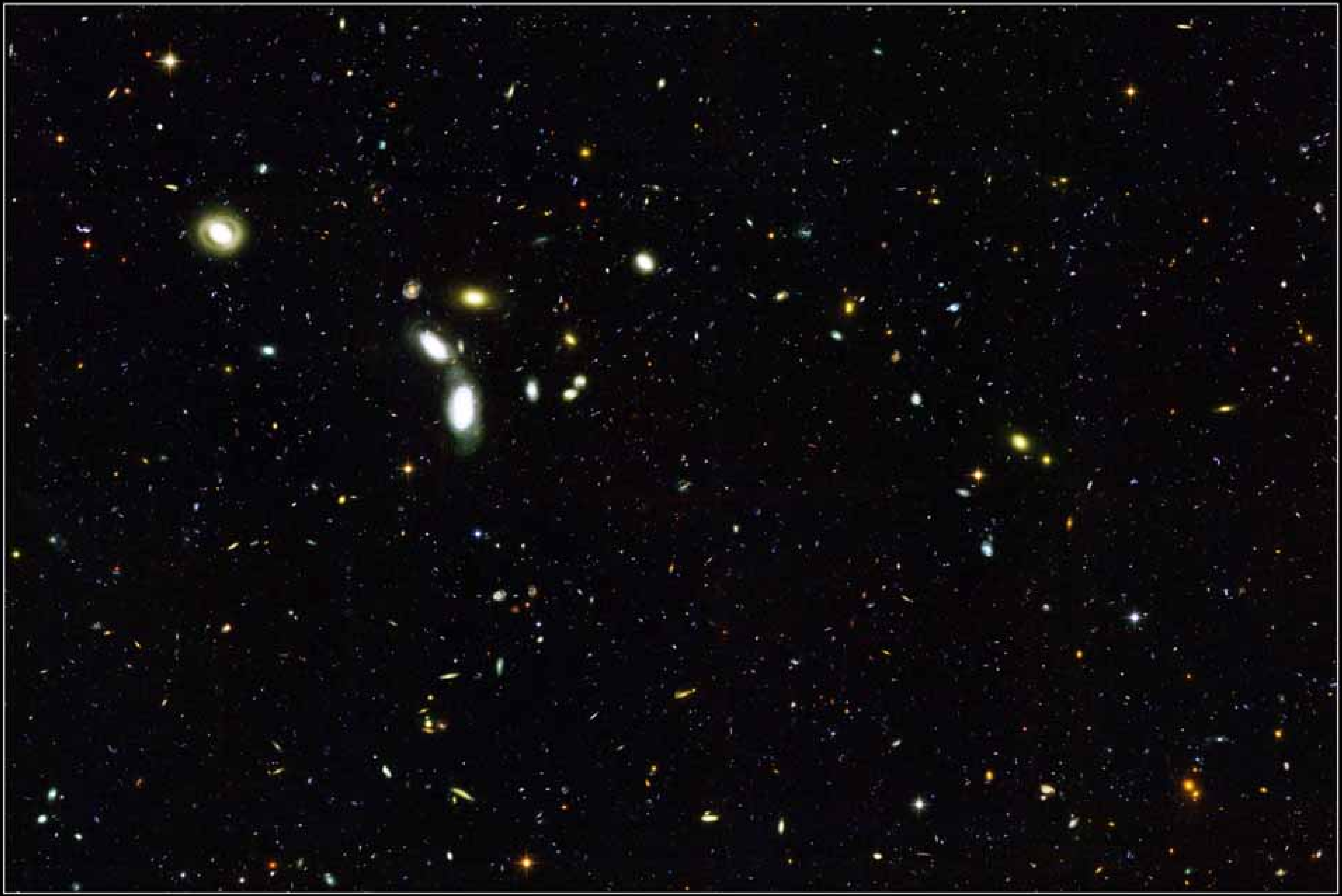

Great Observatories Origins Deep Survey • CDF-S
Hubble Space Telescope • Advanced Camera for Surveys

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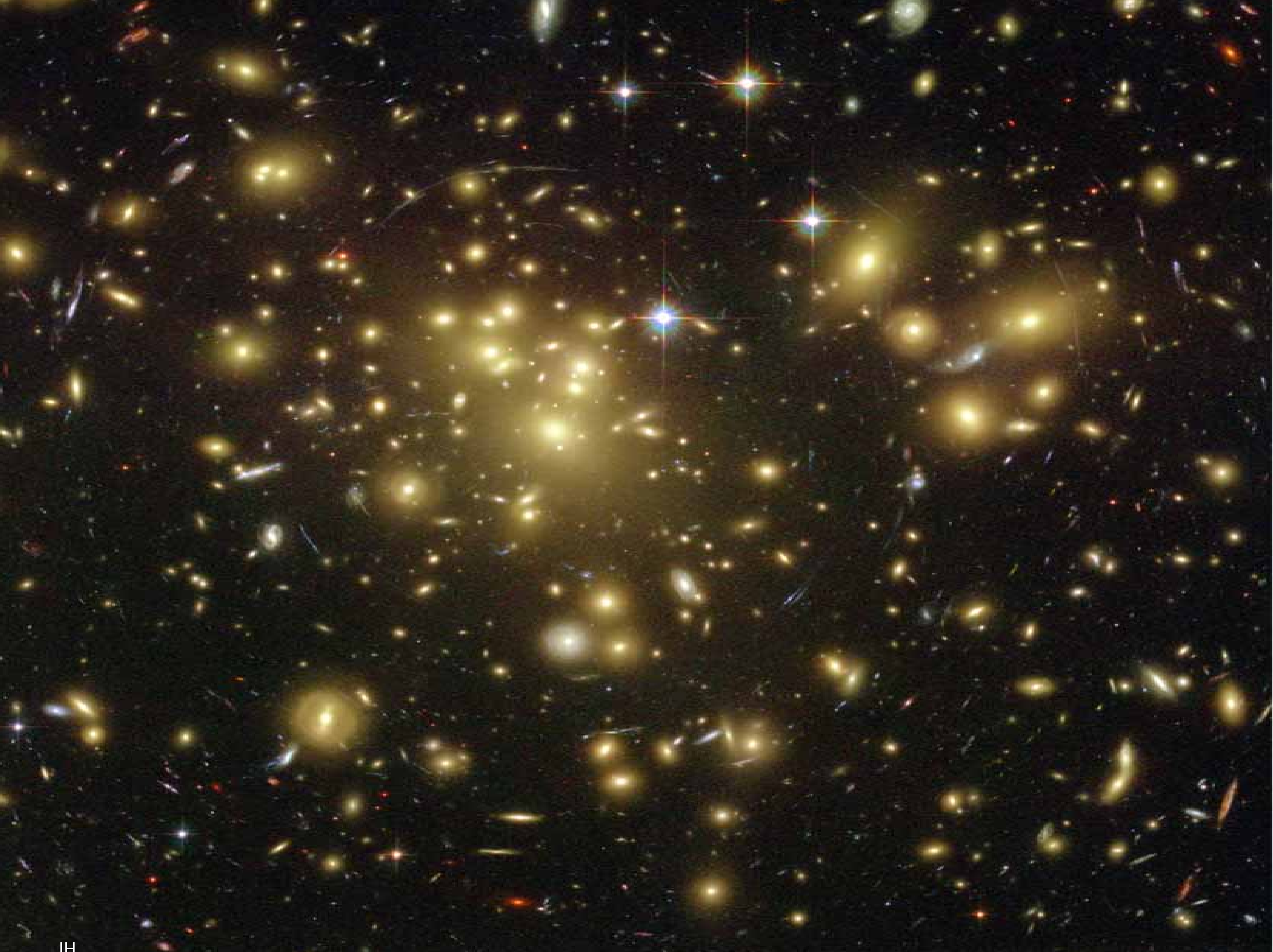
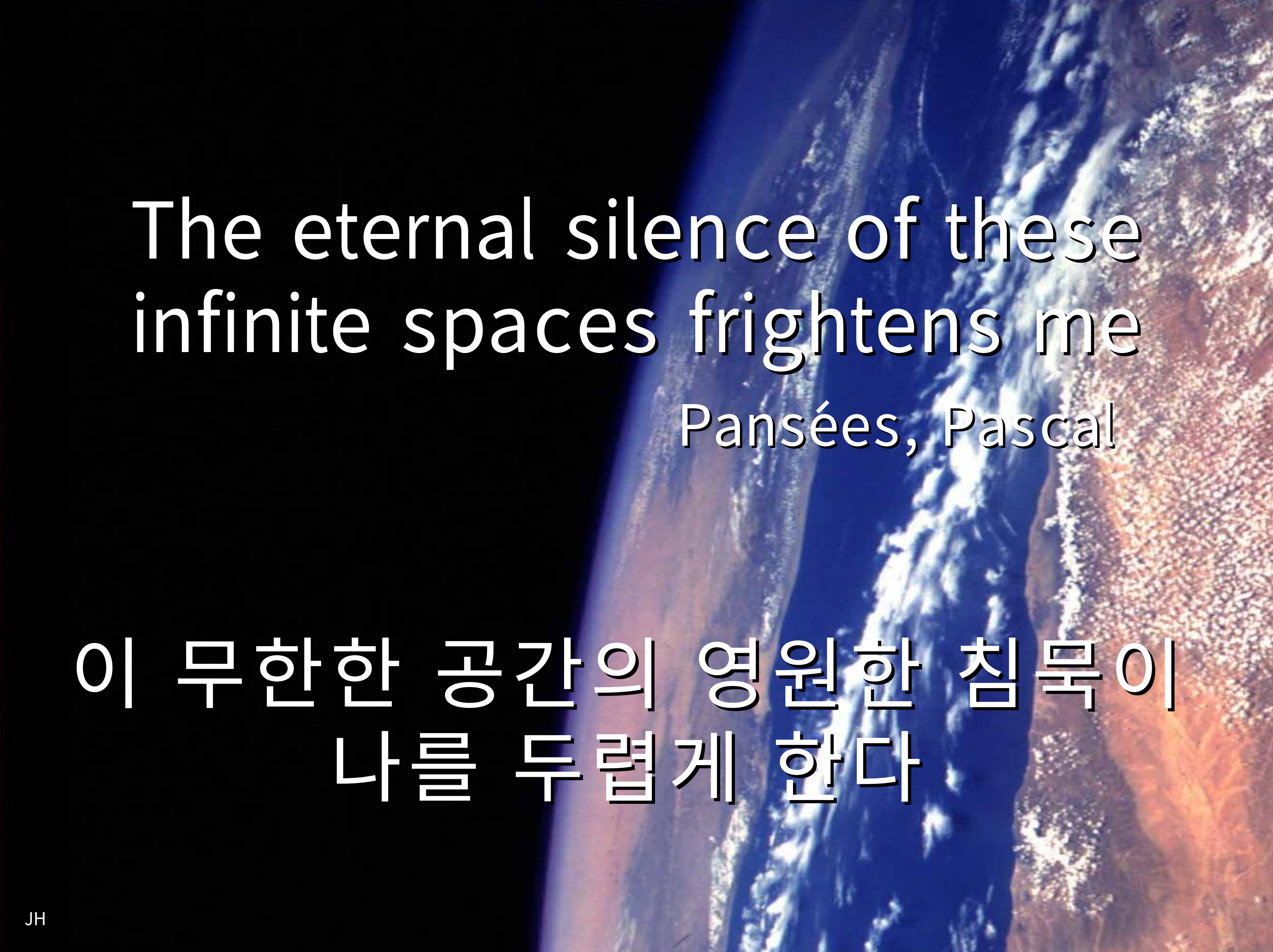



The eternal silence of these
infinite spaces frightens me
Pansées, Pascal
이 무한한 공간의 영원한 침묵이
나를 두렵게 한다
JH

Great silence problem

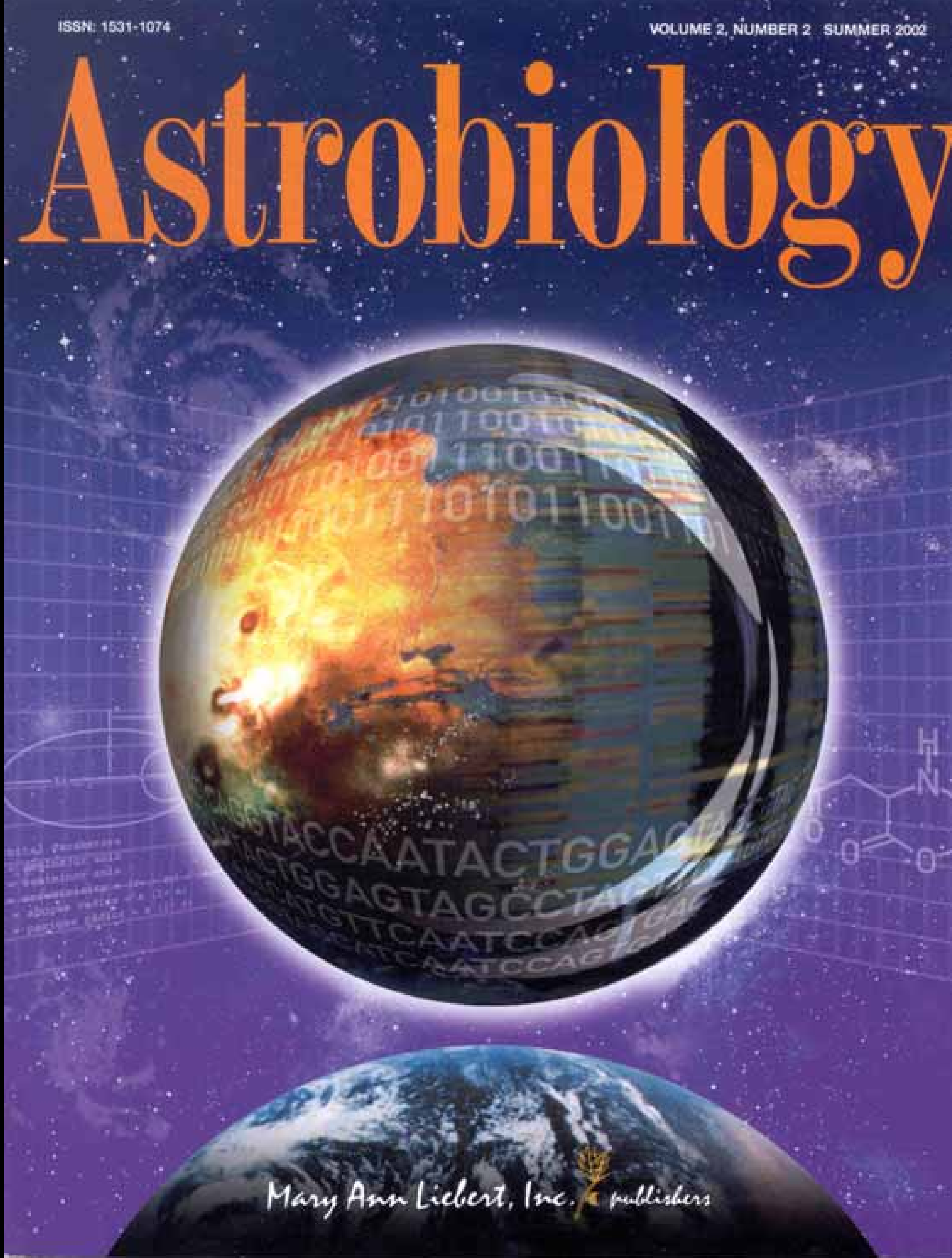
- 우리은하가 만들어 진지 100억년이 되었고, 별 사이를 이동할 문명이 발생하는데 45억년이 걸린다 하자.
- 문명이 별 사이(3광년)를 이동하는데 만년이 걸린다면, 우리은하 (10만광년)를 점거하는데 는 3억년이면 됨.
- 그럼 다들 어디에 있나?

Fermi Paradox (1950)

분야명

- Cosmobiology (John D. Bernal, 1952) 우주생물학
- Astrobiology (Gavriil A. Tikhov, 1953) 천문생물학
- Exobiology (Joshua Lederberg, 1960) 외계생물학
- Bioastronomy 생물천문학

- 우주에서 생명의 기원, 분포와 성질, 운명연구
- 하나의 증거 (지구생명)와 물리-화학에 의존
- **연구대상부터 찾아야 하는 분야!**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Astrobiology
Mary Ann Liebert, Inc. publishers


International Journal of Astrobiology

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Astrobiology

- 생명이 나타날 조건은?
- 지구의 어떤 조건이 생명에 필수적?
- 얼마나 흔할까?
- 어디서 찾을 수 있나?
- 어떻게 생겼을까?
- 어떻게 생명이 나타나고 진화했나?
- 지구생명의 미래는?

Where do we come from ?
What are we ?
Where are we going ?

Paul Gauguin (1897)

우리는 어디서 왔는가? 우리는 누구인가? 우리는 어디로 가는가?
Origin, Nature, Fate

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생명이란?

- 생물학에서는 생명이 무엇인지 중요하지 않지만 우주생물학에서는 중요.
- 무엇을 찾는지는 알아야...

- 생명은 물리-화학 법칙으로 설명가능!
- “생명이란 물질이 진화하는 과정에서 이르게 되는 여러 수준들의 하나에 지나지 않는다.” A. Oparin

생명의 정의

- 생리 (physiological), 대사 (metabolic), 유전 (genetic), 생화학 (biochemical), 열역학 (thermodynamic).
- 정확한 정의는 어려움, 모든 정의에 예외.
- 보면 안다.
- 편리하게는 “다윈적 진화 (번식, 변이, 선택) 를 하는 물질계”.
- 지구생명에서 얻은 편견일수도...

생명의 특성

- 대사(metabolism)
- 번식(reproduction)
- 변이(mutation)
- 외부에너지를 쓸 수 있는 내부에너지로 변화시킬 수 있어야 함.

- 생명의 개체화 책략: 물질적 연속성을 포기하고 정보적 연속성 을 택함.

"온생명" 장회익

진화

- "Nothing in biology makes sense except in the light of evolution."

Theodosius Dobzhansky (1973)

- 변이(variation)와 자연선택(natural selection).
- 방향성이 없으며 (우연이 지배) 진보의 개념이 없다.

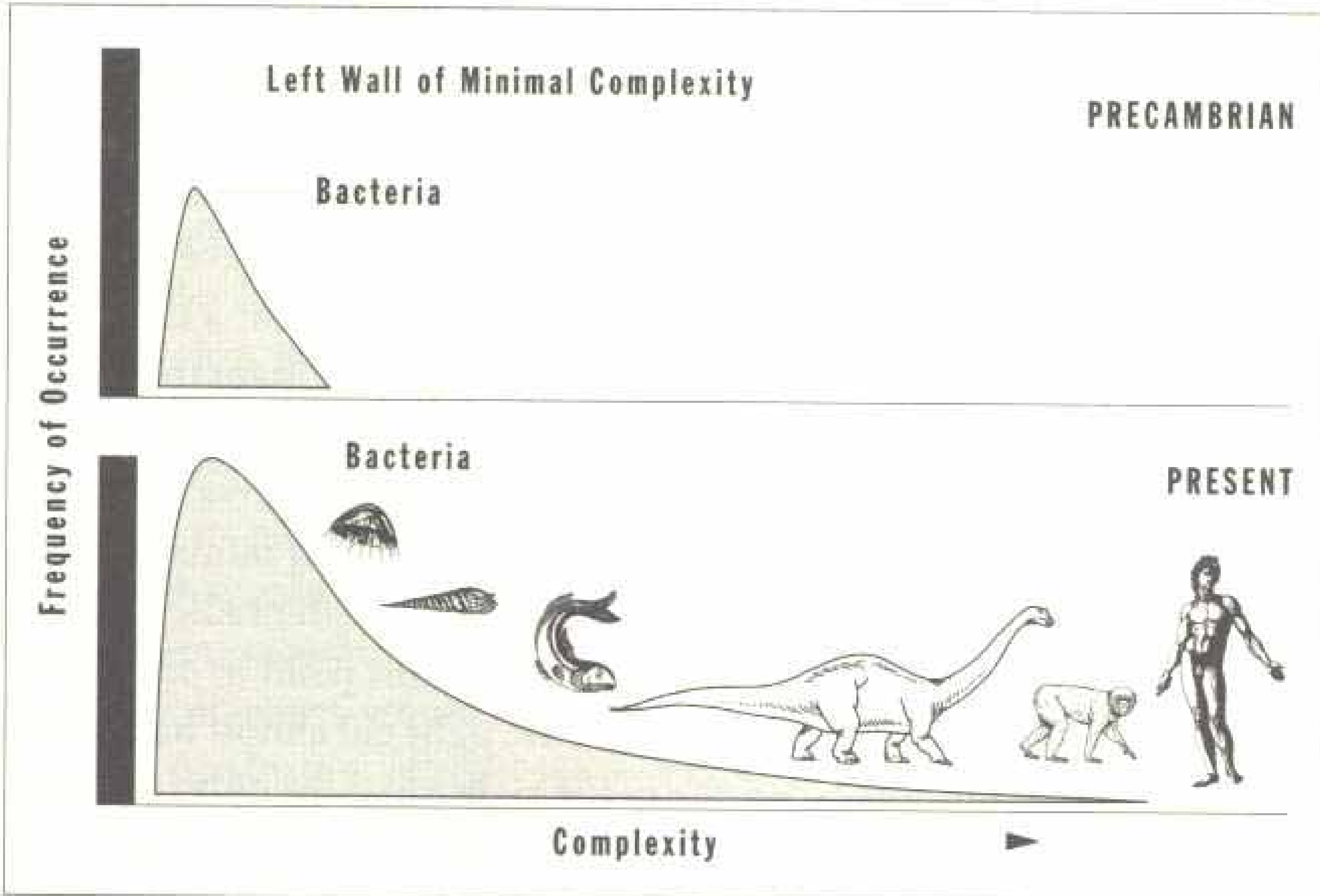

FIGURE 29

The frequency distribution for life's complexity becomes increasingly right skewed through time, but the bacterial mode never alters.

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S.J.Gould “Fullhouse”

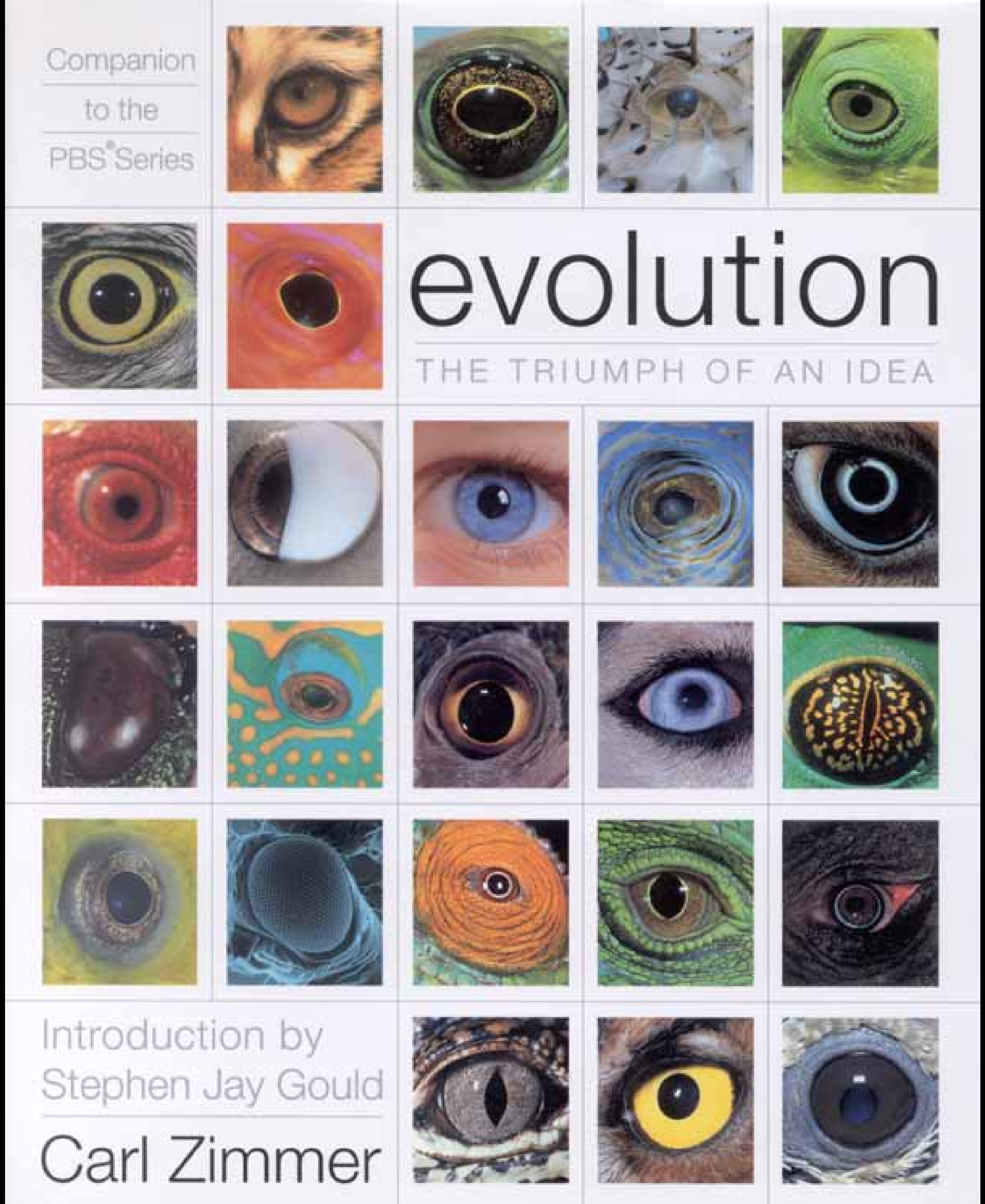
두 관찰

- 한 종의 출현은 반복되지 않는다. Contingency (divergionism) Stephen J. Gould

- 여러 종에서 생존에 적합한 특수한 방법들을 독립적으로 발견. Convergence (convergionism) S. Conway Morris

  예: 날개 (새,박쥐,pterosaurs,가오리,물고기,곤충)

  눈 (~50차례까지 발명).


Companion
to the
PBS® Series
evolution
THE TRIUMPH OF AN IDEA
Introduction by
Stephen Jay Gould
Carl Zimmer

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지구생명은 단일종

- 같은 genetic alphabet, code: AGCT,U
  모두 오른손형
- 같은 기본 아미노산: 20가지
  모두 왼손형
- 같은 에너지 화폐: ATP

- 공통조상의 자손암시

극한환경에 사는 생명

- extremophiles
- 온도: 113C at <3 atm (120-150C)
- 압력
- 소금기(salinity)
- 산도(acidity)
- 최초의 생명일 가능성!
- 진공상태와 강한 복사에도 살아 남음.
- 외계생명 존재에 대해 다시 생각 하게함.

Physical limits for life on Earth

Parameter	Limiting Conditions	Type of Organism
Water	Liquid water required	
Temperature	–2°C (31.8°F) (minimum)	Psychrophiles
	50–80°C (122–176°F)	Thermophiles
	80–115°C (176–239°F)	Hyperthermophiles
Salinity	15–37.5% NaCl	Halophiles
pH	0.7–4	Acidophiles
	8–12.5	Alkalophiles
Atmospheric pressure	Up to 110 Mpa	Barophiles

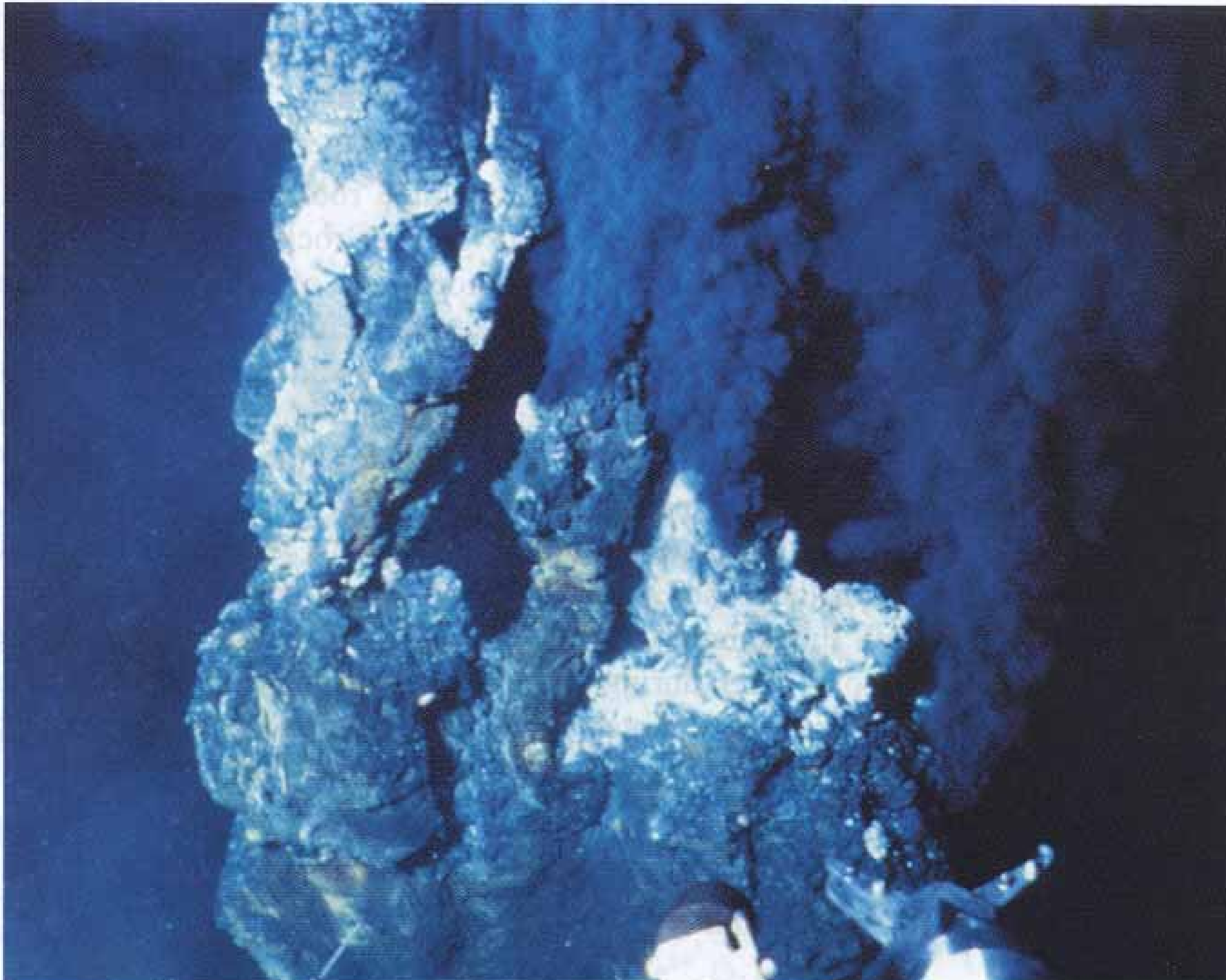

Fig. 11.1 Active deep sea vent chimney, a "Black Smoker" spewing superheated mineral-laden black water into the cold deep sea environment. The plume appears like black "smoke


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Three domains (Carl R. Woese)

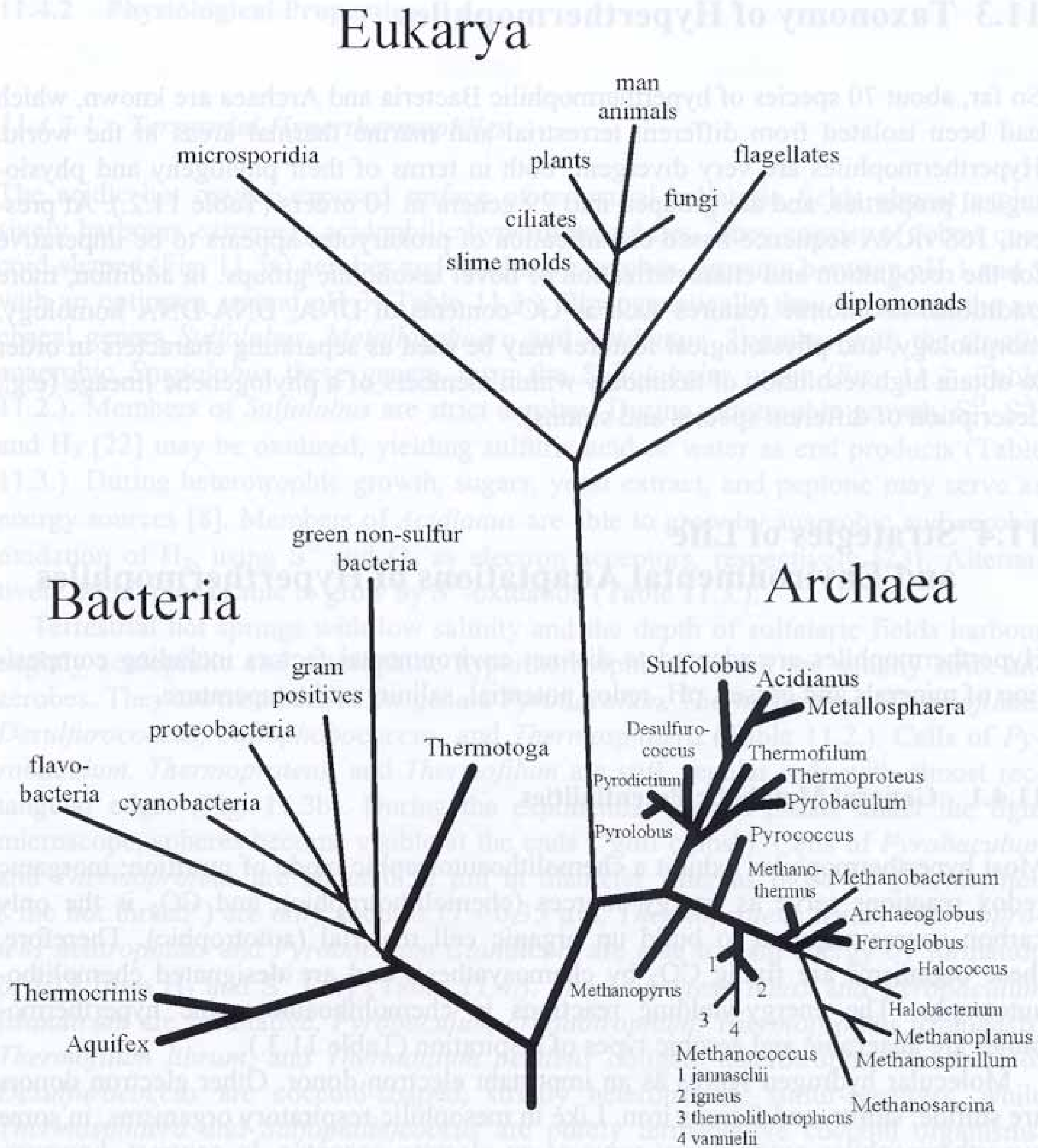

Fig. 11.2 16S rRNA-based phylogenetic tree, [6], modified. Small subunit ribosomal RNA sequences were compared according to Woese [15]. Schematic drawing. Bold lines represent hyperthermophiles.

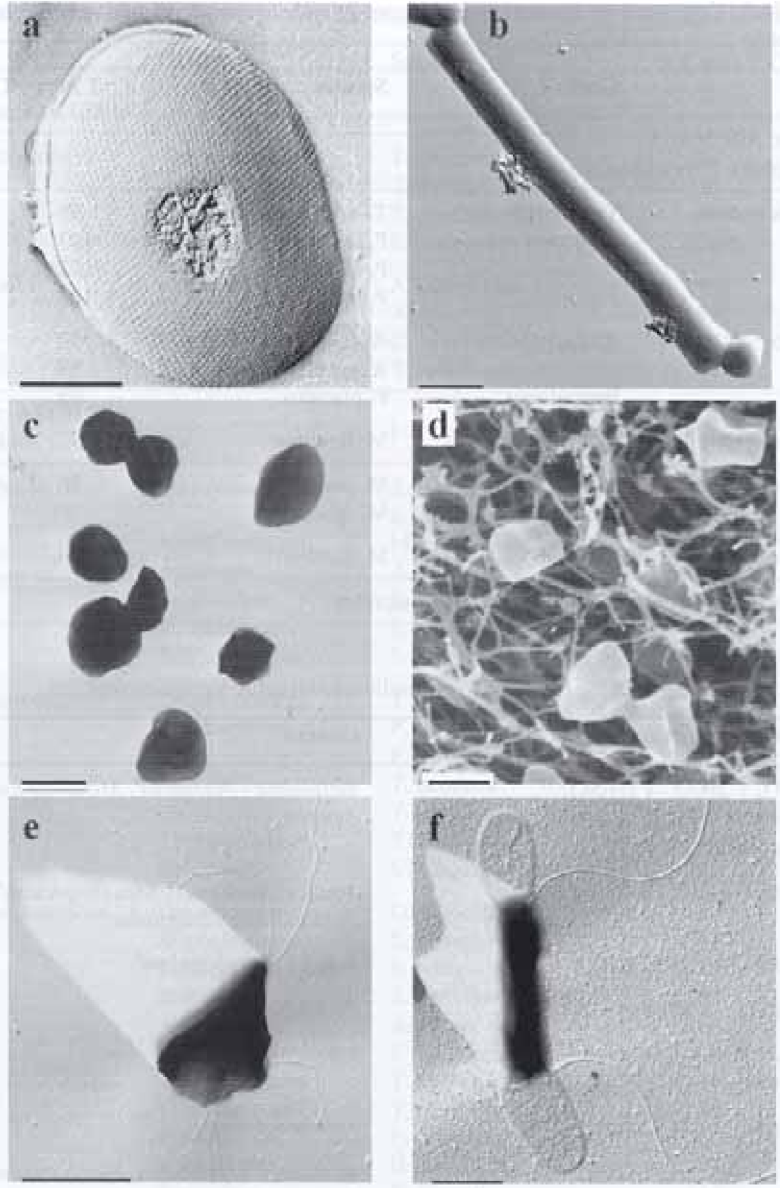

Fig. 11.3 Electron micrographs of cells of hyperthermophilic Archaea and Bacteria

a. *Metallosphaera sedula,* freeze fracturing, bar, 0.2 µm;
b. *Thermoproteus tenax,* Pt-shadowing, bar, 1.0 µm;
c. *Pyrolobus fumarii,* UAc-staining, bar, 1.0 µm;
d. *Pyrodictium abyssi,* scanning micrograph, bar, 1.0 µm;
e. *Archaeoglobus fulgidus,* Pt-shadowing, bar, 1.0 µm;
f. *Thermotoga maritima,* Pt-shadowing, bar, 1.0 µm.

지구생명에 필요한 요소

- 에너지원: 빛, 화학 (oxidation).
- 유기물: C, H, O, N, S, P 로 구성.
- 액체상태 물.

- 물 이외에는 우주에 흔함.
  태양계 생명탐사는 물이 있는 지역탐사.

원소의 기원

- 초기우주 (~1분): H, D, ^3He, ^4He, ^7Li
- 별(주계열): C – Fe
- 별 폭발(supernovae): Fe - U

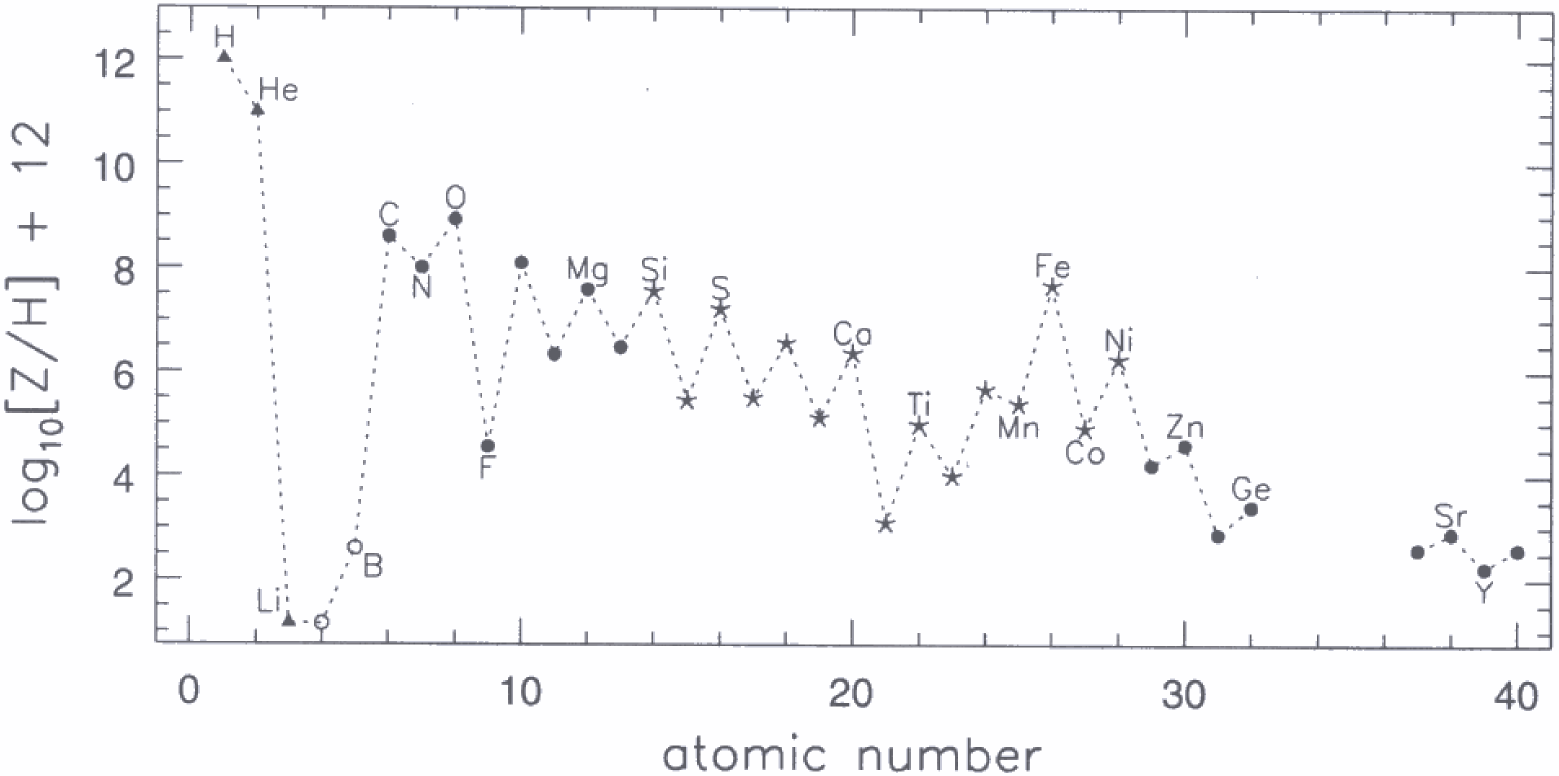

Figure 1.3 Logarithm of the number of atoms of each element found in the Sun, for every 10^{12} hydrogen atoms. Hydrogen, helium, and lithium originated mainly in the Big Bang; the next two elements result from the breaking apart of larger atoms, and the remainder are 'cooked' in stars. Filled dots show elements produced mainly in quiescent burning; asterisks indicate those made largely during explosive burning in a supernova – from Anders & Grevasse.

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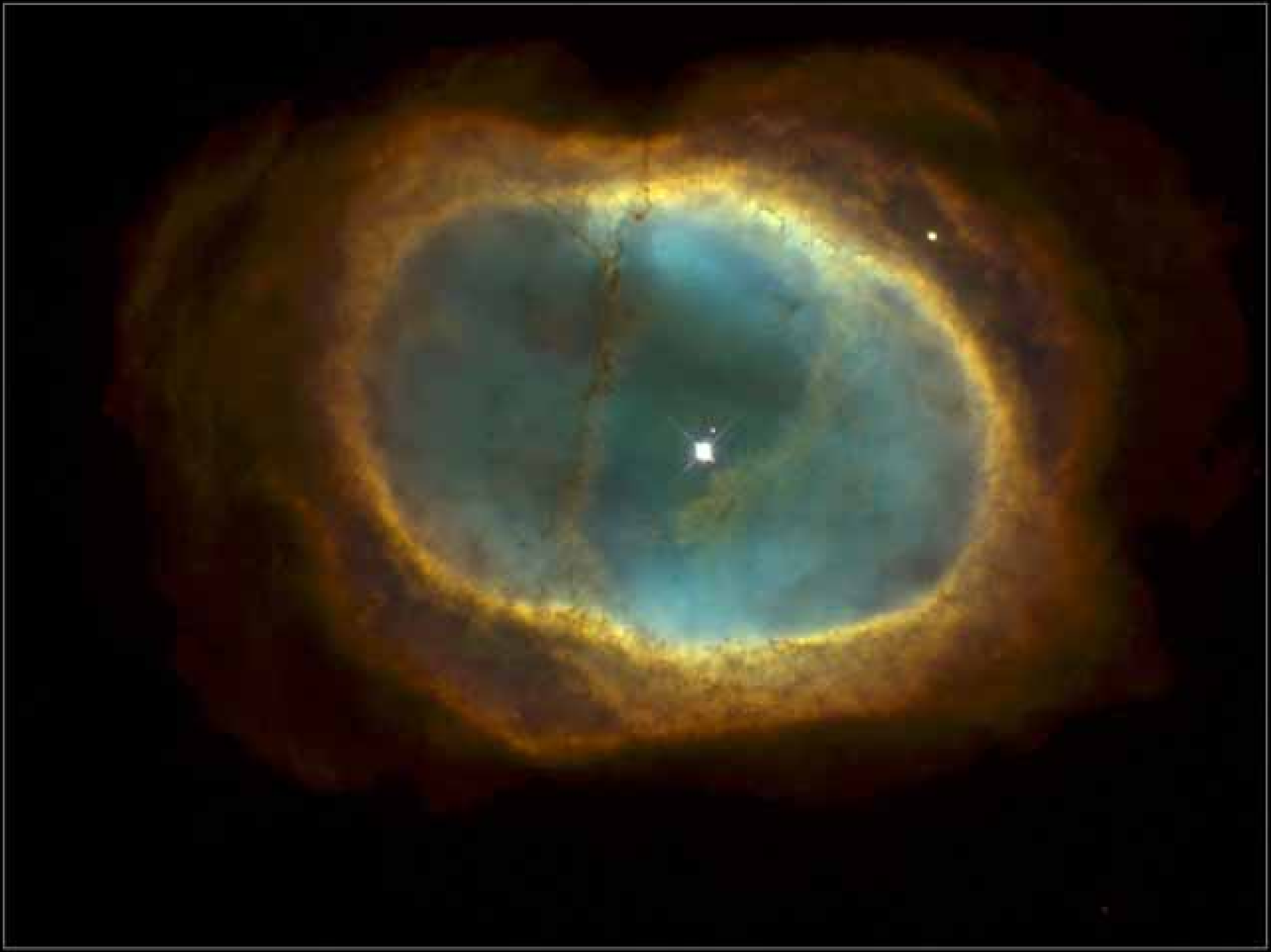
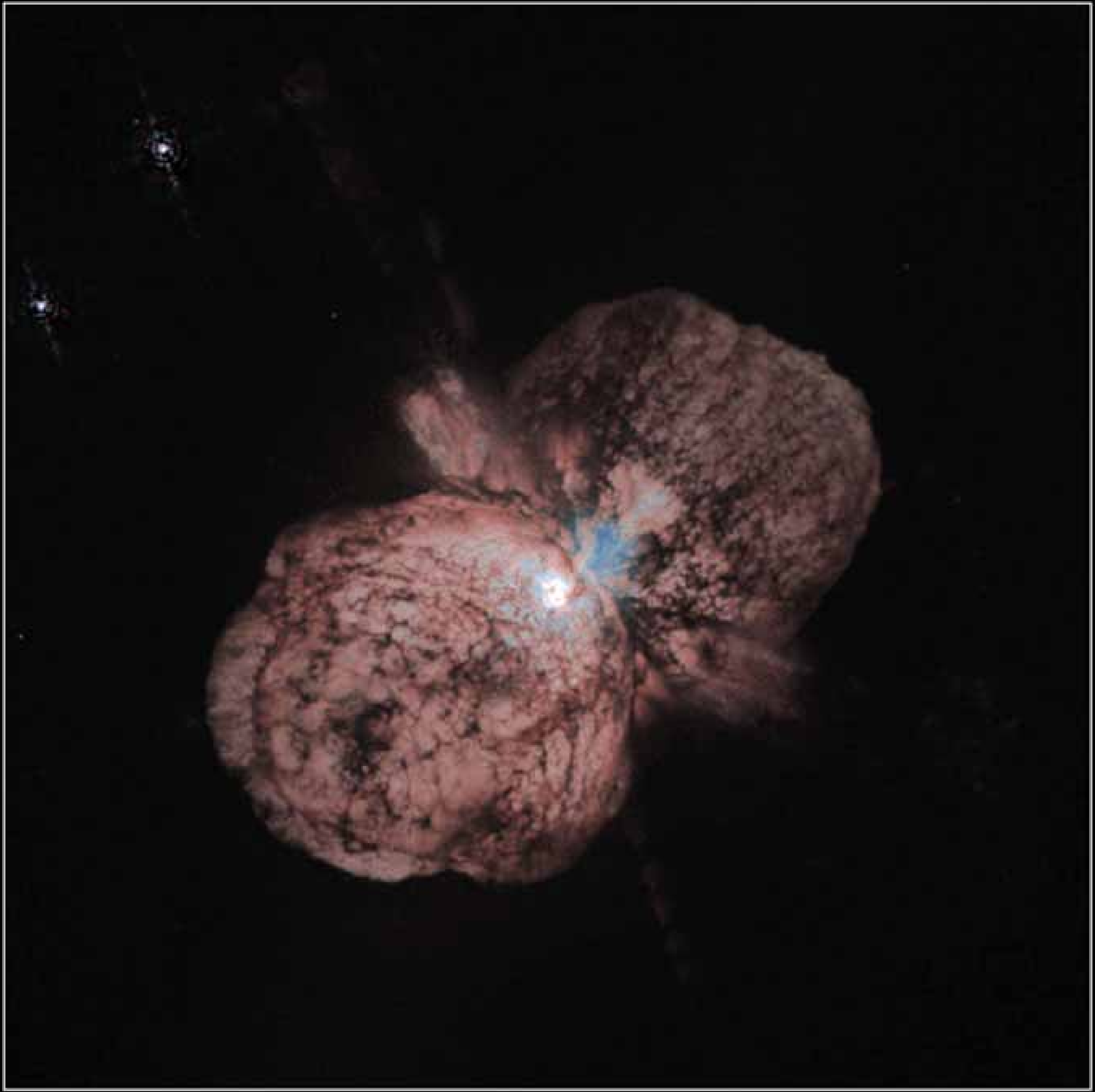
Planetary Nebula NGC 3132



Hubble Heritage

IH



Eta Carinae

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성간 화학

- 생명에 필요한 기본원소는 우주에 풍부.
- 다양한 분자 발견.
- 성간 원소 + UV -> organic chemicals!
- 운석에서 아미노산 발견.
- 최근 성간구름에서 glycine 발견 보고.

Table. 2.1. Interstellar and circumstellar molecules as compiled per October 2000. Observations indicate the presence of molecules larger than 12 atoms, such as polycyclic aromatic hydrocarbons (PAHs), fullerenes and others in the interstellar medium.

Number of Atoms										
2	3	4	5	6	7	8	9	10	11	12+
H_2	C_3	c-C_3H	C_5	C_5H	C_6H	CH_3C_3N	CH_3C_4N	CH_3C_5N ?	HC_9N	C_6H_6
AlF	C_2H	l-C_3H	C_4H	l-H_2C_4	CH_2CHCN	$HCOOCH_3$	CH_3CH_2CN	$(CH_3)_2CO$		$HC_{11}N$
AlCl	C_2O	C_3N	C_4Si	C_2H_4	CH_3C_2H	CH_3COOH ?	$(CH_3)_2O$	NH_2CH_2COOH ?		PAHs
C_2	C_2S	C_3O	l-C_3H_2	CH_3CN	HC_5N	C_7H	CH_3CH_2OH			C_{60}^+
CH	CH_2	C_3S	c-C_3H_2	HC_3NC	$HCOCH_3$	H_2C_6	HC_7N			
CH^+	HCN	C_2H_2	CH_2CN	HC_3OH	NH_2CH_3		C_8H			
CN	HCO	CH_2D^+ ?	CH_4	HC_3SH	c-C_2H_4O					
CO	HCO^+	HCCN	HC_3N	HC_3NH^+						
CO^+	HCS^+	$HCNH^+$	HC_2NC	HC_2CHO						
CP	HOC^+	HNCO	HCOOH	NH_2CHO						
Csi	H_2O	HNCS	H_2CHN	C_5N						
HCl	H_2S	$HOCO^+$	H_2C_2O							
KCl	HNC	H_2CO	H_2NCN							
NH	HNO	H_2CN	HNC_3							
NO	MgCN	H_2CS	SiH_4							
NS	MgNC	H_3O^+	H_2COH^+							
NaCl	N_2H^+	NH_3								
OH	N_2O	SiC_3								
PN	NaCN	CH_3								
SO	OCS									
SO^+	SO_2									
SiN	c-SiC_2									
SiO	CO_2									
SiS	NH_2									
CS	H_3^+									
HF	H_2D^+									

The Astrophysical Journal, 593:848–867, 2003 August 20

INTERSTELLAR GLYCINE

Yi-Jehng Kuan,[1,2] Steven B. Charnley,[3] Hui-Chun Huang,[1] Wei-Ling Tseng,[1] and Zbigniew Kisiel[4]
Received 2002 November 15; accepted 2003 April 1

ABSTRACT

We have searched for interstellar conformer I glycine (NH_2CH_2COOH), the simplest amino acid, in the hot molecular cores Sgr B2(N-LMH), Orion KL, and W51 e1/e2. An improved search strategy for intrinsically weak molecular lines, involving multisource observations, has been developed and implemented. In total, 82 spectral frequency bands, in the millimeter-wave region, were observed over a 4 yr period; 27 glycine lines were detected in 19 different spectral bands in one or more sources. The rotational temperatures derived from "rotation diagrams" are 75^{+29}_{-16} K for Sgr B2(N-LMH), 141^{+76}_{-37} K for Orion KL, and 121^{+71}_{-32} K for W51 e1/e2. The total column densities inferred are $4.16^{+3.22}_{-1.82} \times 10^{14}$ cm^{-2} for Sgr B2, $4.37^{+1.79}_{-1.27} \times 10^{14}$ cm^{-2} for Orion, and $2.09^{+1.22}_{-0.77} \times 10^{14}$ cm^{-2} for W51. Production of interstellar glycine by both gas-phase ion-molecule reactions and by ultraviolet photolysis of molecular ices is briefly discussed. The discovery of interstellar glycine strengthens the thesis that interstellar organic molecules could have played a pivotal role in the prebiotic chemistry of the early Earth.

Subject headings: astrobiology — ISM: abundances — ISM: individual (Orion Kleinmann-Low, Sagittarius B2(N-LMH), W51 e1/e2) — ISM: molecules — line: identification — radio lines: ISM

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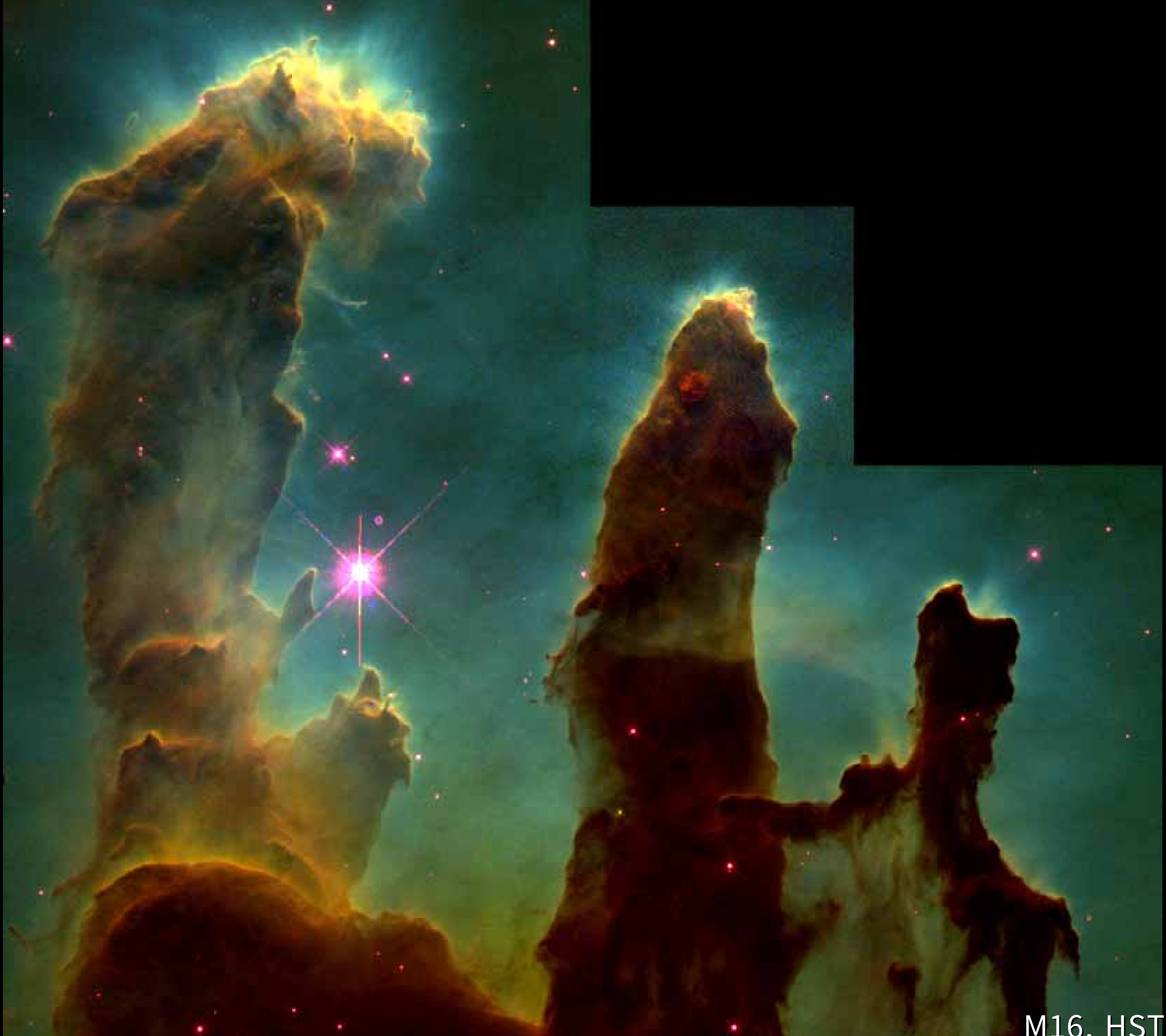
Trifid Nebula M20, HST



M16, HST

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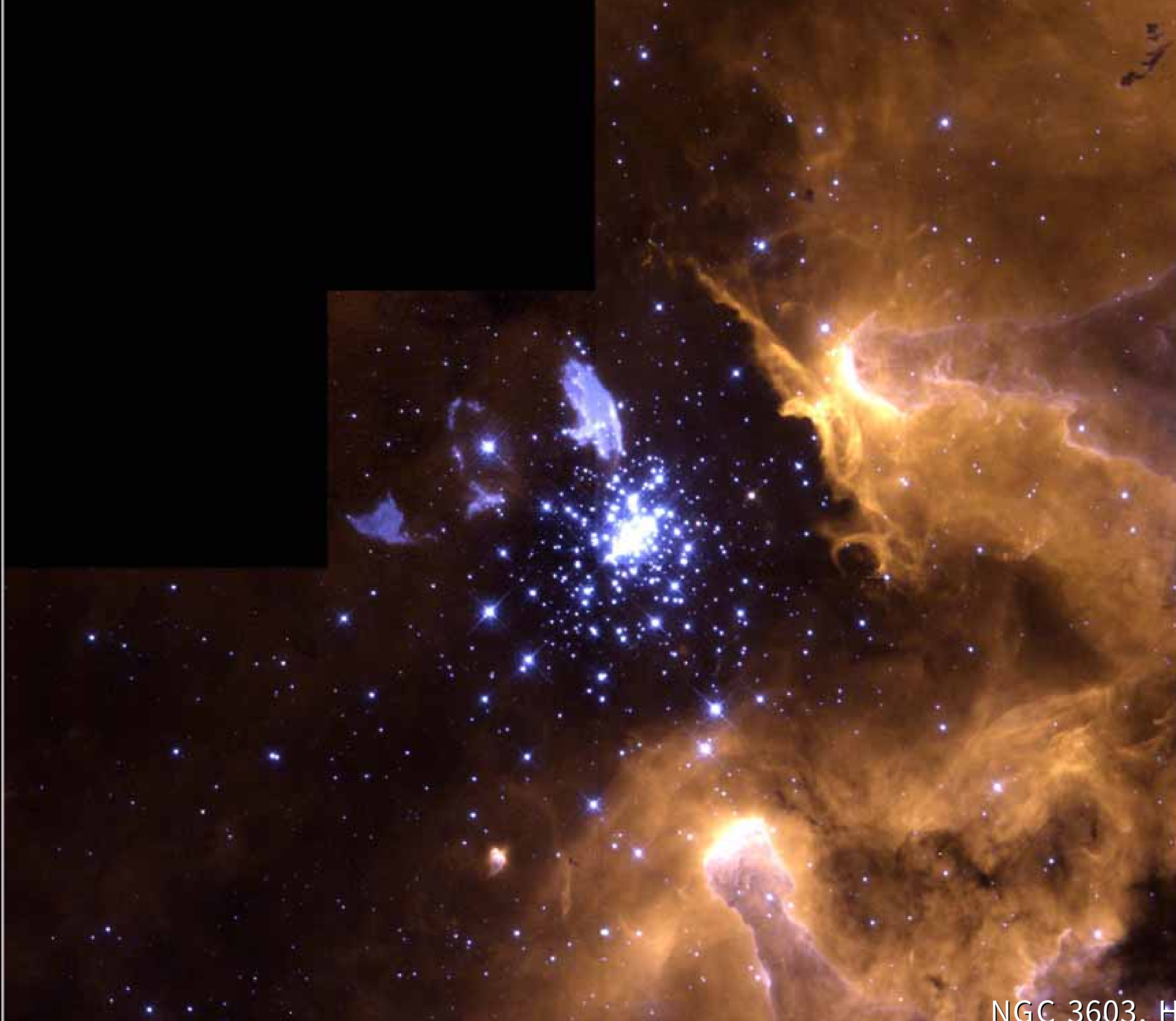

NGC 3603, HST

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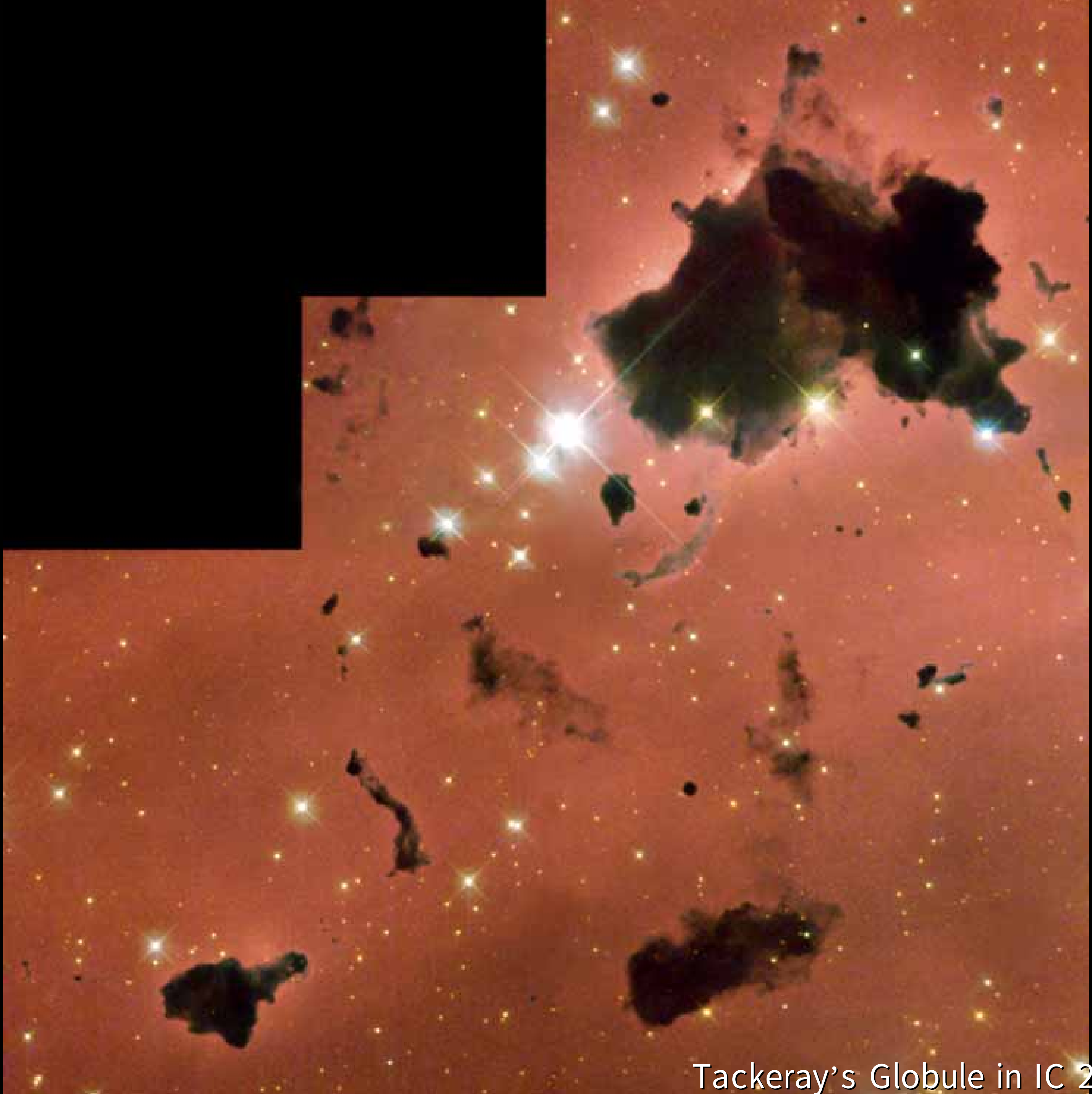

Tackeray's Globule in IC 2944, HST

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The Dumbbell Nebula • M27

Hubble Heritage

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물

- 얼음이 물에 뜸
- 열용량이 큼
- 증발할 때 많은 열을 가져감
- 용해도 (solubility)가 큼
- 강한 표면장력
- 점성 (viscosity)
- 잠열 (latent heat)
- 투명도 (transparency)

Liquid	Melting temp.	Boiling temp.	Range for liquid
Water (H_2O)	0 °C	100 °C	100 °C
Ammonia (NH_3)	−78 °C	−33 °C	45 °C
Methane (CH_4)	−182 °C	−164 °C	18 °C
Ethane (C_2H_6)	−183 °C	−89 °C	94 °C

[Figure 7.1]
Melting and boiling temperatures for liquids that might provide a medium for the occurrence of life.

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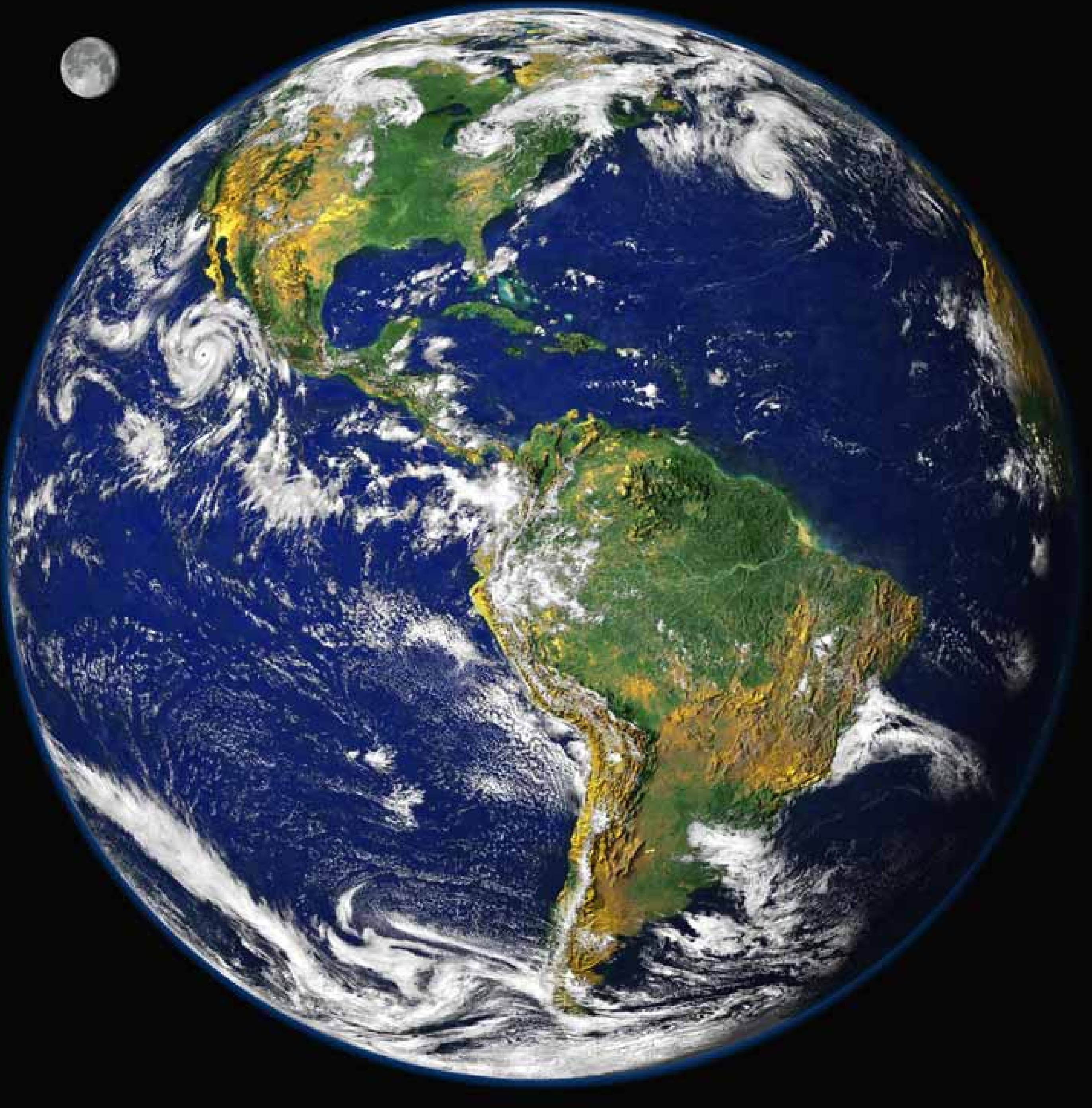
Jakosky

지구의 특수성

- 대기를 지닐 정도로 큰 질량.
- 유체상태 물이 존재할 낮은 온도.
- 유기화학 반응이 활발할 수 있는 온도.
- 오래 살 수 있는 해.
- 생명에 필요한 충분한 원소.

이 조건들이 특수하지 않을 수도 있고 필요하지 않을 수도 있다.



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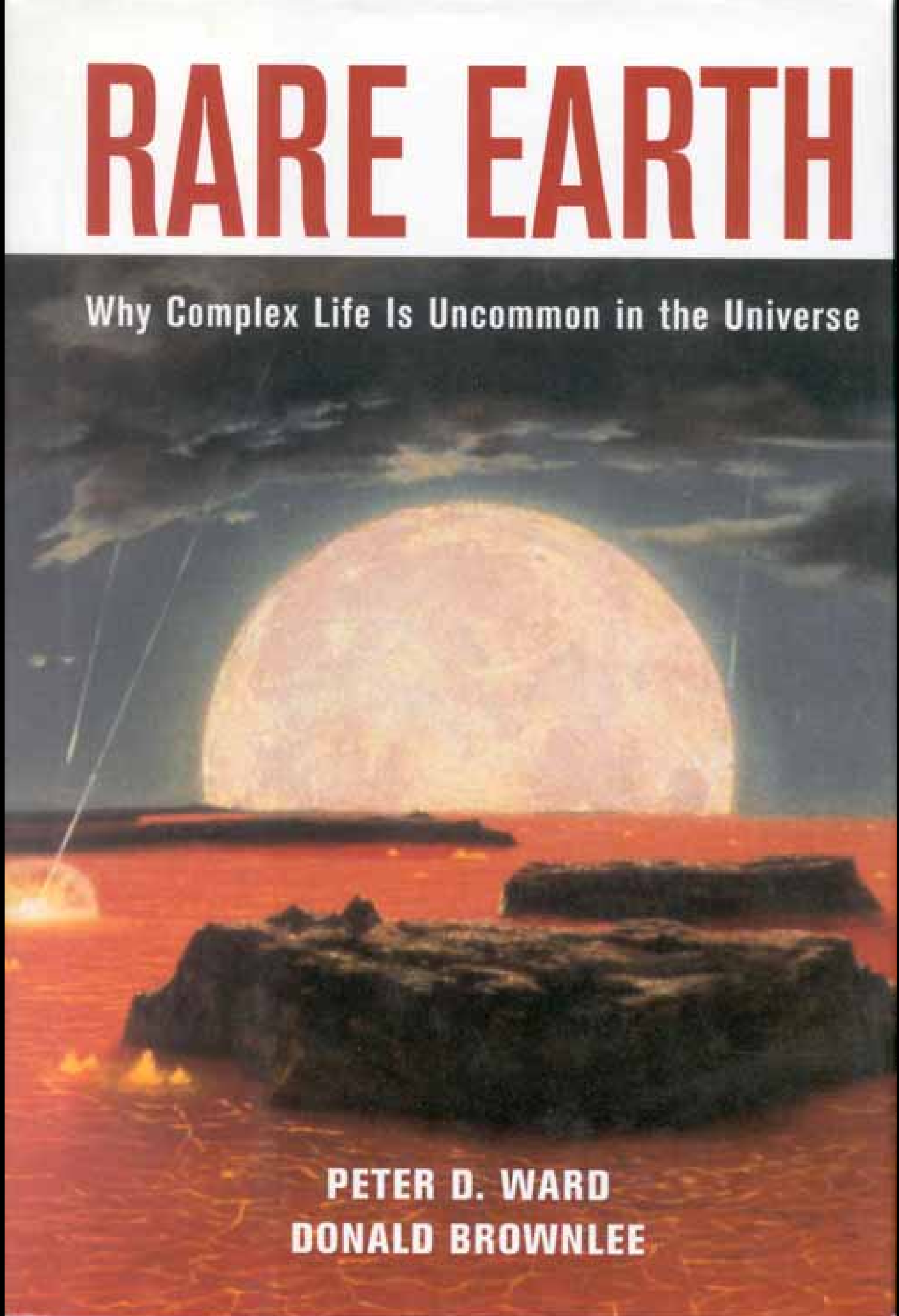
지구생명의 존재조건

- 판구조(Plate tectonics) - CO_2 순환.
- 목성형 행성의 존재 - 충돌확률을 줄임.
- 충돌: 진화에 필요.
- 우주선: 적당량의 돌연변이.
- 달의 존재: 지축안정화.
- .....

  Rare Earth?

  Life everywhere?


RARE EARTH
Why Complex Life Is Uncommon in the Universe
PETER D. WARD
DONALD BROWNLEE

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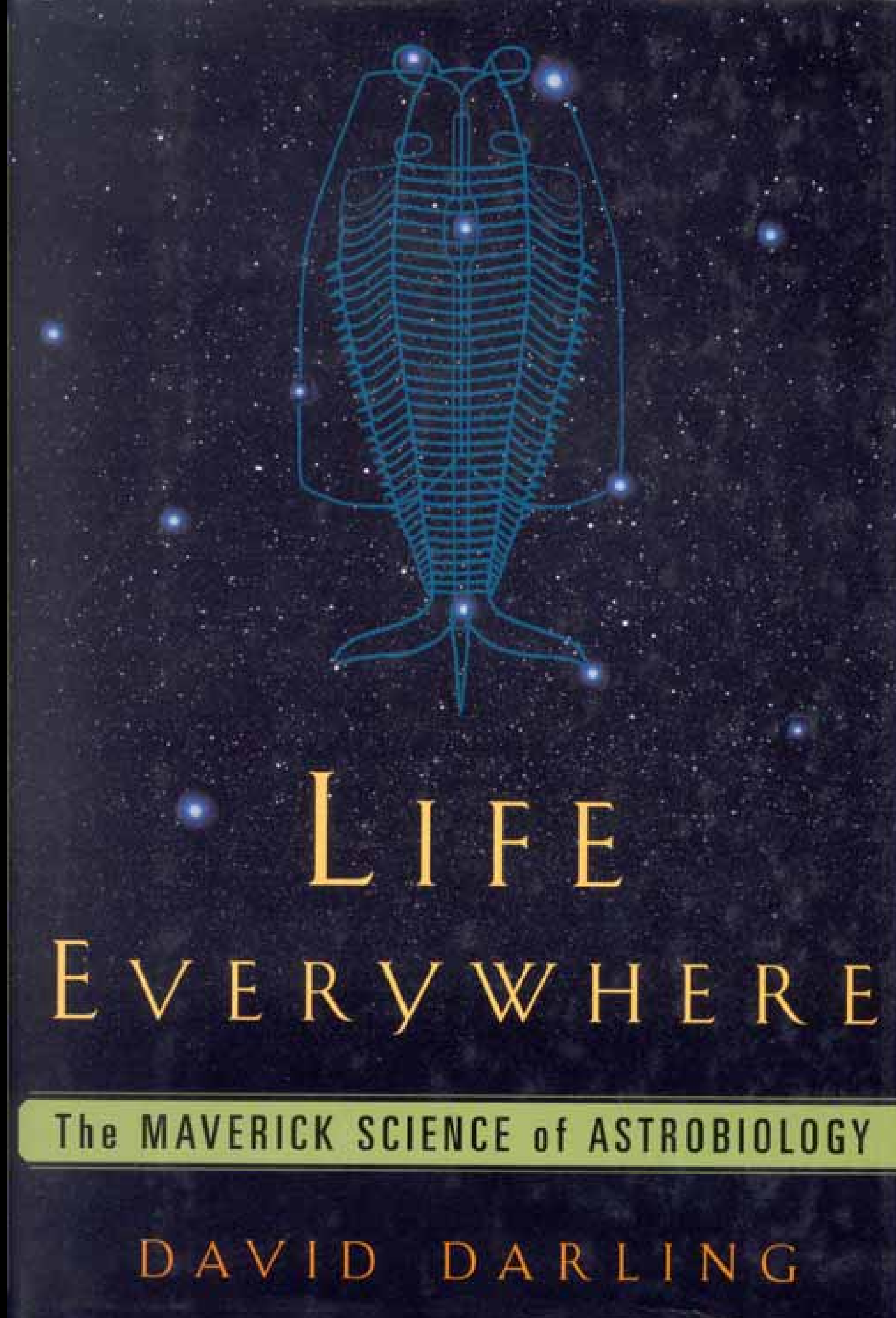
LIFE
EVERYWHERE
The MAVERICK SCIENCE of ASTROBIOLOGY
DAVID DARLING

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충돌(impact)

- 지구에는 tectonic, 풍화, 수화 작용으로 흔적이 드물지만 다른 천체를 보면...
- 초기 지구에 상당량의 물과 유기물을 제공했을 가능성

  -> 지구생명의 기원에 역할.
- 지구 생명진화의 동력으로의 기능.

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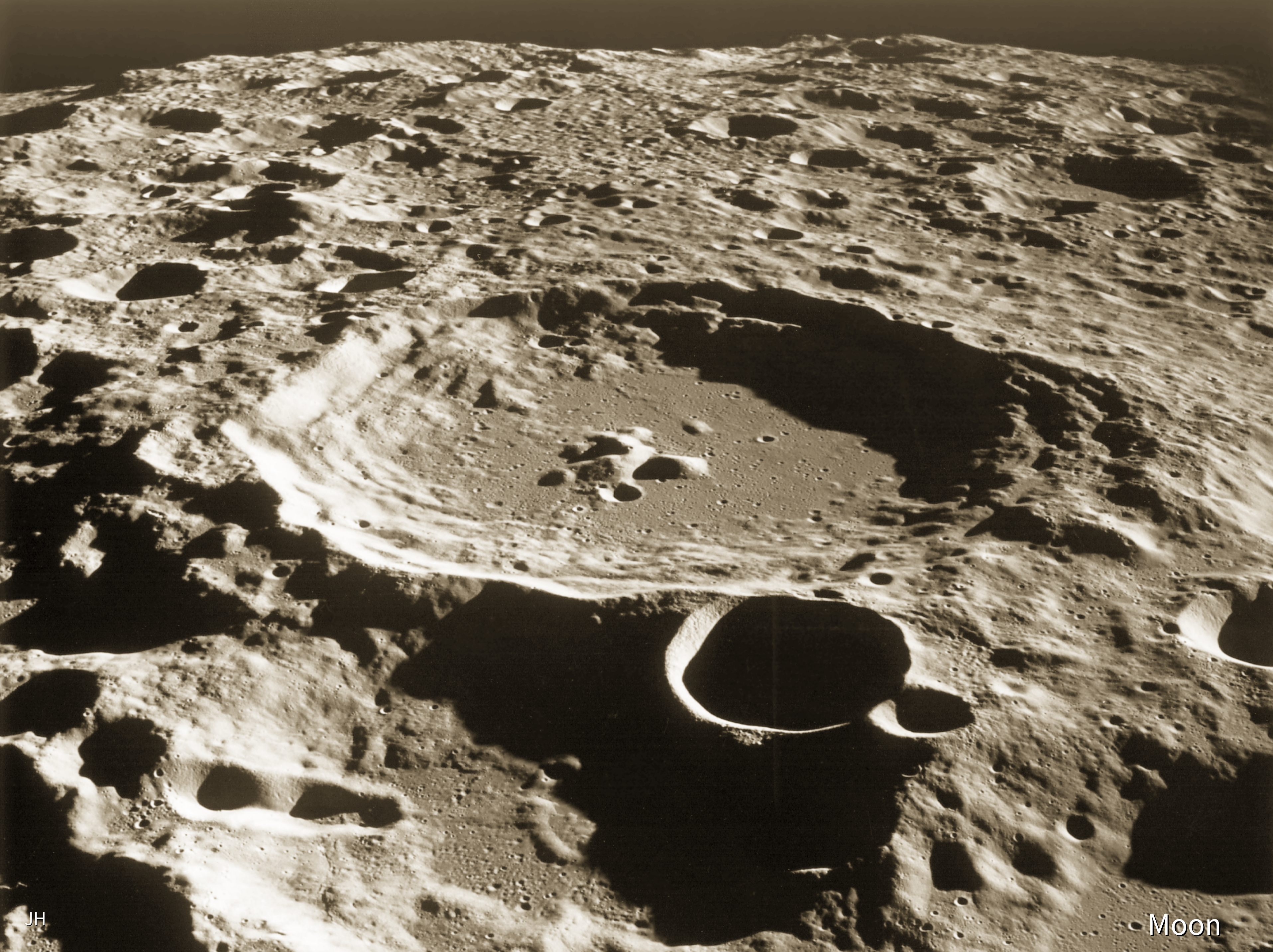
Mercury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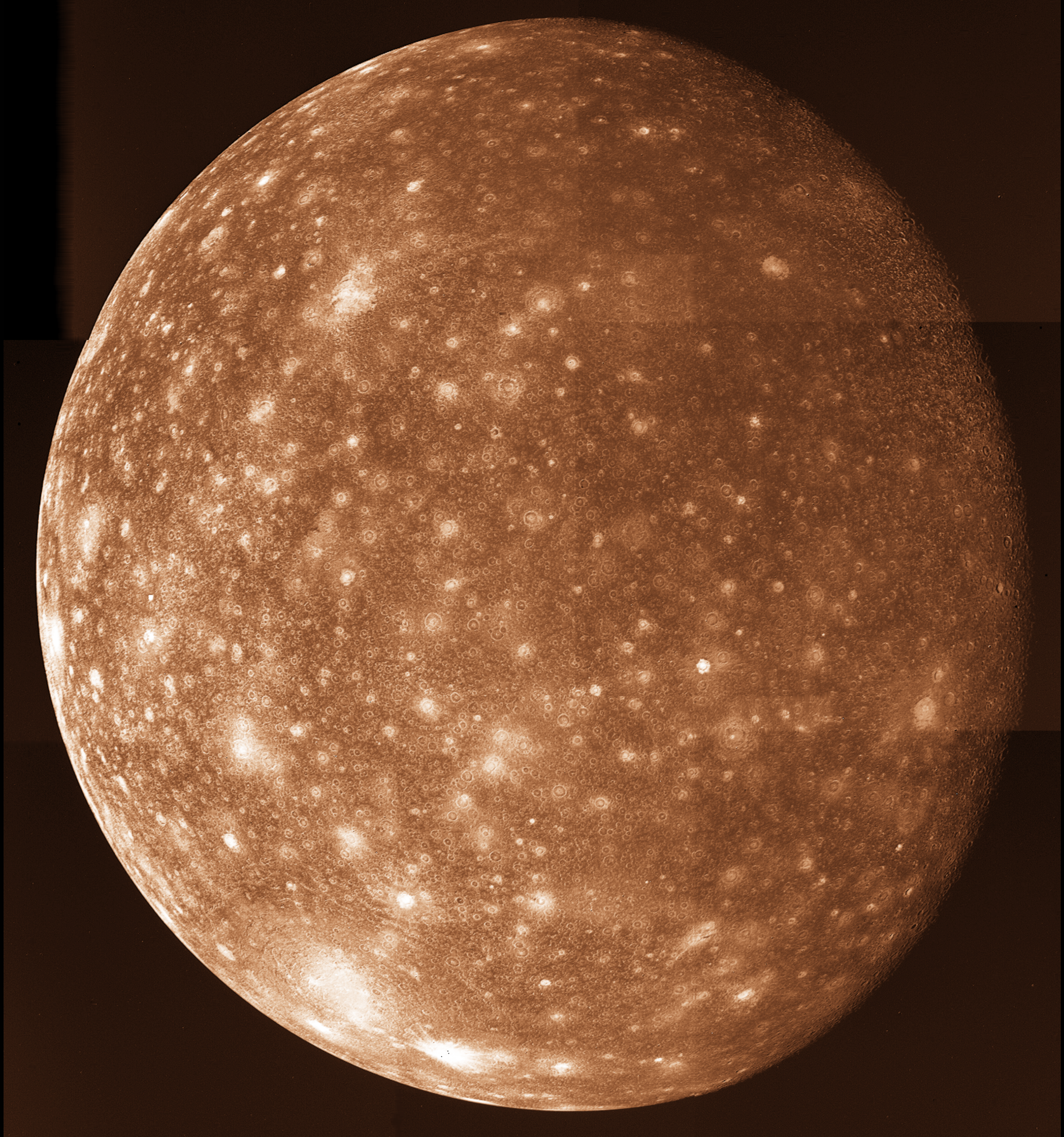
Moon


JH
Phobos



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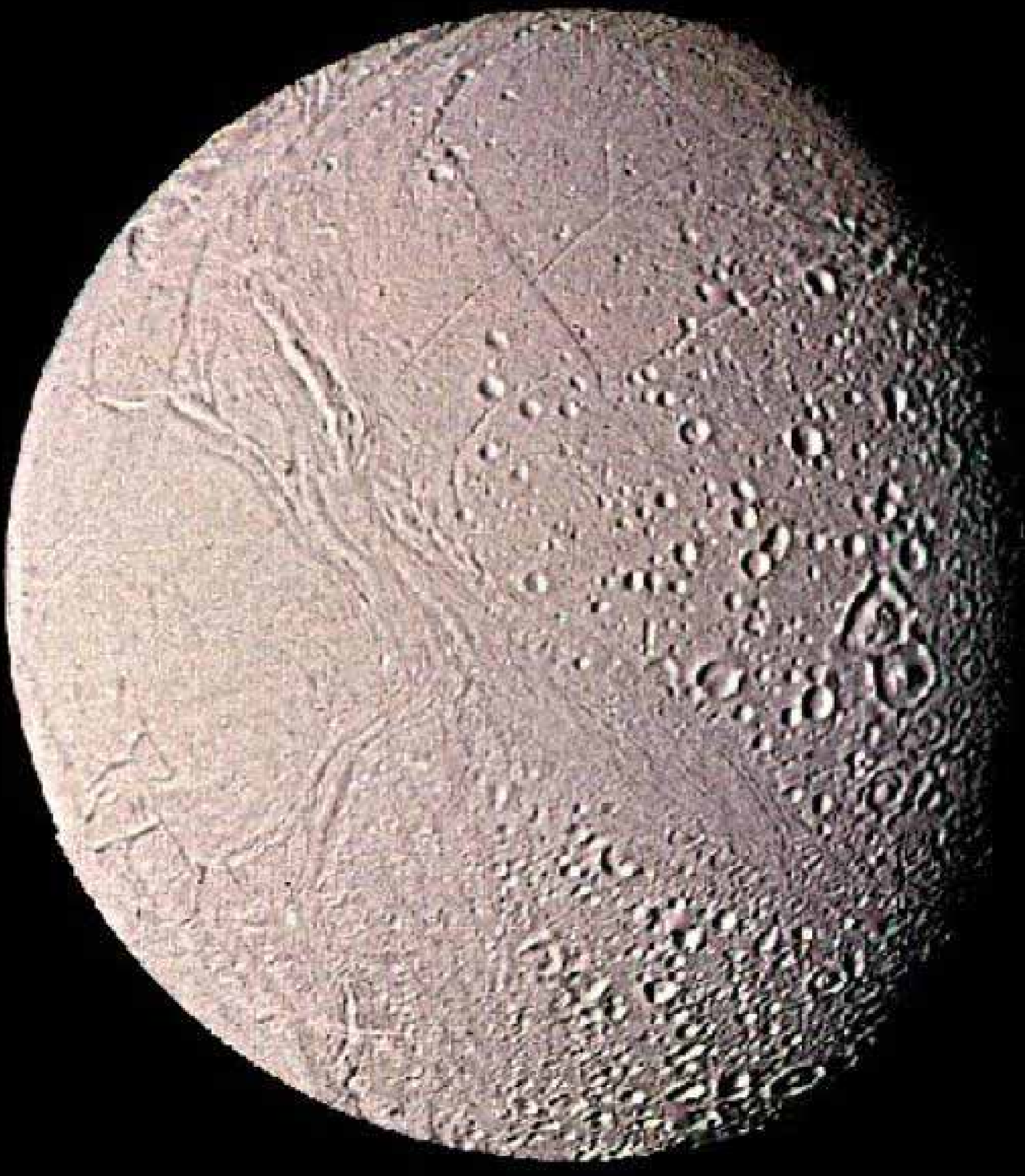
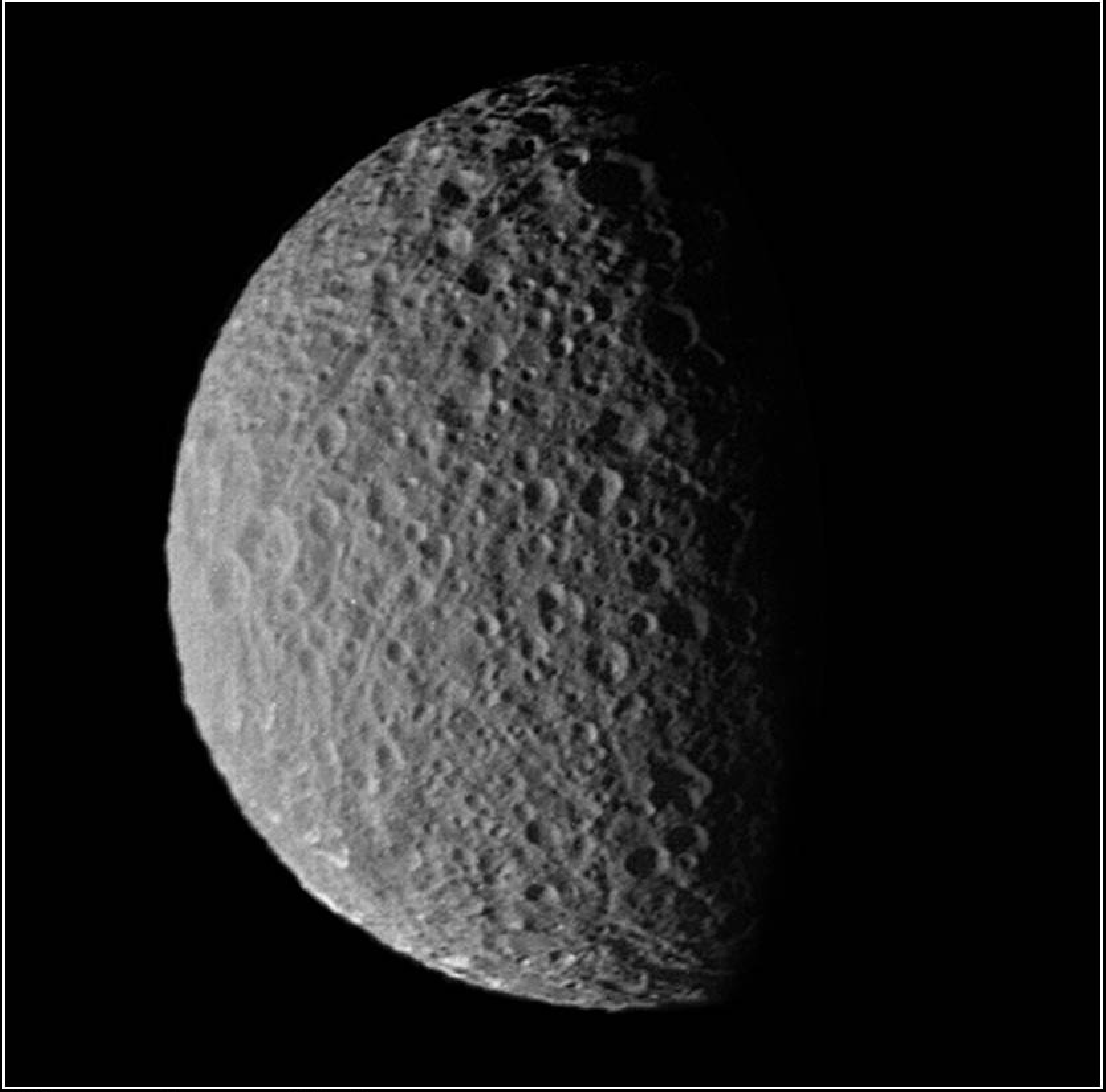
Callisto



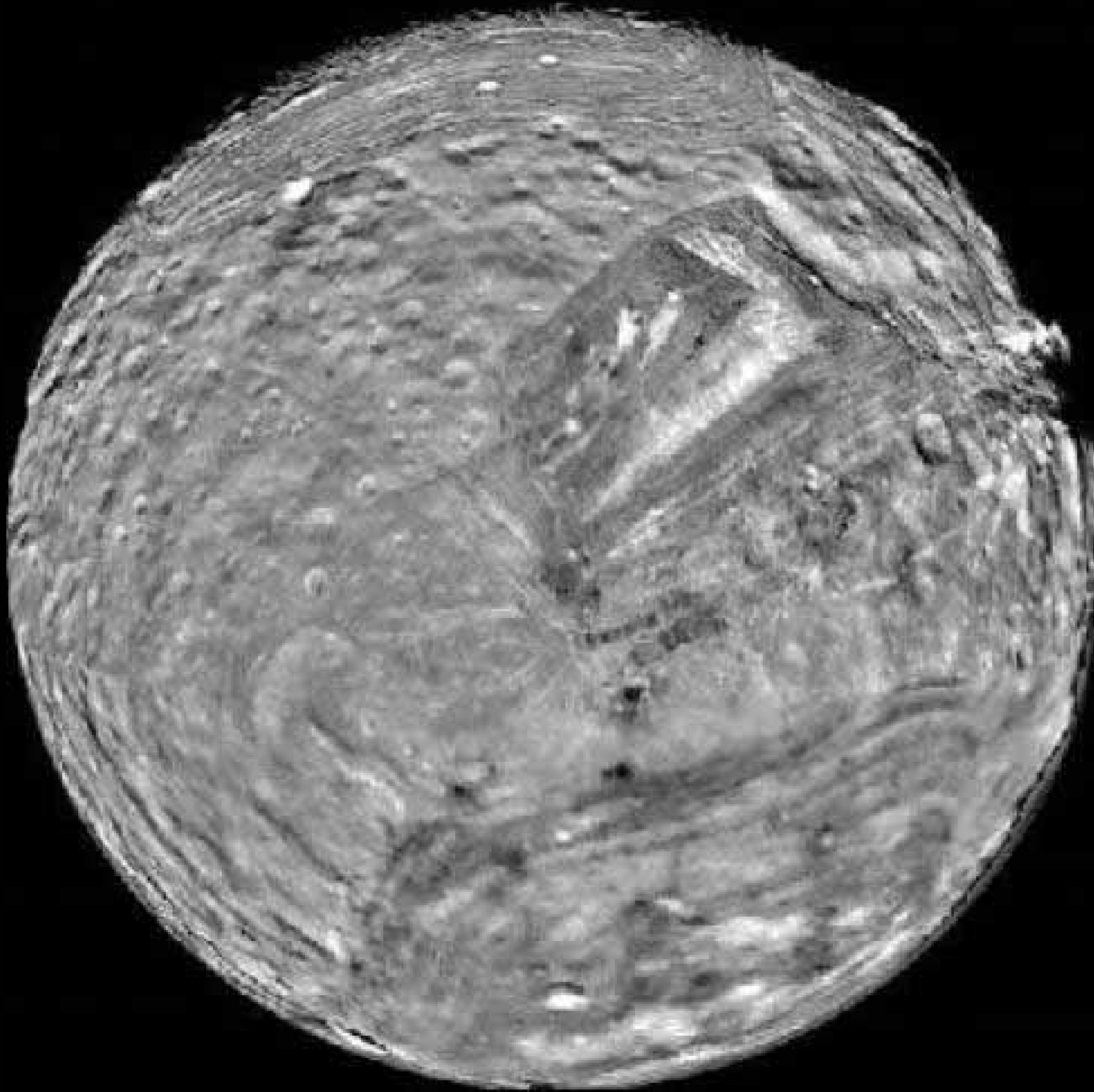
JH

Enceladus - Saturn



JH

Mimas • Moon of Saturn



JH

Miranda - Uranus

The Manicougan crater, in Quebec Canada, is about 30 million years old.

JH

http://www.spaceguarduk.com/

충돌에너지

- $(1/2)mv^2$
- 1Mt TNT= 4.2×10^{22} erg
- 히로시마 ~ 0.2Mt
- H bomb ~ 60Mt
- 지상 모든 핵탄두 ~ 10000Mt
- 목성 SL9 ~ 2×10^5 – 6×10^6Mt
- KT impact (10km) ~ 6×10^7Mt
- 1km -> 인류에 치명타 가능성.
- 특히 바다에 떨어질 경우 위험.

TABLE 12–1 Height of deep-water wave and (->) tsunami 1,000 kilometers away from point of impact

Size of impactor	*50 m*	*100 m*	*300 m*	*1 km*
Type of object				
Iron	2 m -> 80 m	7 m -> 280 m	40 m ->1.6 km	700 m -> 28 km(!)
Hard stone	0.8 m -> 32 m	2 m -> 80 m	25 m -> 1 km	200 m -> 8 km
Average time between impacts	100 yr	1,000 yr	20,000 yr	200,000 yr

JH

Verschuur

위험도 평가

Table 2
Mean Probabilities of Dying Due to Certain Accidental Causes for U.S. Residents

Cause of death	*Probability*
Automobile accident	1 in 100
Homicide	1 in 300
House or other fire	1 in 800
Accidental shooting	1 in 2,500
Electrocution	1 in 5,000
Asteroid/comet impact	1 in 10,000*
Airplane disaster	1 in 20,000
Flood	1 in 30,000
Tornado	1 in 60,000
Snake bite or insect sting	1 in 100,000
Fireworks accident	1 in 1 million
Botulism poisoning	1 in 3 million

*Value is the author's.

JH

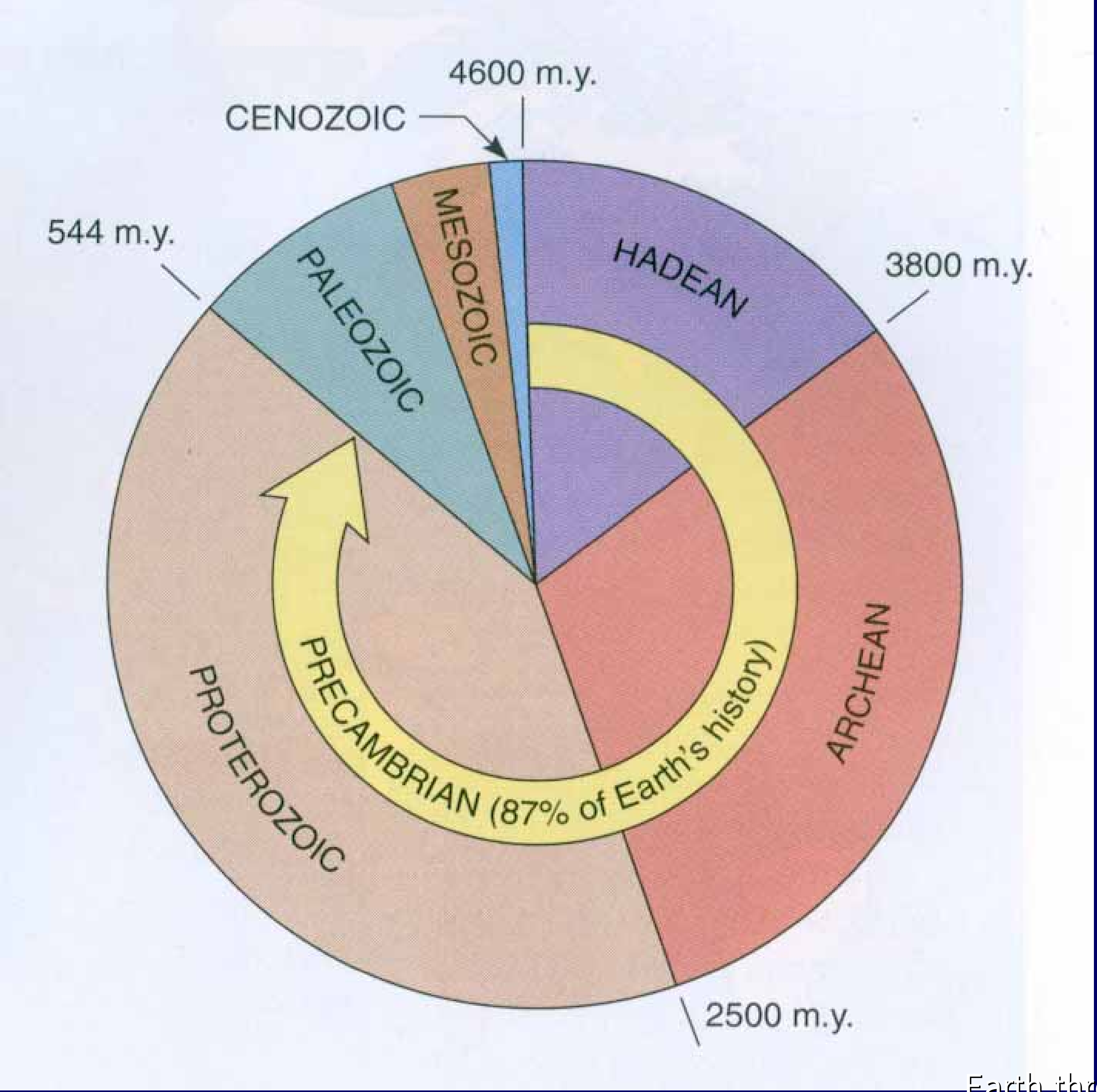
Steel

Extinction (절멸)

- 안정된 환경에서 생명은 거의 진화하지 않는다.
- 기존생명이 “적응하기에 너무 빠른 환경의 변화”가 일어나면 절멸
- 이 틈에 새로운 종이 빠르게 진화

Punctuated equilibrium

- 절멸율과 운석 충돌율이 비슷
- 진화의 원동력으로서 역할
- Bad gene? Or bad luck?



JH

Earth through time

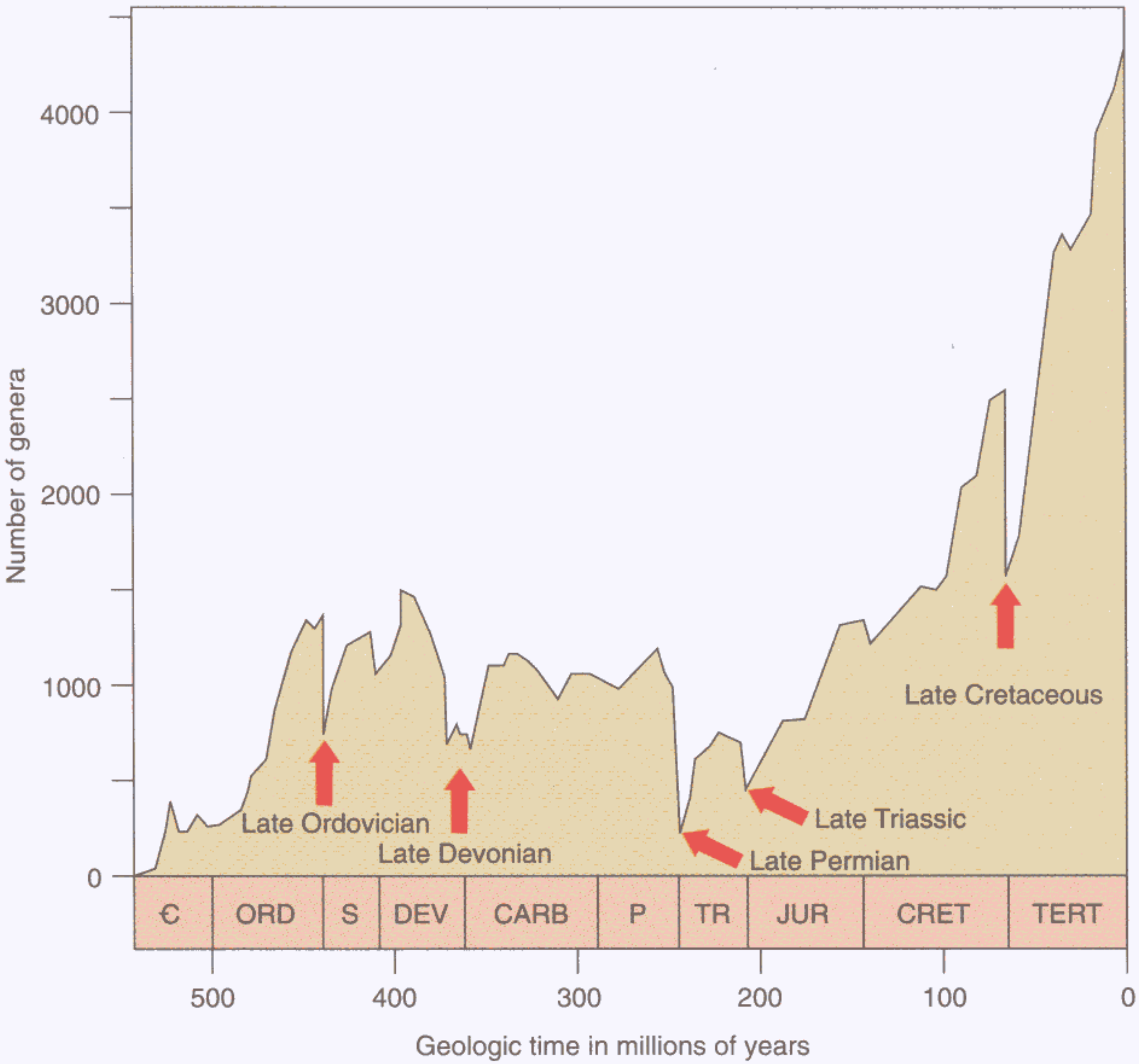
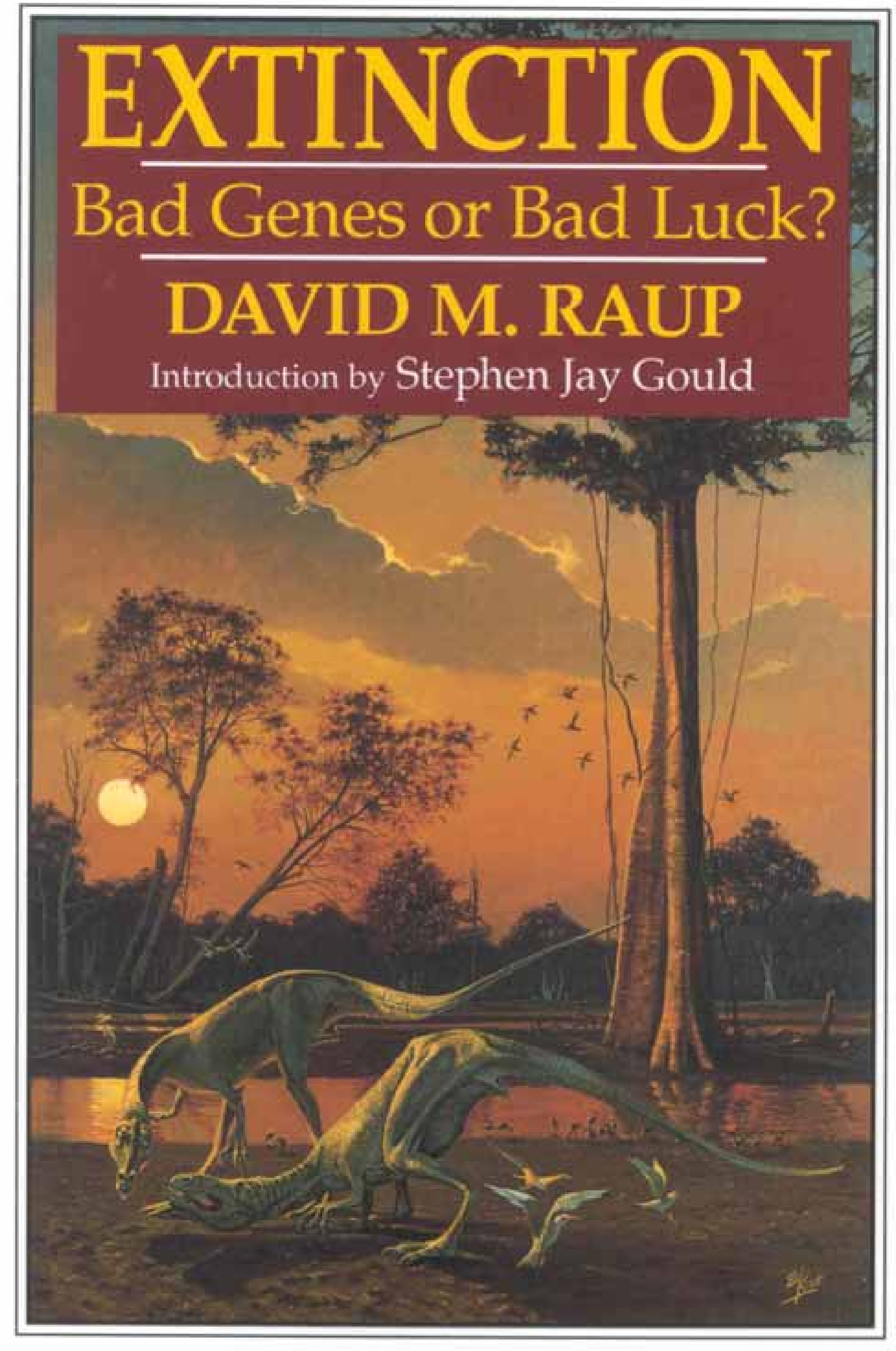


FIGURE 10–84 Diversity **of marine animals compiled from a database recording first and last occurrences of more than 34,000 genera.** The graph depicts five major episodes of mass extinction (global extinctions over a short span of geologic time). *(Adapted from Sepkoski, J. J., Jr. 1994.* Geotimes *39(3):15–17.)*


EXTINCTION
Bad Genes or Bad Luck?
DAVID M. RAUP
Introduction by Stephen Jay Gould

JH

KT impact

- 10km 소행성이나 혜성.
- 증거: shocked minerals.
- 지표에 드믄 원소 (Ir, Pb,...)
- 버키볼안에 잡힌 동위원소!

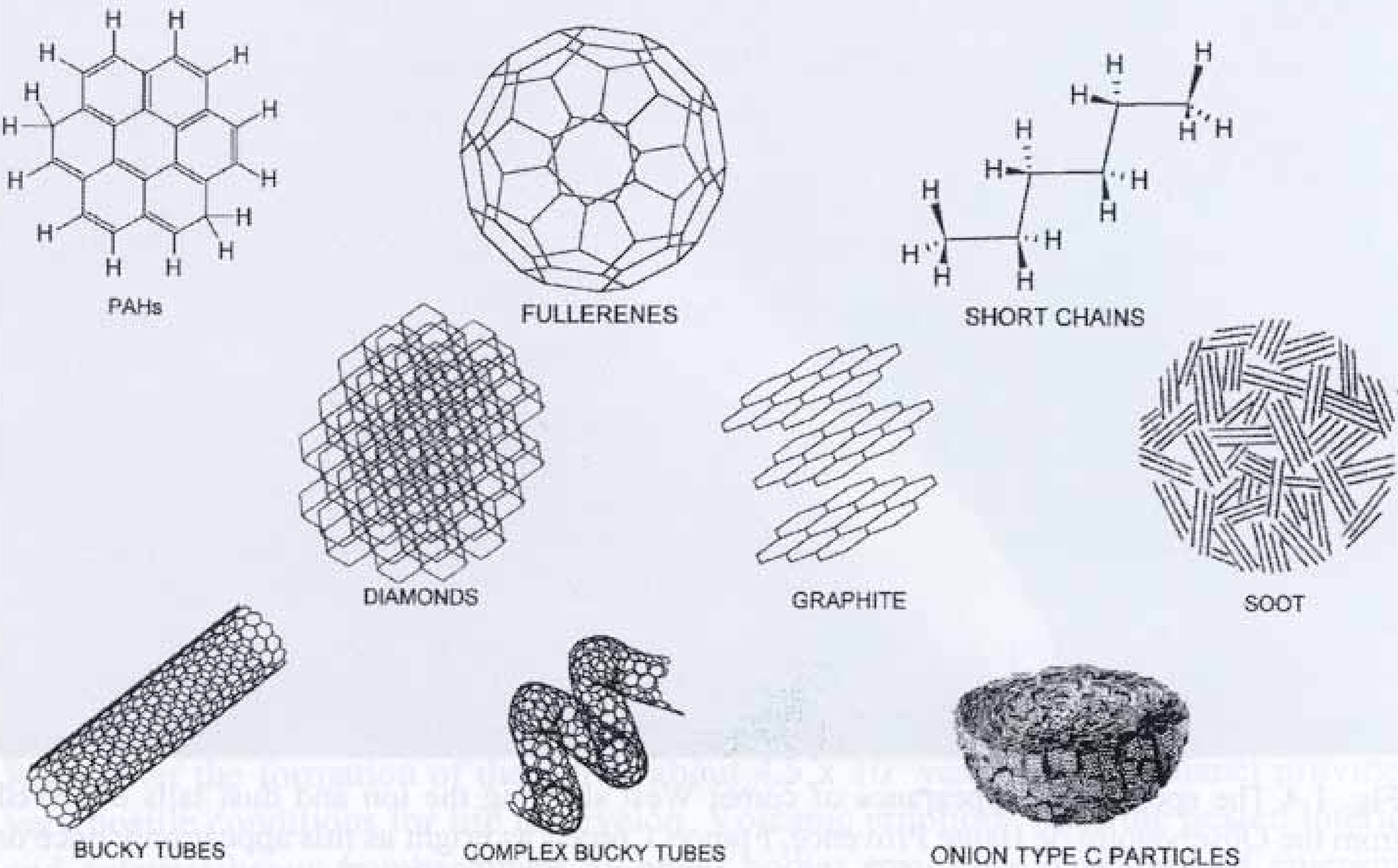


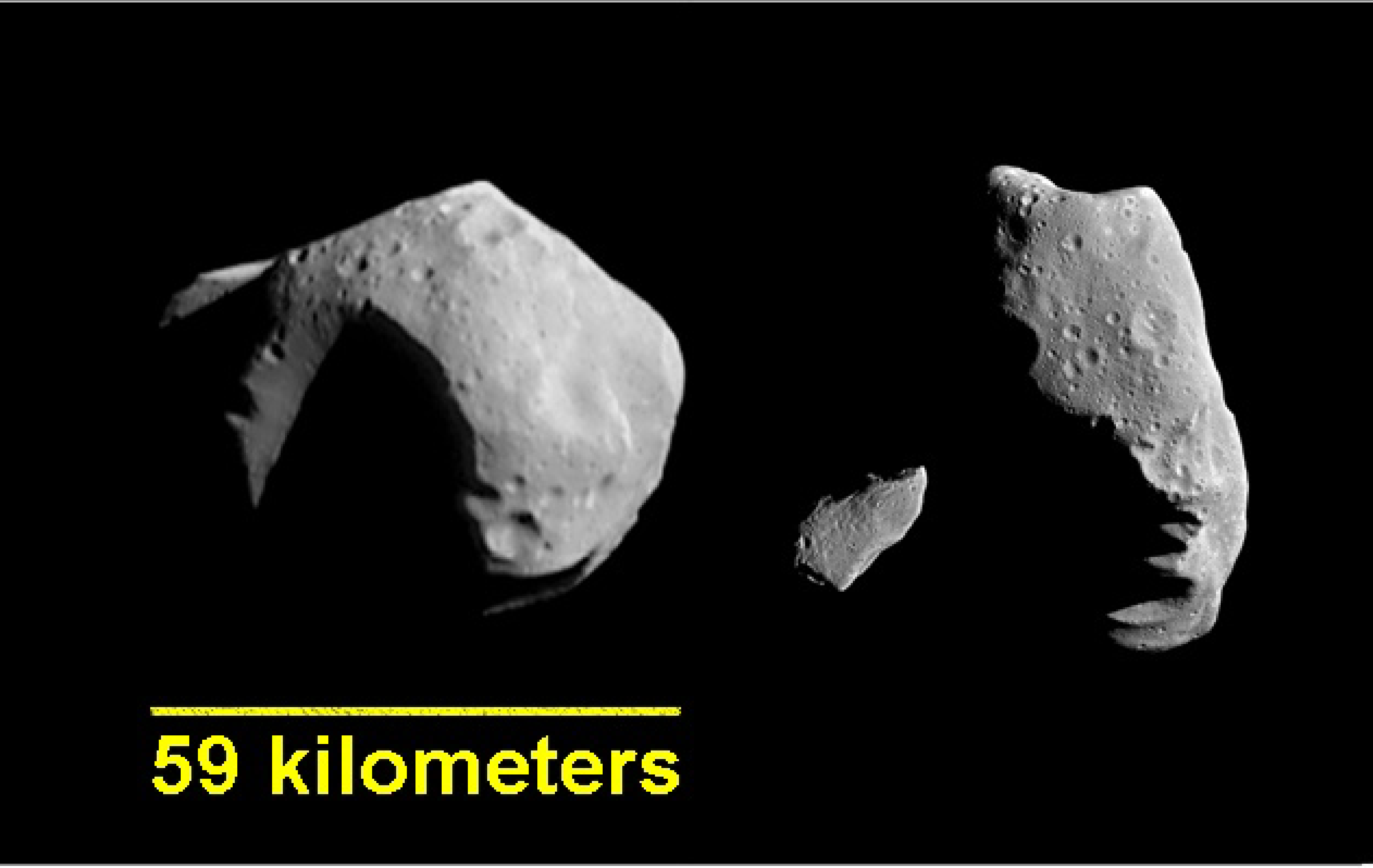
Fig. 1.3 Some of the various forms of carbon that are likely present in gaseous and solid state in the interstellar medium and in solar system material.

JH

Gaspra

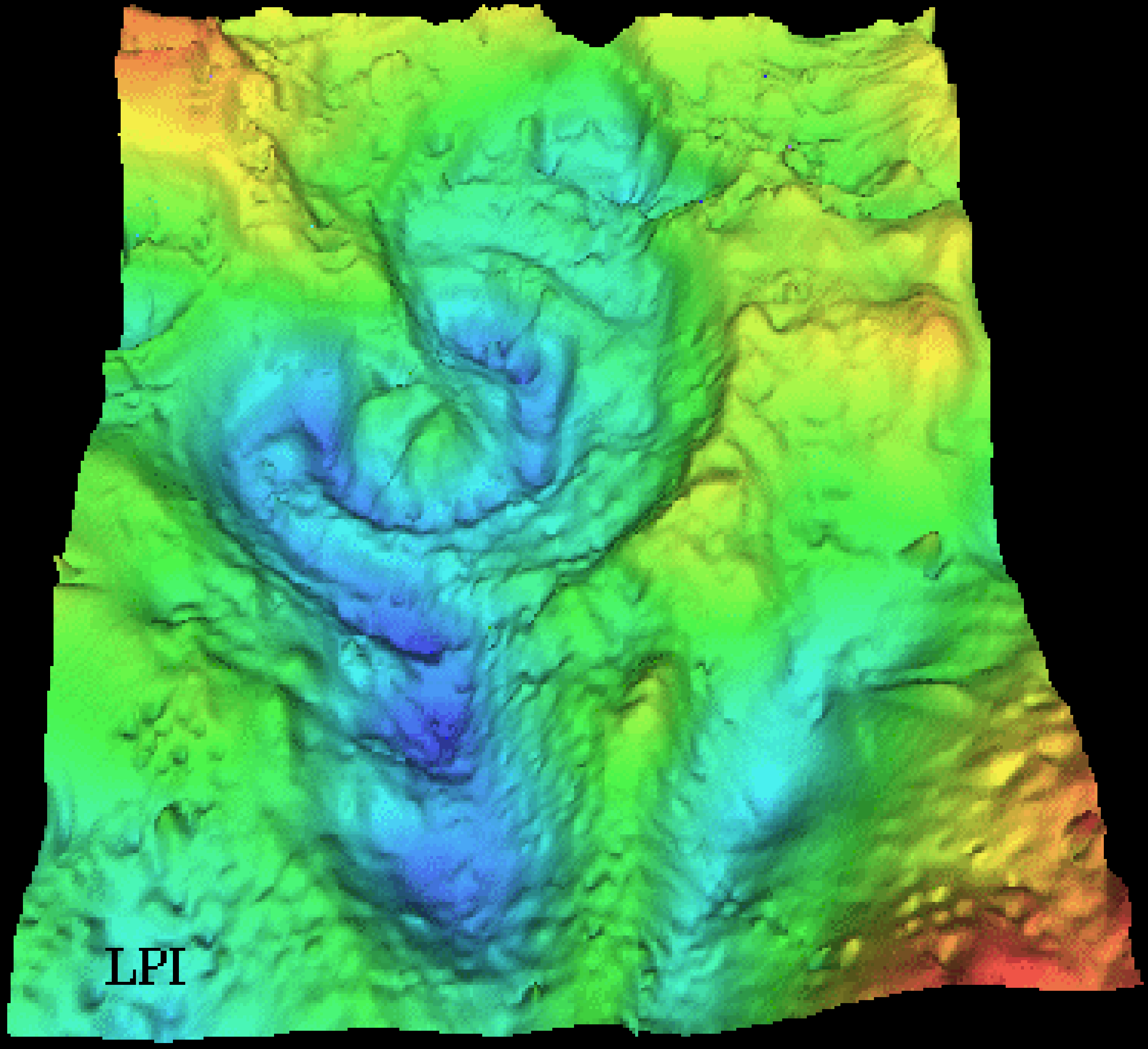
JH

Ida and Dactyl



Mathilde Gaspra Ida

JH



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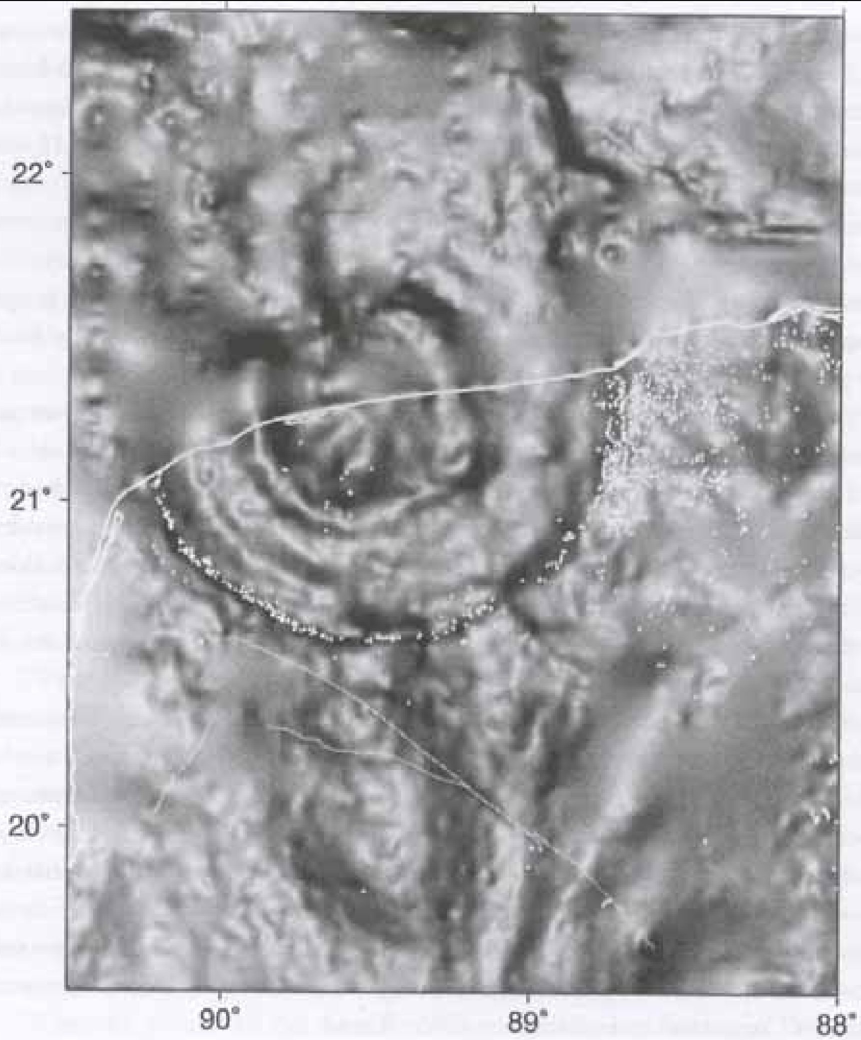
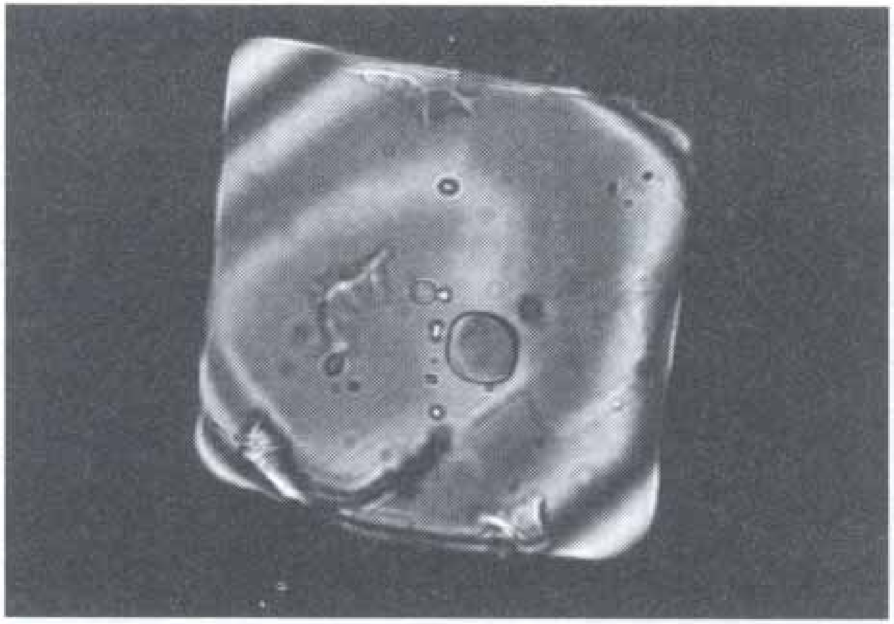


Figure 2-1 The Chicxulub crater as revealed on gravitational maps. The image shows the gravity structure for the northwest corner of the Yucatan Peninsula. The buried Chicxulub crater is revealed as a striking series of nearly concentric rings. The locations of the coastline, cenotes (water-filled sinkholes), and recent faults are shown in white. Areas lacking data appear blurred, and offshore ship tracks make broad, linear features in the plot at upper left. The numbers along the edge of the map are longitude (horizontal, at bottom) and latitude, along the left side. (Courtesy A. R. Hildebrand and Geological Survey of Canada)

Figure 2-3 A typical cenote in the Yucatan, a sinkhole now filled with water, which is used by locals for recreation. Many of the cenotes are arrayed around the edge of the crater that lies far beneath the surface, as shown in Figure 2-1. (Courtesy Glen Penfield)

JH

Verschuur



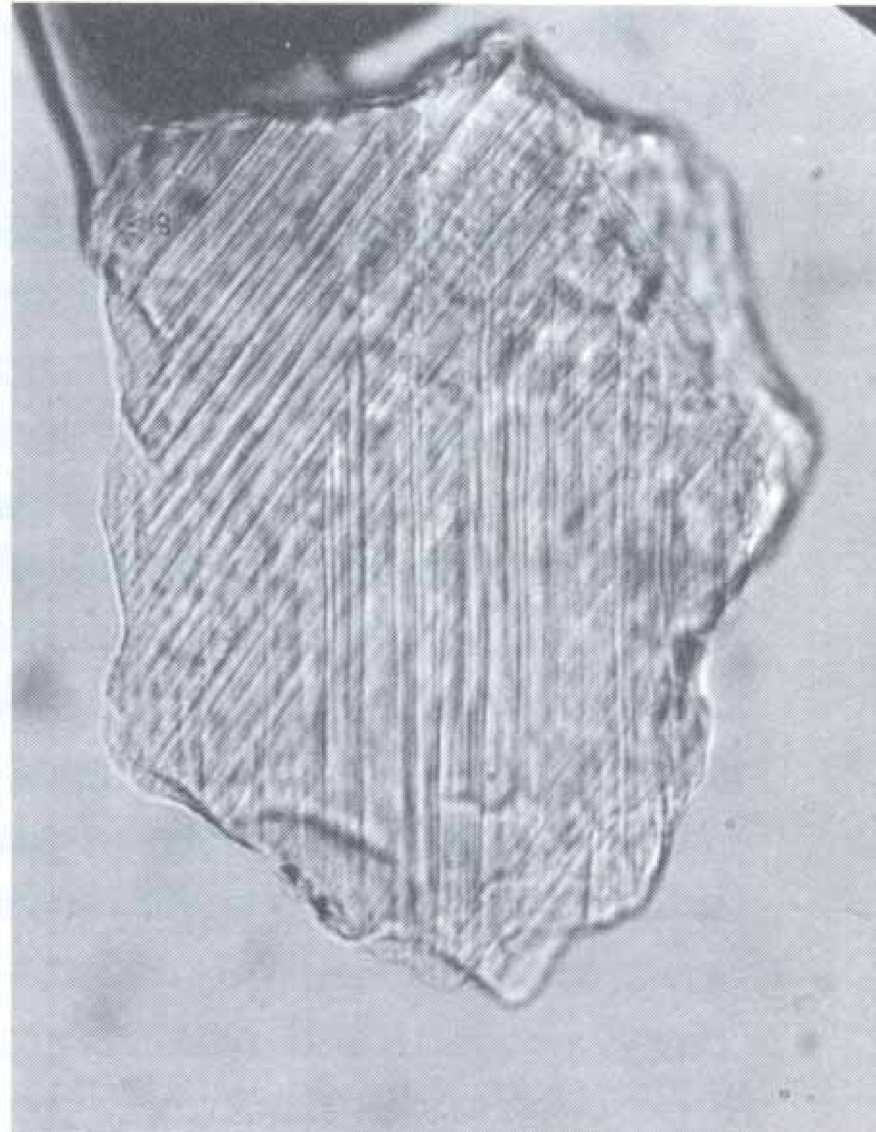


FIGURE 12 (Top) Unshocked quartz from an explosive volcanic rock in the Jemez Mountains, New Mexico. Note the absence of shock planes. (Right) Shocked quartz from the K–T boundary in the Raton Basin, Colorado, showing two sets of shock planes. [Photo courtesy of Glenn Izett.[27]]

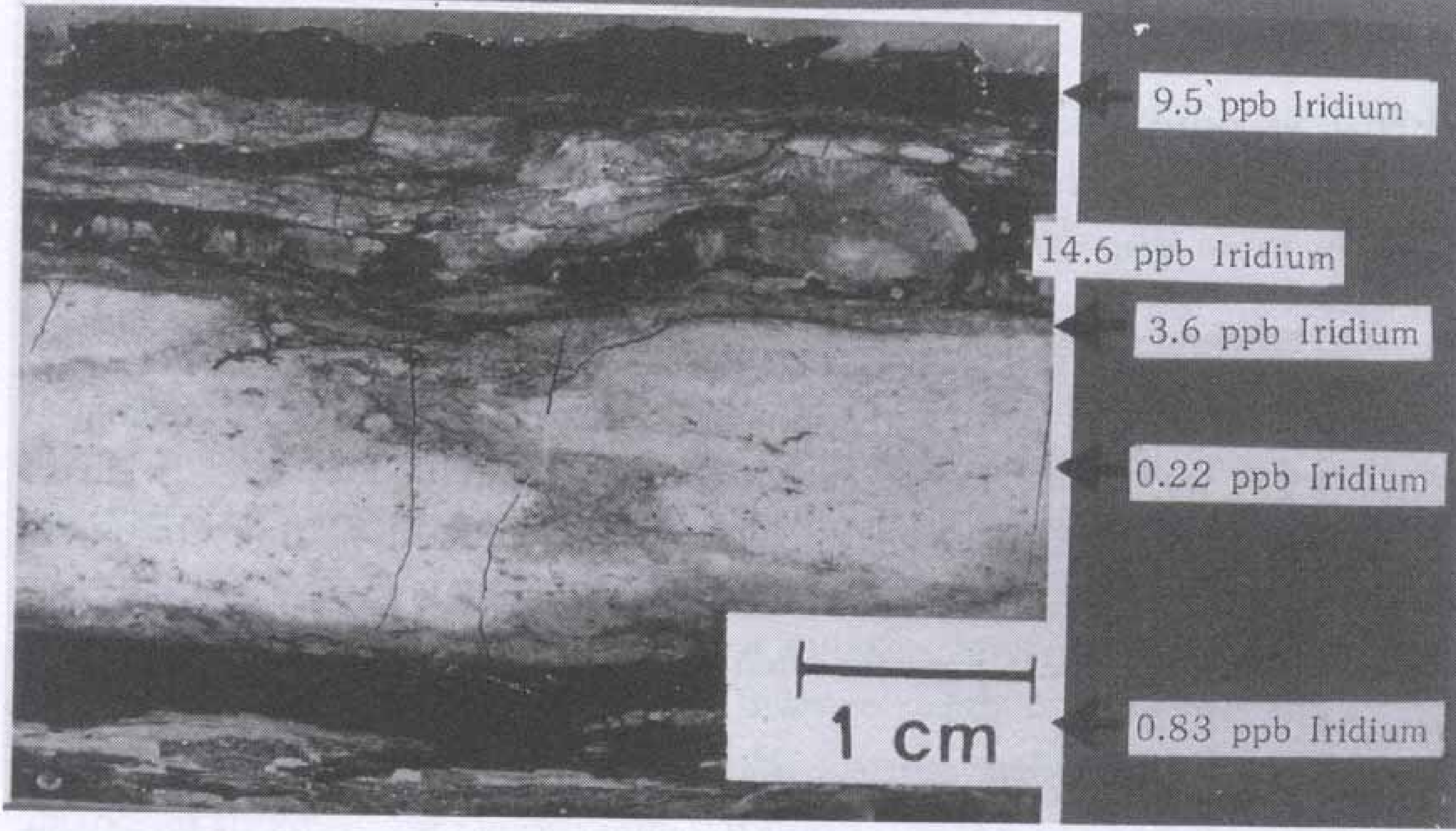
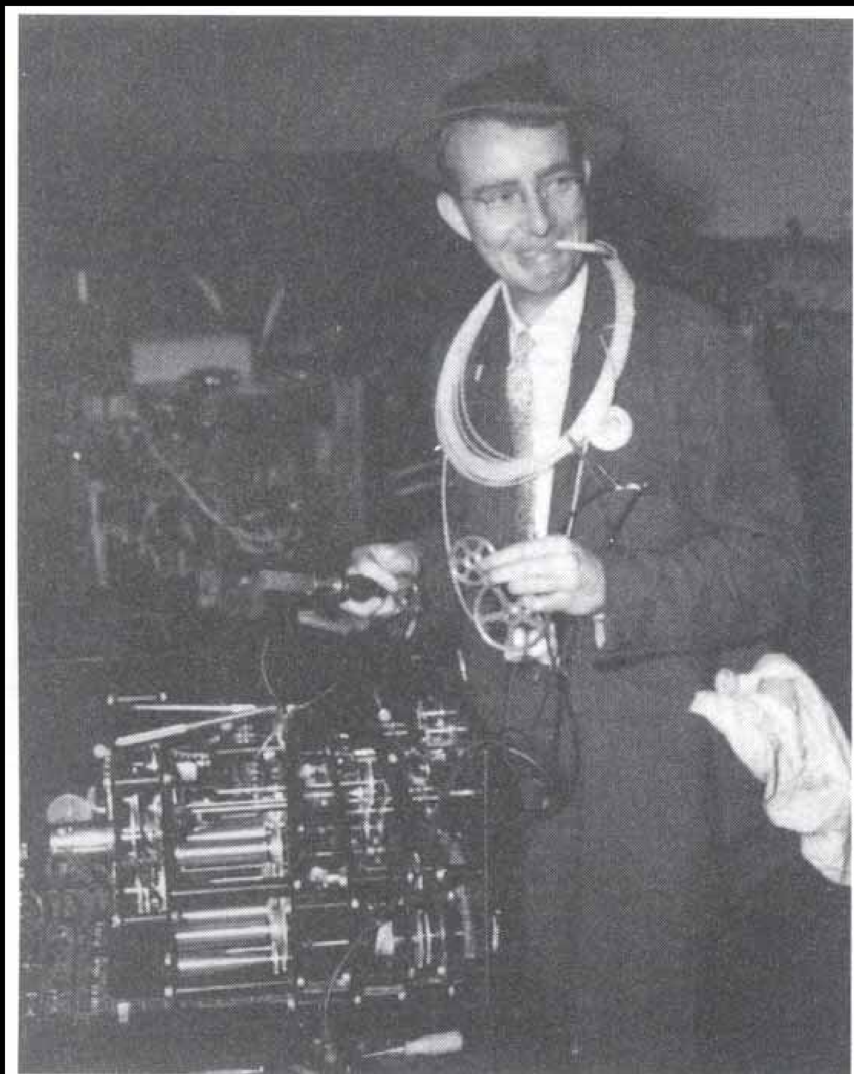
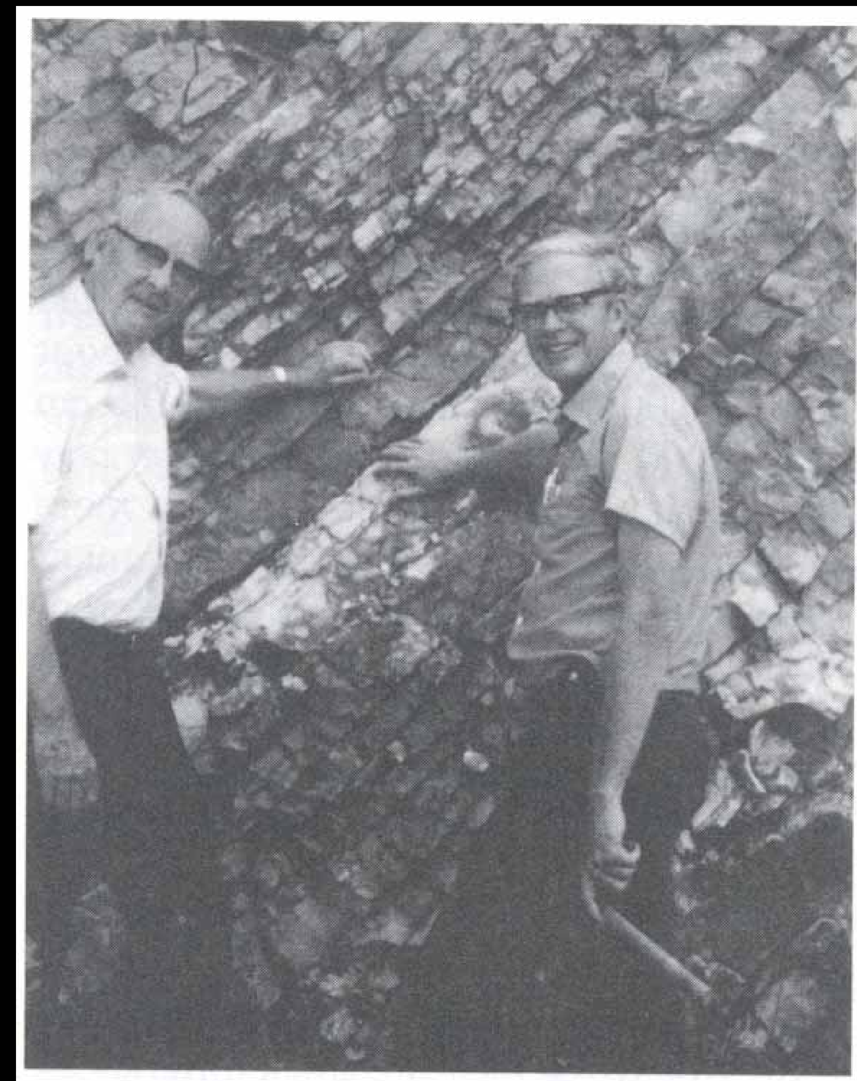


Figure 1-2 A close-up view of the K/T boundary layer from the Clear Creek North site, a few kilometers south of Trinidad, Colorado. In ascending order, the boundary interval consists of (1) carbonaceous shale of Cretaceous age, (2) a layer of white clay about 1.5 centimeters thick called the K/T boundary clay bed, or the



Luis Alvarez



with his son Walter

JH

Powell

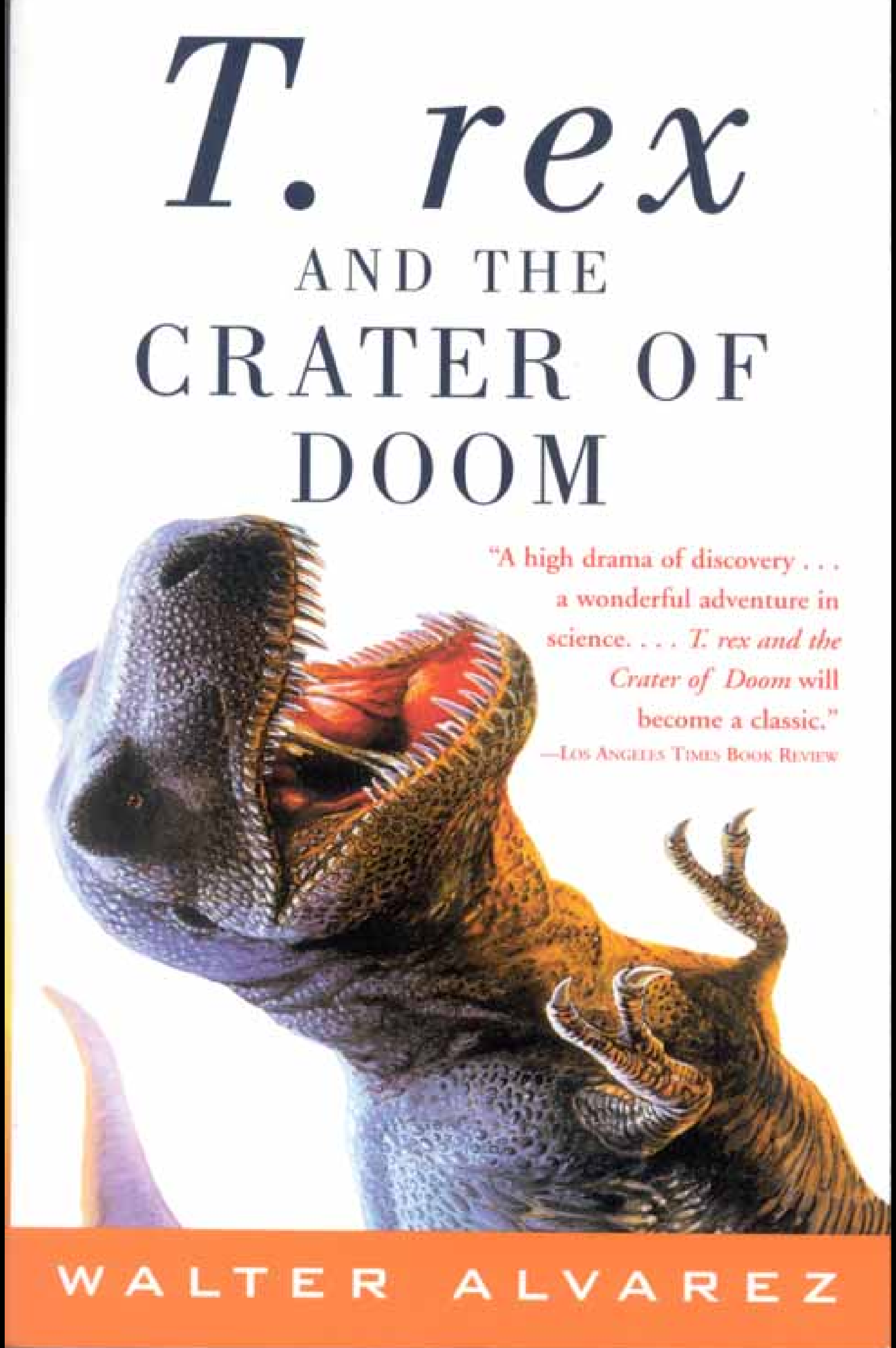
Table 3

Environmental Stresses Produced by Large Impacts, Such As That at the K/T Boundary

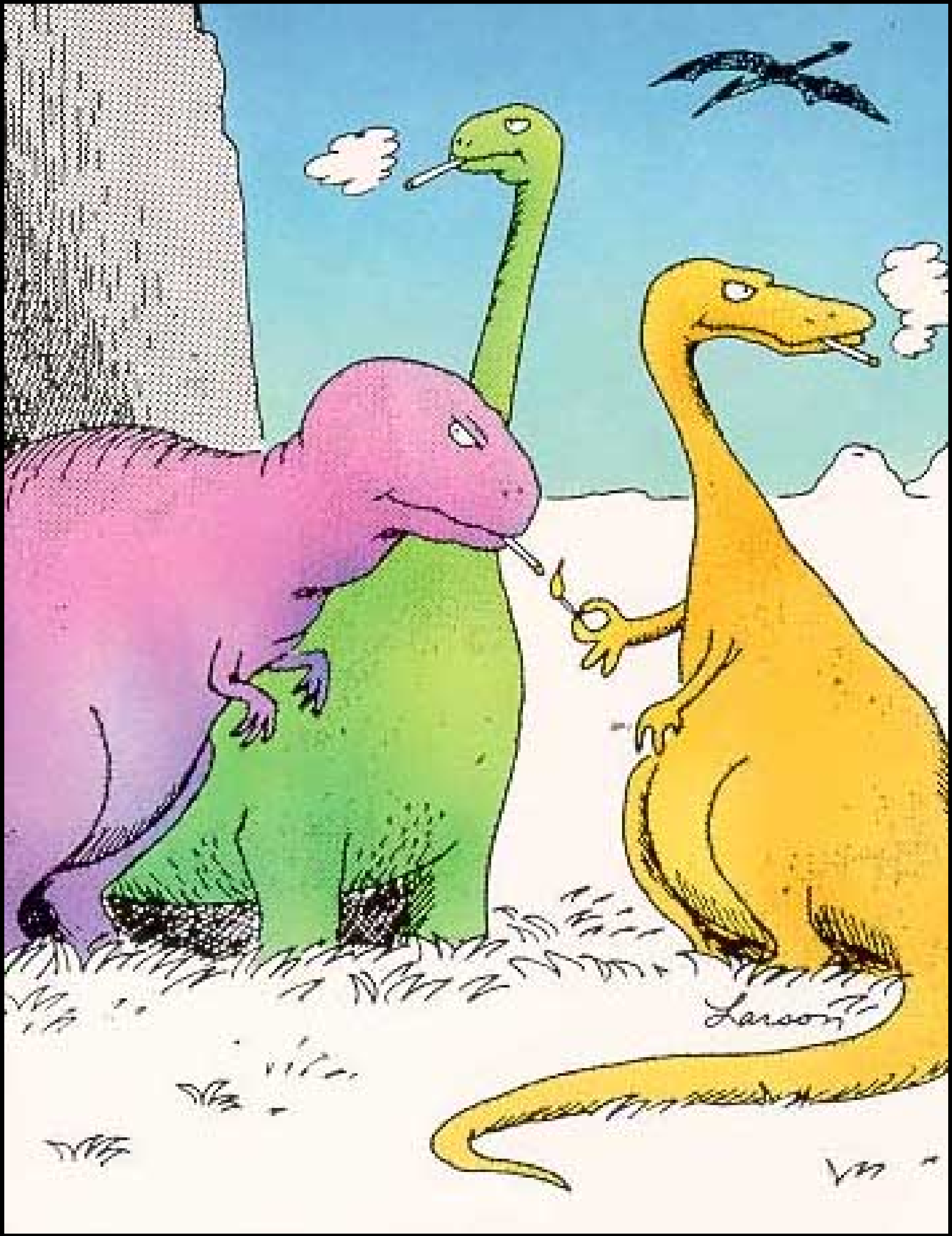
Stress Induced	*Time Scale*
Darkness (loss of photosynthesis)	Months
Cold (impact winter)	Months/years
Winds (500 km/hr plus)	Hours
Tsunamis	Hours/days
Greenhouse (H_2O)	Months
Greenhouse (CO_2)	10,000–500,000 yrs
Fires	Months
Pyrotoxins (poisons produced by fire)	Years
Acid rain	Years
Ozone layer destruction	Decades
Volcanism triggered by impacts	Millennia
Mutagens	Millennia

JH

Steel

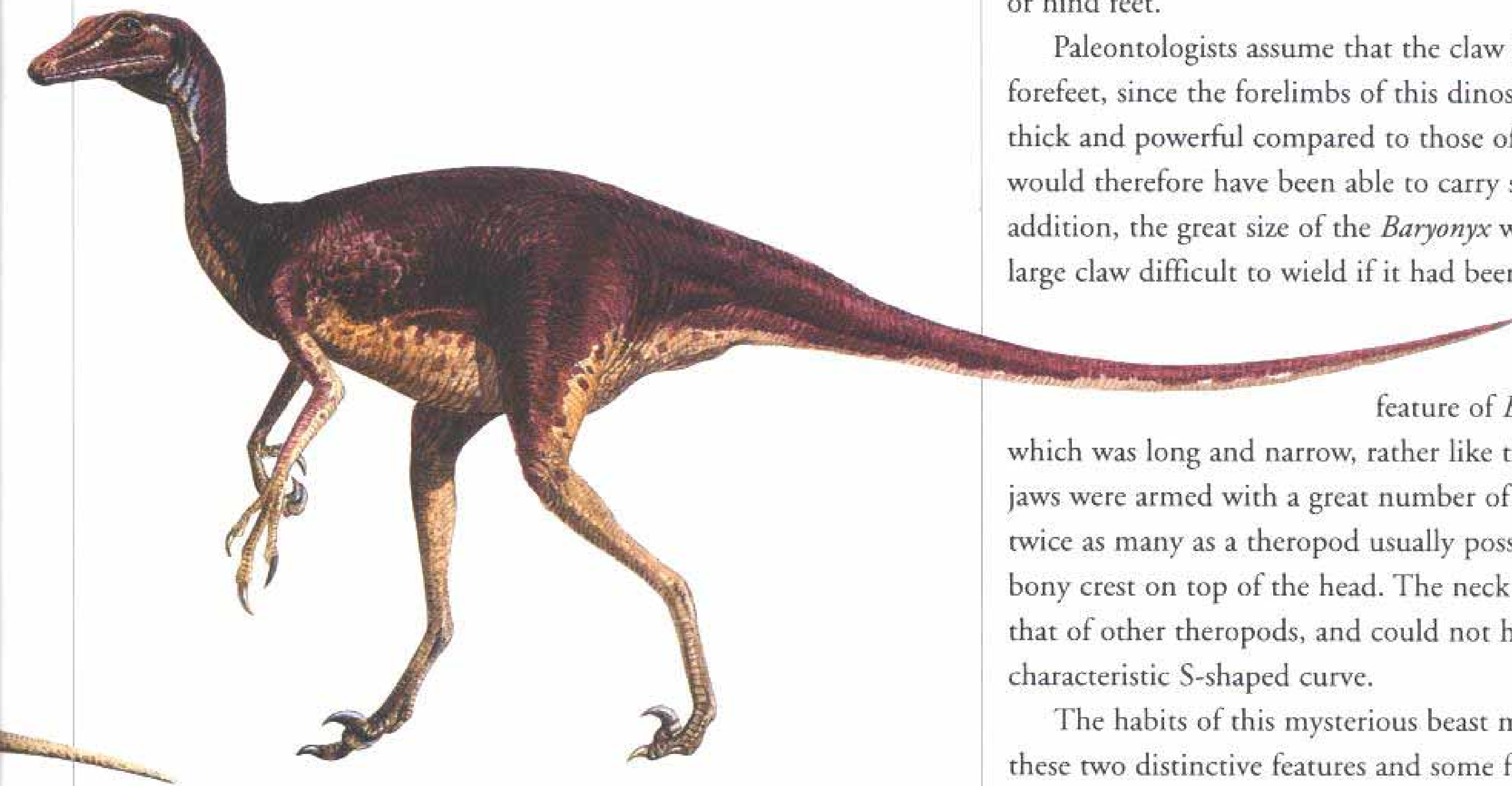

T. rex
AND THE
CRATER OF
DOOM
"A high drama of discovery . . .
a wonderful adventure in
science. . . . T. rex and the
Crater of Doom will
become a classic."
—Los Angeles Times Book Review
WALTER ALVAREZ

JH



The real reason dinosaurs became extinct! (The far side, Gary Larson)

❑공룡이 6500만년전에 절멸 당하지 않았더라면,



or hind feet.

Paleontologists assume that the claw belong
forefeet, since the forelimbs of this dinosaur we
thick and powerful compared to those of other
would therefore have been able to carry such a
addition, the great size of the *Baryonyx* would h
large claw difficult to wield if it had been locate
ani
The s
feature of *Baryony*
which was long and narrow, rather like that of
jaws were armed with a great number of small,
twice as many as a theropod usually possessed.
bony crest on top of the head. The neck was no
that of other theropods, and could not have be
characteristic S-shaped curve.

The habits of this mysterious beast may be
these two distinctive features and some fish rem
found with the skeleton. It is possible that *Bary*

❑ Stenonikosaurus inequalis가 우리 대신 지능을 갖추었을 수도

JH

지구생명의 전멸가능성

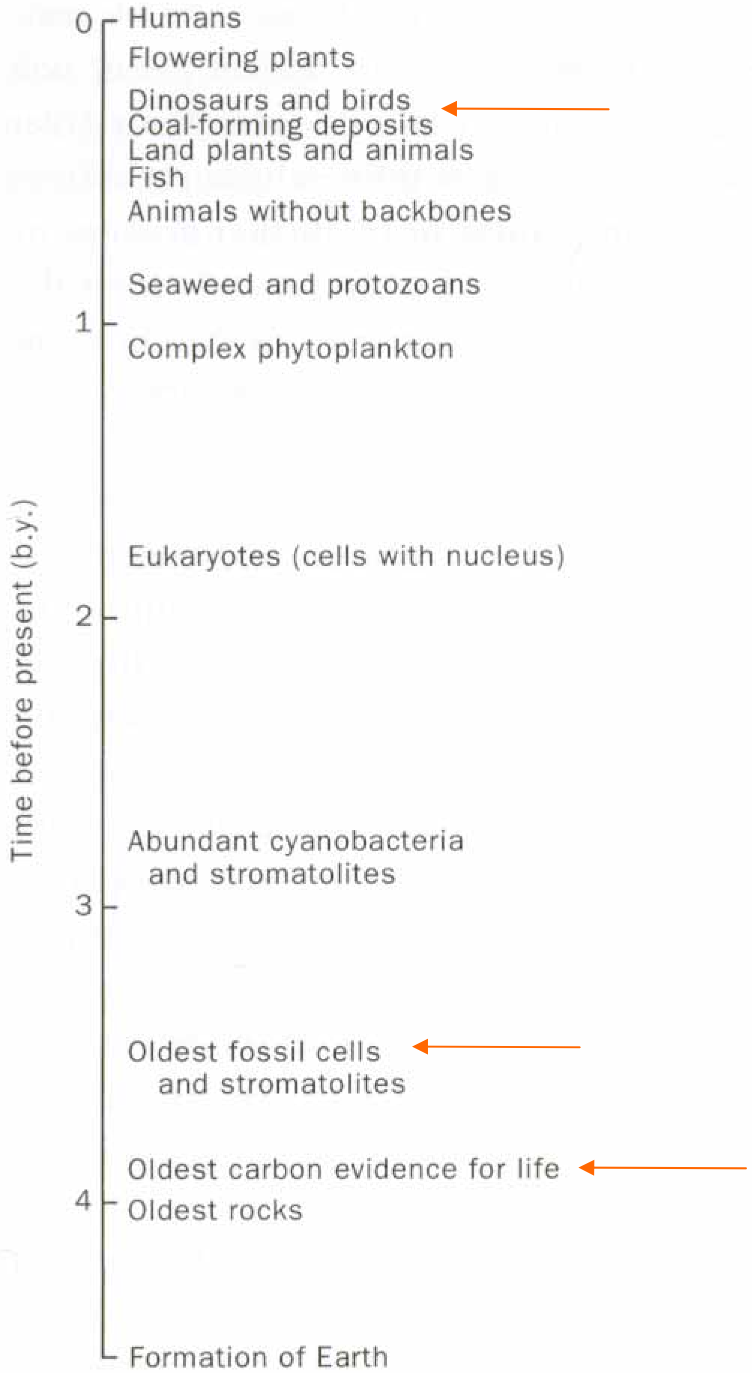
- 인류의 핵전쟁으로는 인류조차 멸종 시키기 어렵지만, 자연현상은 지구생명을 전멸 시킬 가능성이 있다.
- 예: 1. asteroid impact
  2. supernova explosion
  3. gamma ray burst
  4. sun's evolution to giant stage

1.은 방어가능성, 2.-3.은 제어 불가

4.는 수십억년 뒤의 먼 미래

지구생명의 탄생

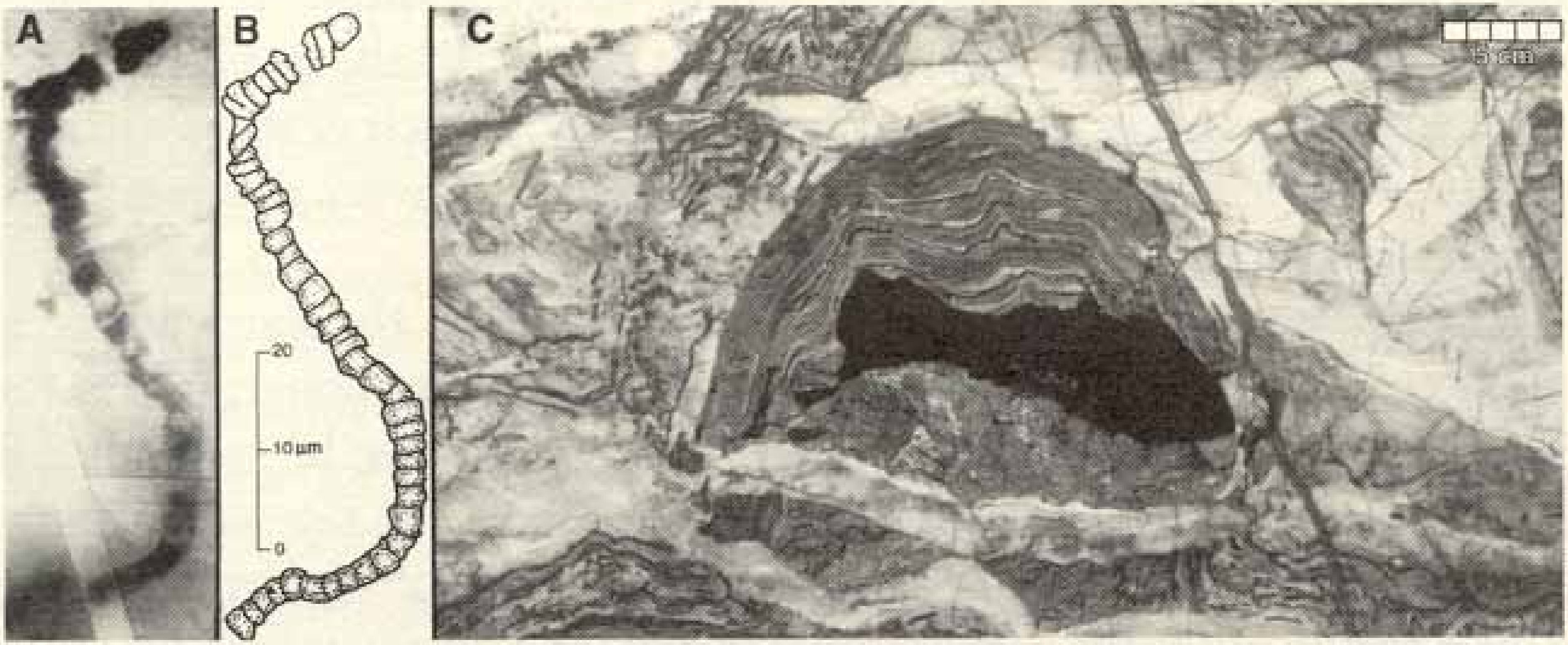
- 생명이 존재할 조건이 갖추어지자 곧 출현.
- 350-400km 충돌 -> 2000K 가열!
- 150-190km -> photic zone (200m) 증발.
- 38억년 전까지 충돌추정.
- 38억년 전 생명의 흔적 ($^{12}C/^{13}C$).
- 35억년 전 생명화석.



[Figure 4.1]
The time of appearance of different types of organisms in the terrestrial geologic record.

JH

Earliest Fossil Evidence for Life on Earth

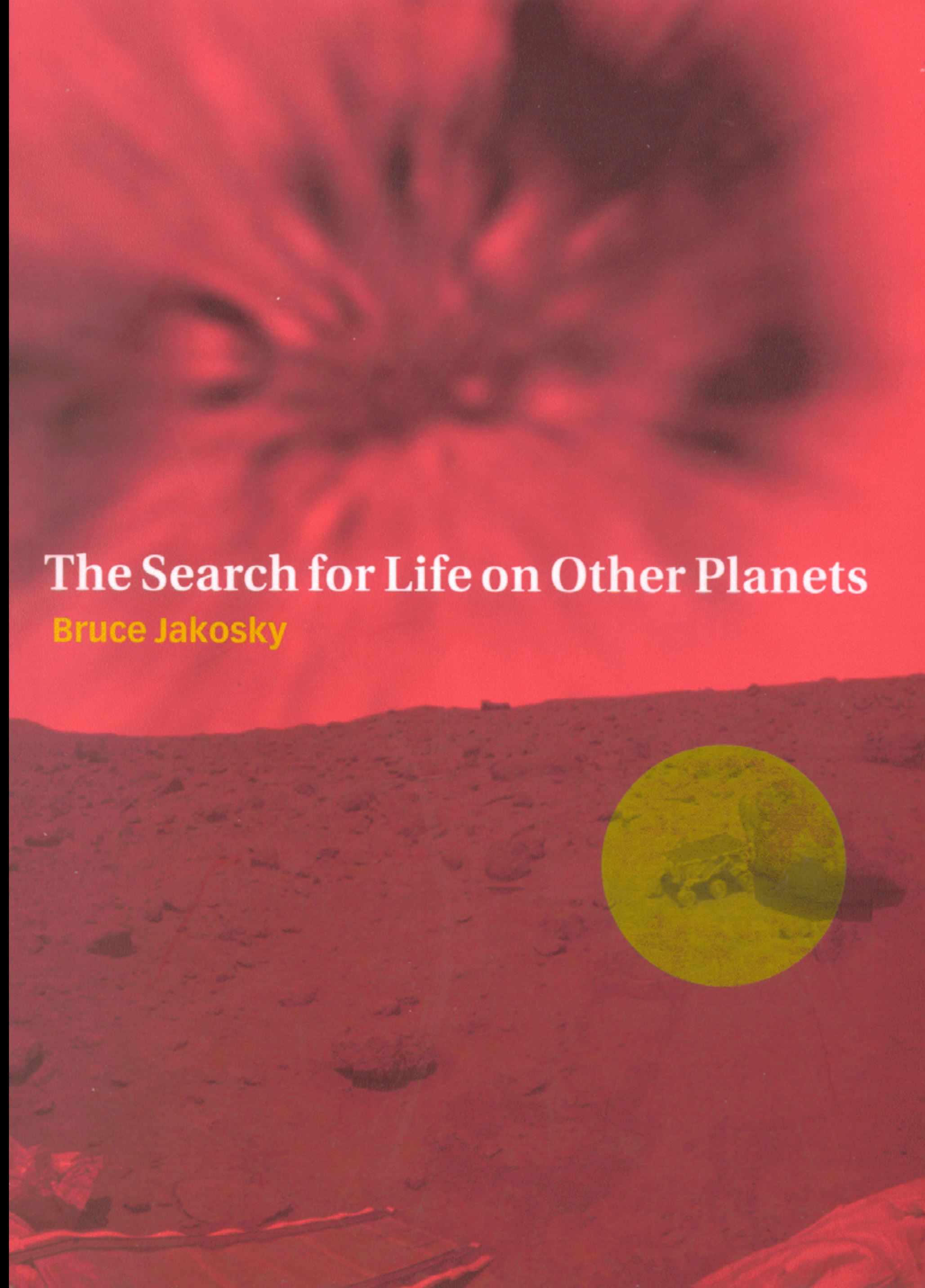


A 3.5 billion-year-old stromatolite and associated microfossil.

JH

태양계 탐사

- 화성
- 유로파
- 가니메데
- 타이탄
- 거대가스행성



JH




JH

Viking 탐사(1976)

1. Gas metabolism: 토양에서 대사로 생긴 대기변화 측정.

2. Labeled release: 유기물 대사로 발생한 CO_2를 lavel 된 방사성 C로 측정.

3. Pyrolytic release: 방사성 C로 lavel 한 토양 가열로 발생한 방사성 화합물 측정.

4. Mass spectrometer: 지구생명에 필수적인 유기화합물 직접 찾기.

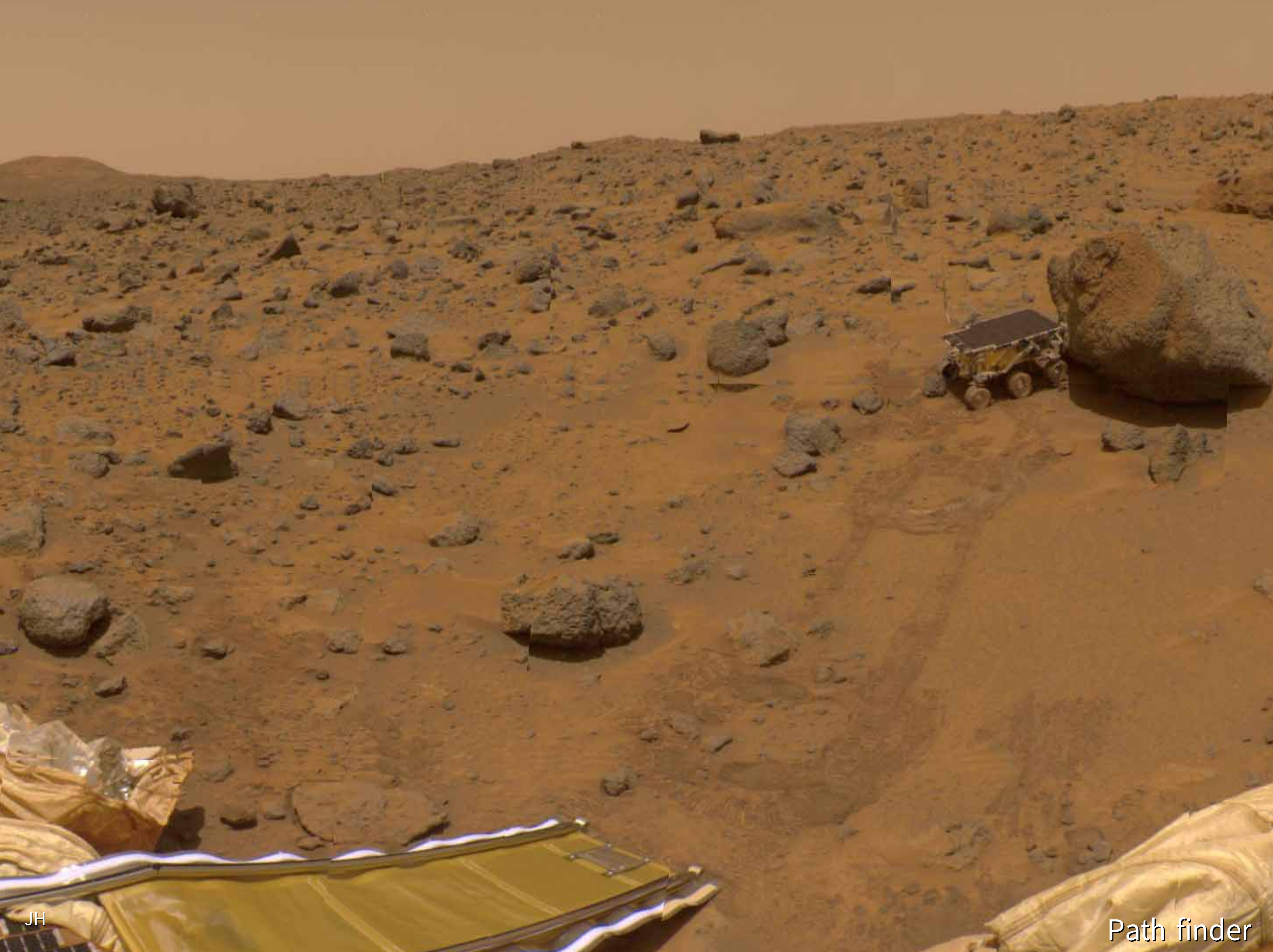
가정: 화성생명은 지구생명과 유사한 대사.

결과: *1.-3.* 긍정적, *4.*번의 유기물은 전혀 못 찾음,
*1.-3.*은 화성의 특이한 토양 화학환경 때문으로 결론.

최근: superoxide 환경임이 밝혀짐 (2000).

JH


JH
Viking


JH
Path finder

화성 운석 (1996) episode

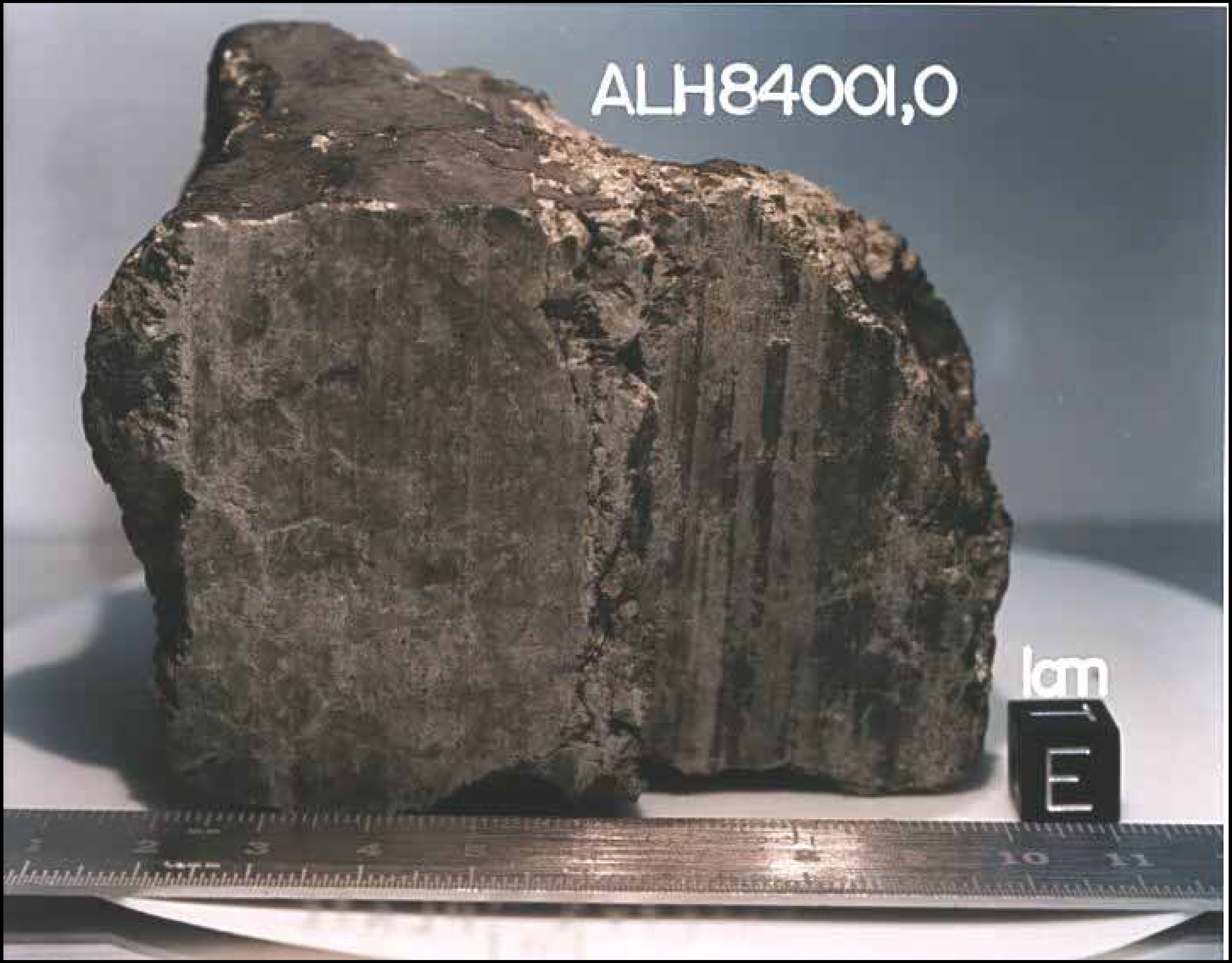
- ALH84001
- 화석?
- Inorganic 과정으로 만들 수 있음
- 지구 박테리아보다 너무 작음 (nanobacteria?)
- Cell wall, division, growth 증거 없음
- 오염가능성
- 언론 play
- “놀라운 결론에는 놀라운 증거가 필요”
- 앞으로도 생명판별이 쉽지 만은 않을 것임

Search for Past Life on Mars: Possible Relic Biogenic Activity in Martian Meteorite ALH84001

David S. McKay, Everett K. Gibson Jr.,
Kathie L. Thomas-Keprta, Hojatollah Vali,
Christopher S. Romanek, Simon J. Clemett,
Xavier D. F. Chillier, Claude R. Maechling, Richard N. Zare

Fresh fracture surfaces of the martian meteorite ALH84001 contain abundant polycyclic aromatic hydrocarbons (PAHs). These fresh fracture surfaces also display carbonate globules. Contamination studies suggest that the PAHs are indigenous to the meteorite. High-resolution scanning and transmission electron microscopy study of surface textures and internal structures of selected carbonate globules show that the globules contain fine-grained, secondary phases of single-domain magnetite and Fe-sulfides. The carbonate globules are similar in texture and size to some terrestrial bacterially induced carbonate precipitates. Although inorganic formation is possible, formation of the globules by biogenic processes could explain many of the observed features, including the PAHs. The PAHs, the carbonate globules, and their associated secondary mineral phases and textures could thus be fossil remains of a past martian biota.

JH



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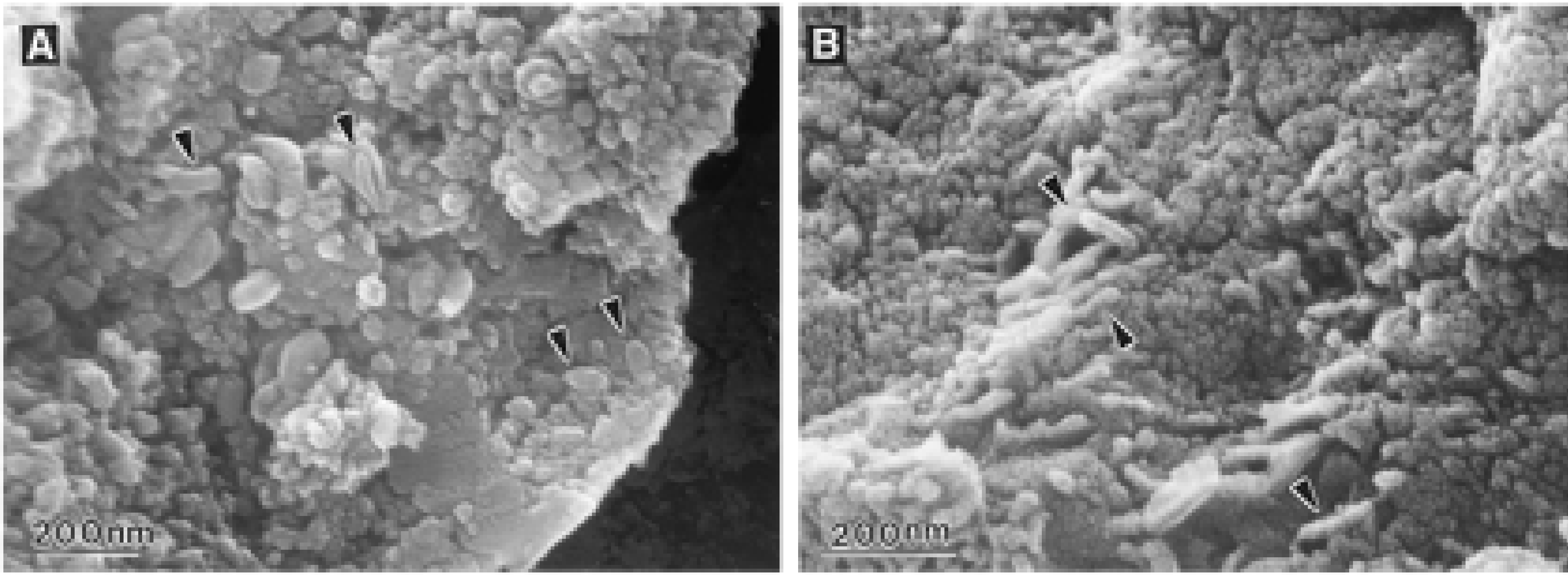

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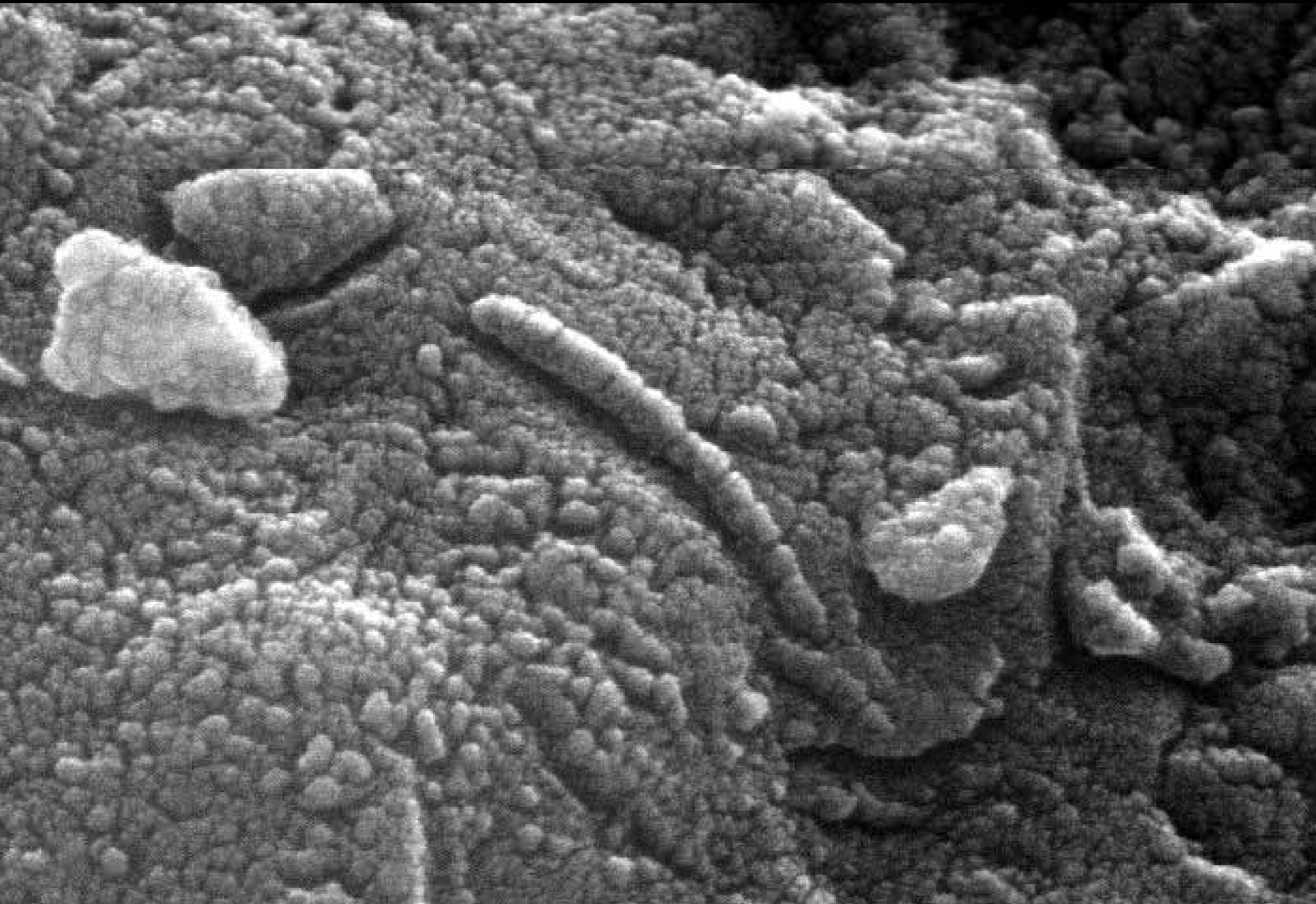

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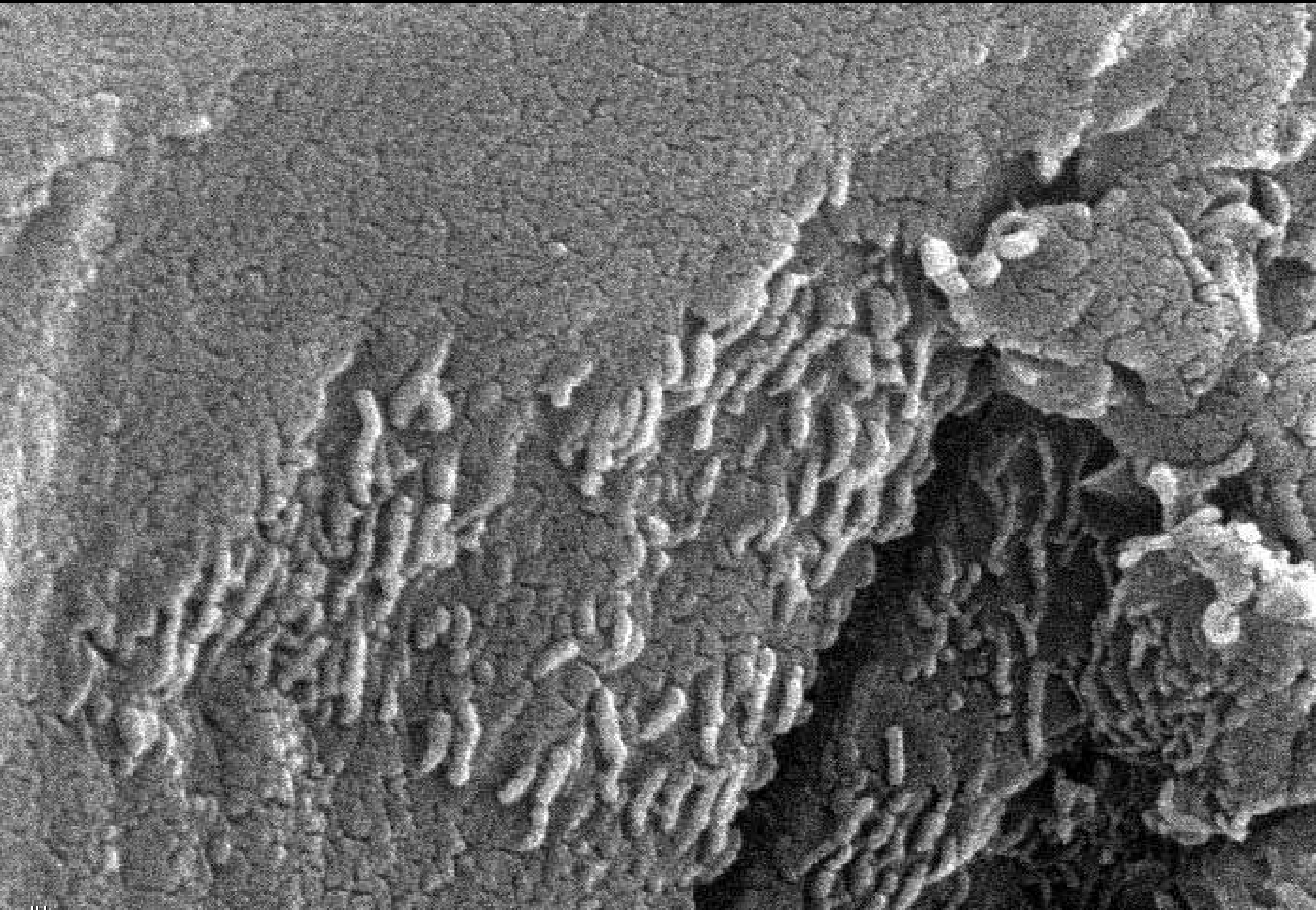
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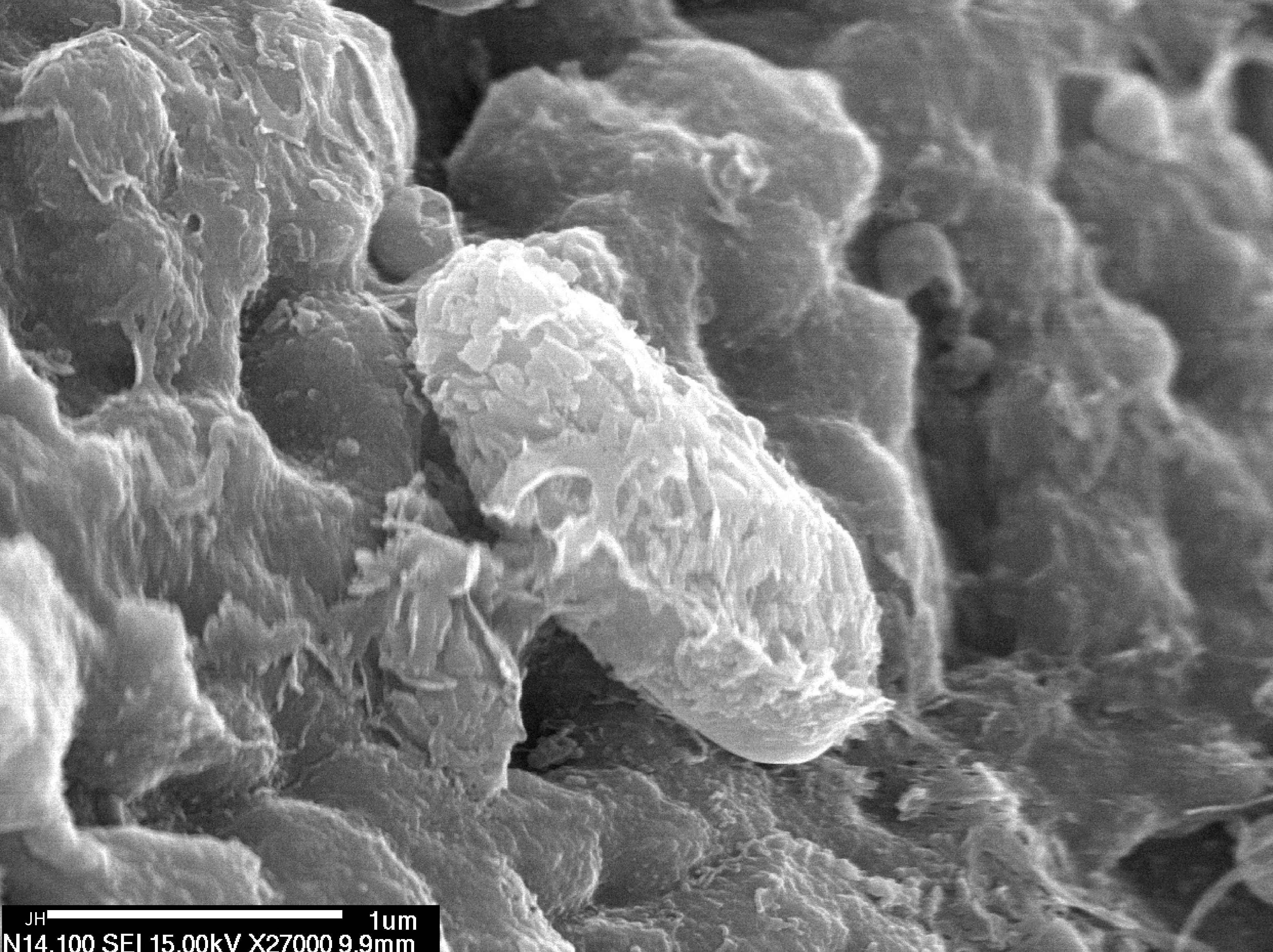

JH
1um
N14.100 SEI 15.00kV X27000 9.9mm

Panspermia

- 행성사이에는 서로 이동가능.
- 포자상태로 별 사이 이동.

- 인간의 우주탐사는 지구생명의 지배자인 박테리아들이 우주로 퍼지려는 진화의 한 단계인가?

화성 생명

- 초기환경은 생명탄생 유지에 적합.
- 지금도 표면이나 근처에 물 존재 가능.
- 최근에 일어난 화산이나 지열 시사.
- 표면 밑 현생생명을 부정할 수는 없다.
- 그러나, … "White Mars".

Many scientists think Mars's outburst flood channels like this were formed when water gushed out to the surface, causing the ground to collapse. The water flowed hundreds of kilometers in rampaging floods. But the collapse of carbon dioxide-saturated terrain could also create these features. Image courtesy of NASA/JPL.

JH

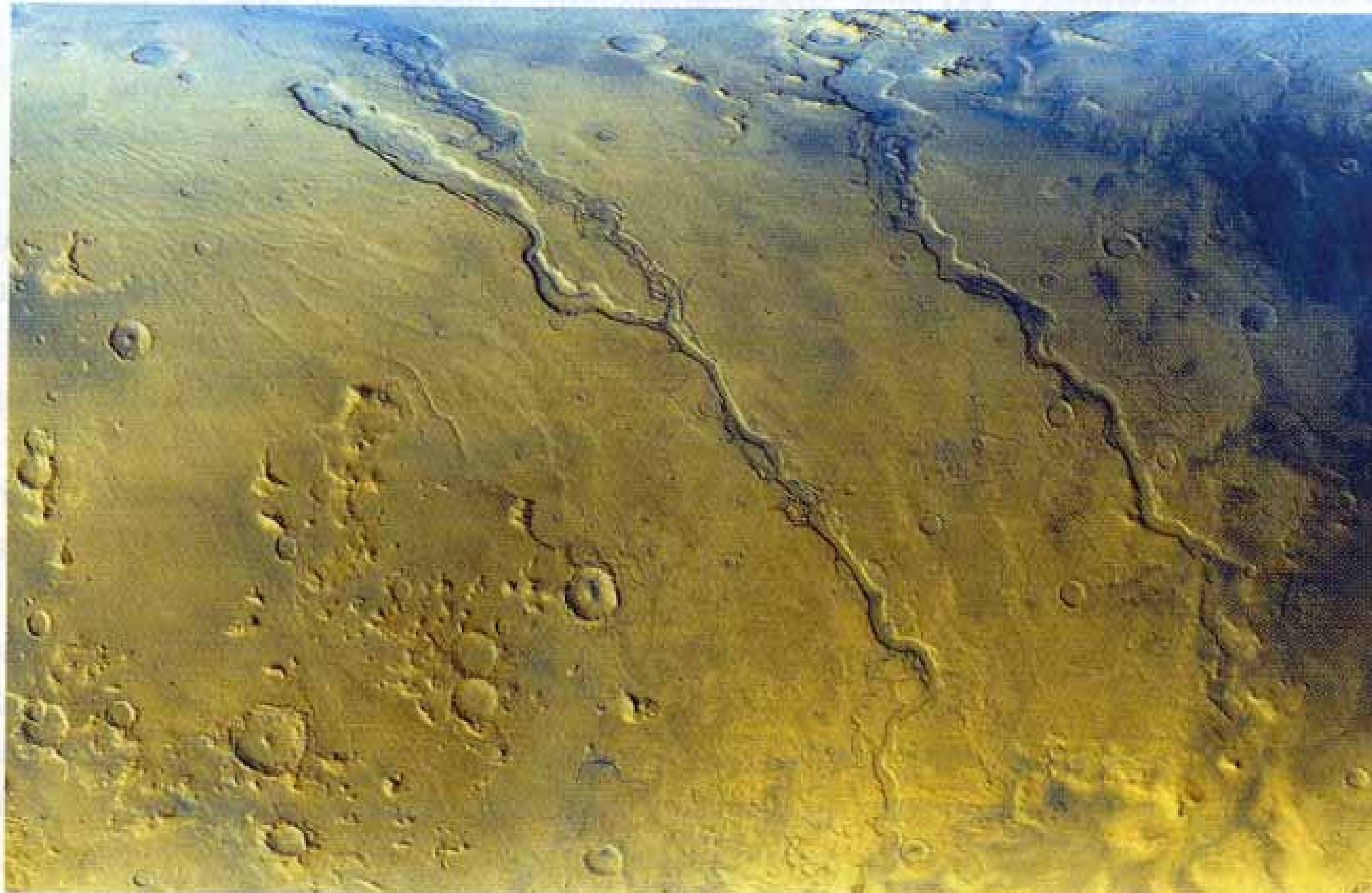


Fig. 6.1 Outflow channels near the highland volcano Hadriaca Patera. The close proximity of the collapse features and the volcano (caldera at upper left of the image) suggests an origin by volcano-ice interactions [e.g., 95]. From left to right: Dao Vallis, Niger Vallis, and Harmakhis Vallis, each one more than 1 km deep and 8-40 km wide. MOC wide angle image, width ~800 km, centered at 40 °S, 270 °W, north toward left, illumination from lower left (NASA/JPL/Malin Space Science Systems).

Fig. 6.4 *Lineated valley fill* in fretted terrain at 34.4 °N, 302.0 °W. Detail of MOC image 46704, image height 5.5 km (resolution 13.2 m/pixel), illumination is from above (NASA/JPL/Malin Space Science Systems).

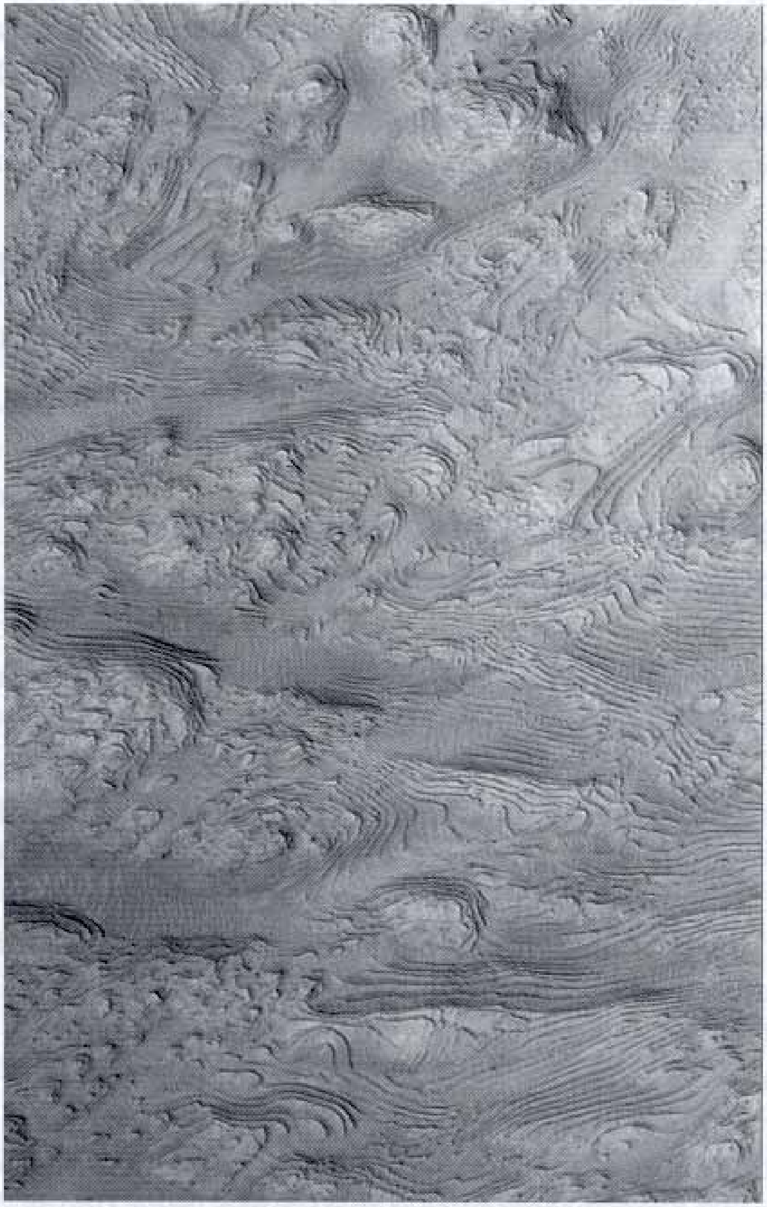


Fig. 6.6 Hundreds of *layers* of the same thickness characterize the interior of an old impact crater in Arabia Terra. The repeated changes between single layers indicate repeated changes in the depositional environments. A plausible process which may have formed these deposits is sedimentation in a standing body of water. Image width is about 3 km (NASA/Malin Space Science Systems/RPIF/DLR).

JH

Astrobiology

High-resolution Mars Global Surveyor images show numerous gullies emerging from cliff sides and crater walls. Many scientists think outbursts of liquid water from underground aquifers created the gulleys. But outbursts of liquid carbon dioxide could also be responsible. Images courtesy of NASA/Malin Space Science Systems.

JH

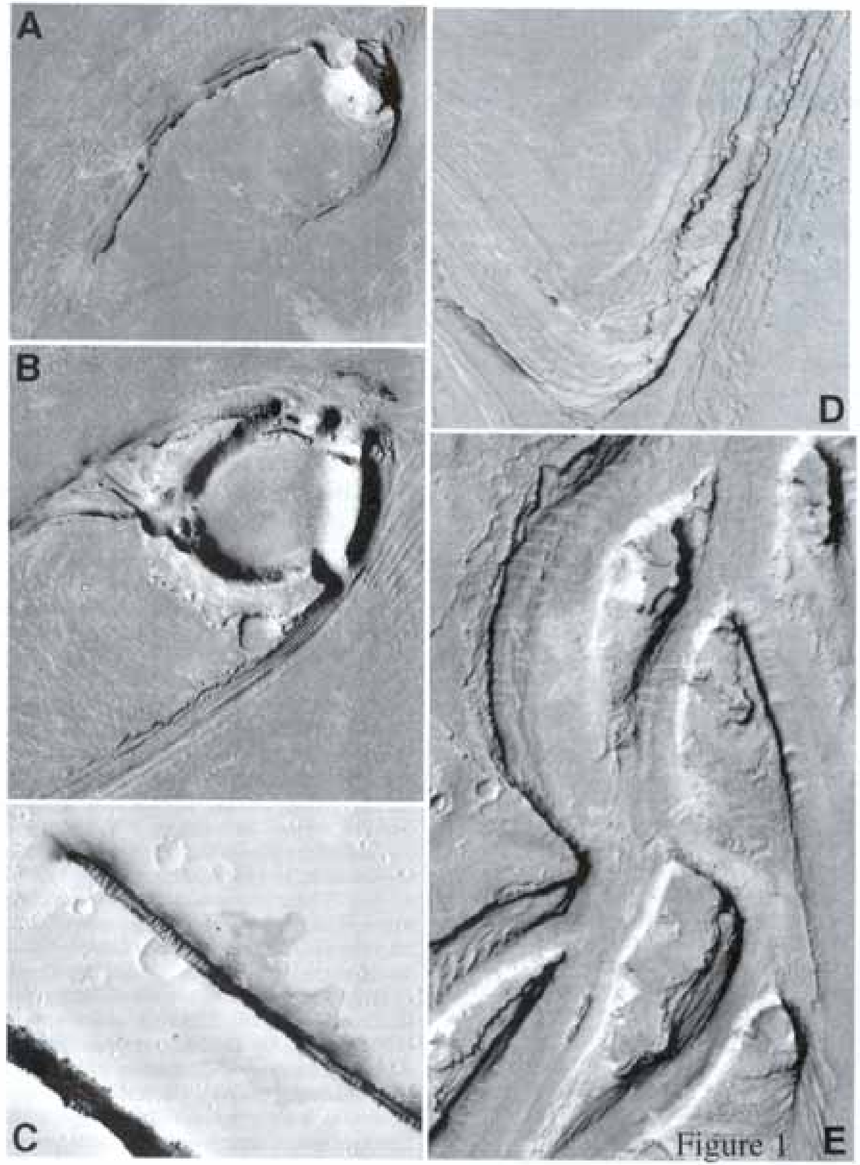
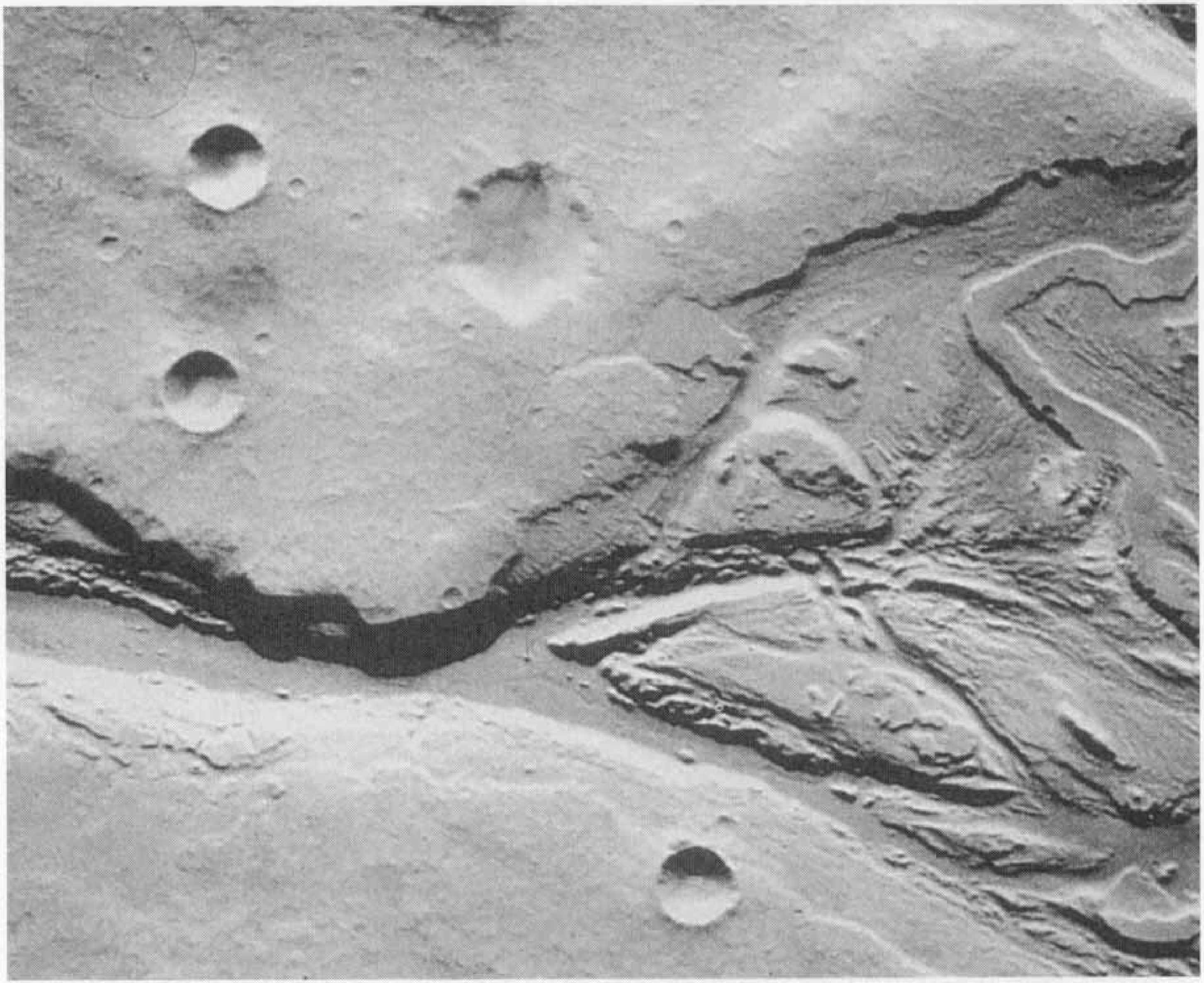


Figure 1. MOC images of Cerberus Fossae and associated channels. A–C are 3 km across, D is 1.5 km across, E is 1.25 km across. North is about 10 degrees right of up; illumination is from the left. A) Portion of M07-00614, (9.66° N, 155.81° E). Streamlined mesa with rounded, topographically higher end pointing upslope (to the right) and pointed, lower end down slope. The mesa slopes gradually downward via thin terracing. Longitudinal grooving is apparent to the north. Inferred flow towards the southwest. B) Portion of M07-00614. Streamlined mesa with similar orientation and terracing. Crater sits at upslope end; mesa formation is hypothesized to be by deposition in its lee during flood flow. C) Portion of M02-01973, (10.35° N, 156.20° E), showing extrusion of lava from Cerberus Fossae as indicated by arrows. D) Portion of M11-00331, (8.98° N, 155.61° E). Down slope end of streamlined mesa showing multiple fine layers. E) Portion of M21-01914, (7.89° N, 153.95° E). Multiple features in a channel southwest of Cerberus Fossae that show streamlining, terracing and rearward-facing slopes, but of a more irregular nature than in sub-Figures A and B. Formation is hypothesized to be by erosion of layered terrain.

JH



This Viking Orbiter view of a heavily eroded region of Mars shows enormous flood channels, some requiring water flow rates far larger than that of the Amazon River. Photograph courtesy of NASA

JH

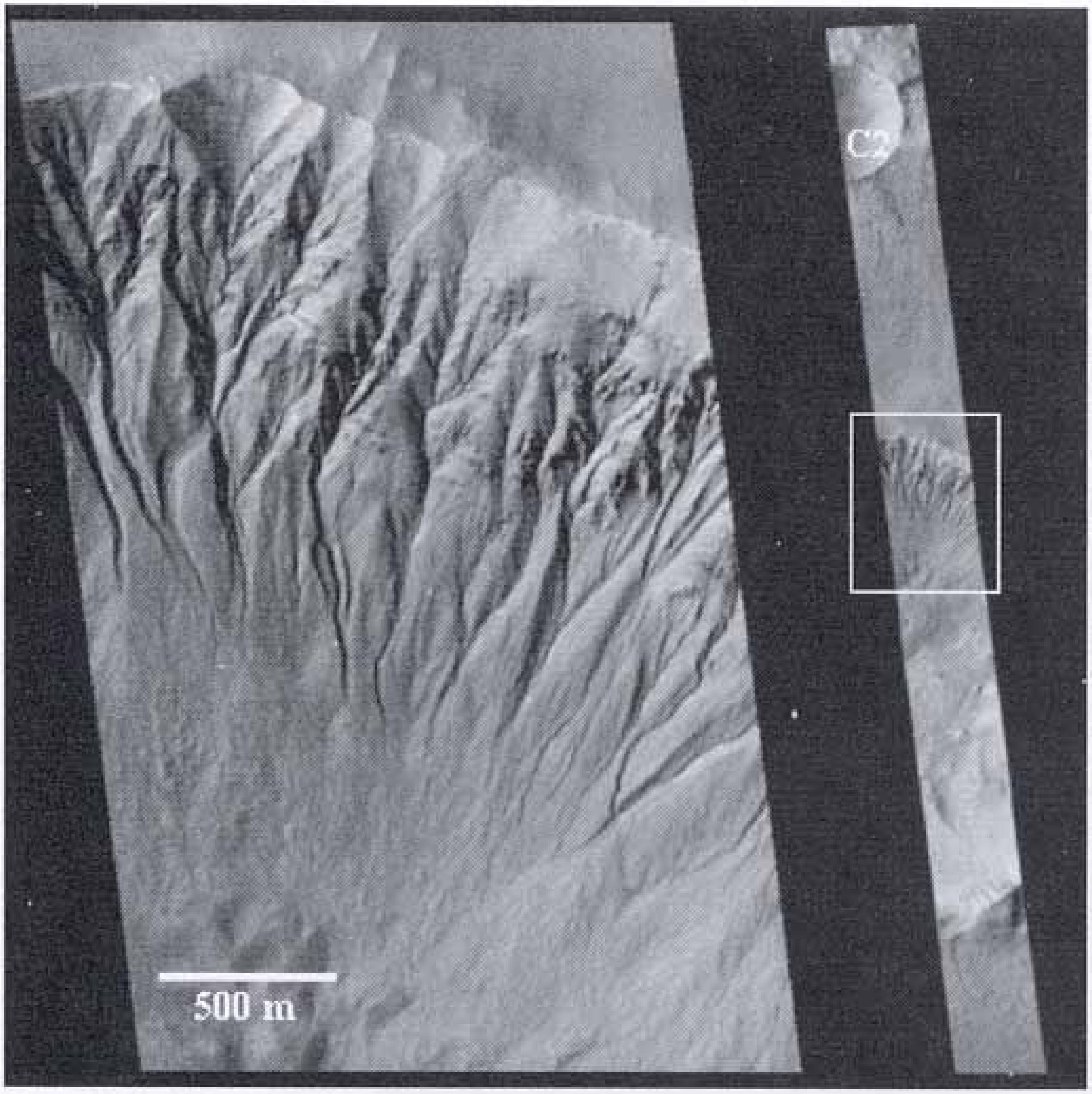


FIG. 2. (left) Gullies and debris aprons in the E-Gorgonum crater (detail of MOC image MO7-1873, 2.79 m/pixel resolution). (right) The image footprint from Fig. 1 is shown, with part of crater C2 seen on the right. The drainage in E-Gorgonum occurs only in the directions of C1 and C2, and where the fault A intersects the crater on the west rim. Image credit: NASA JPL/MSSS.

JH

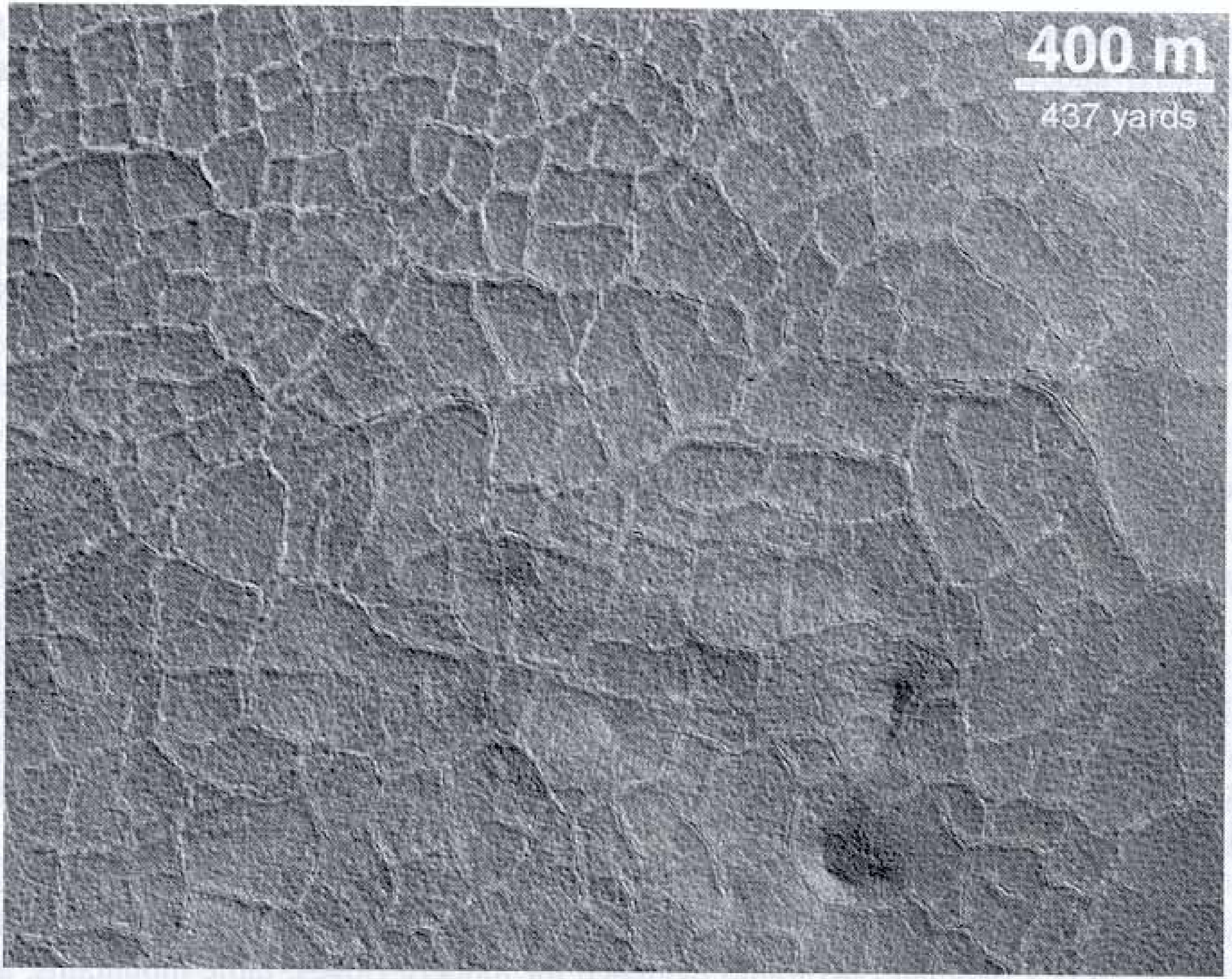
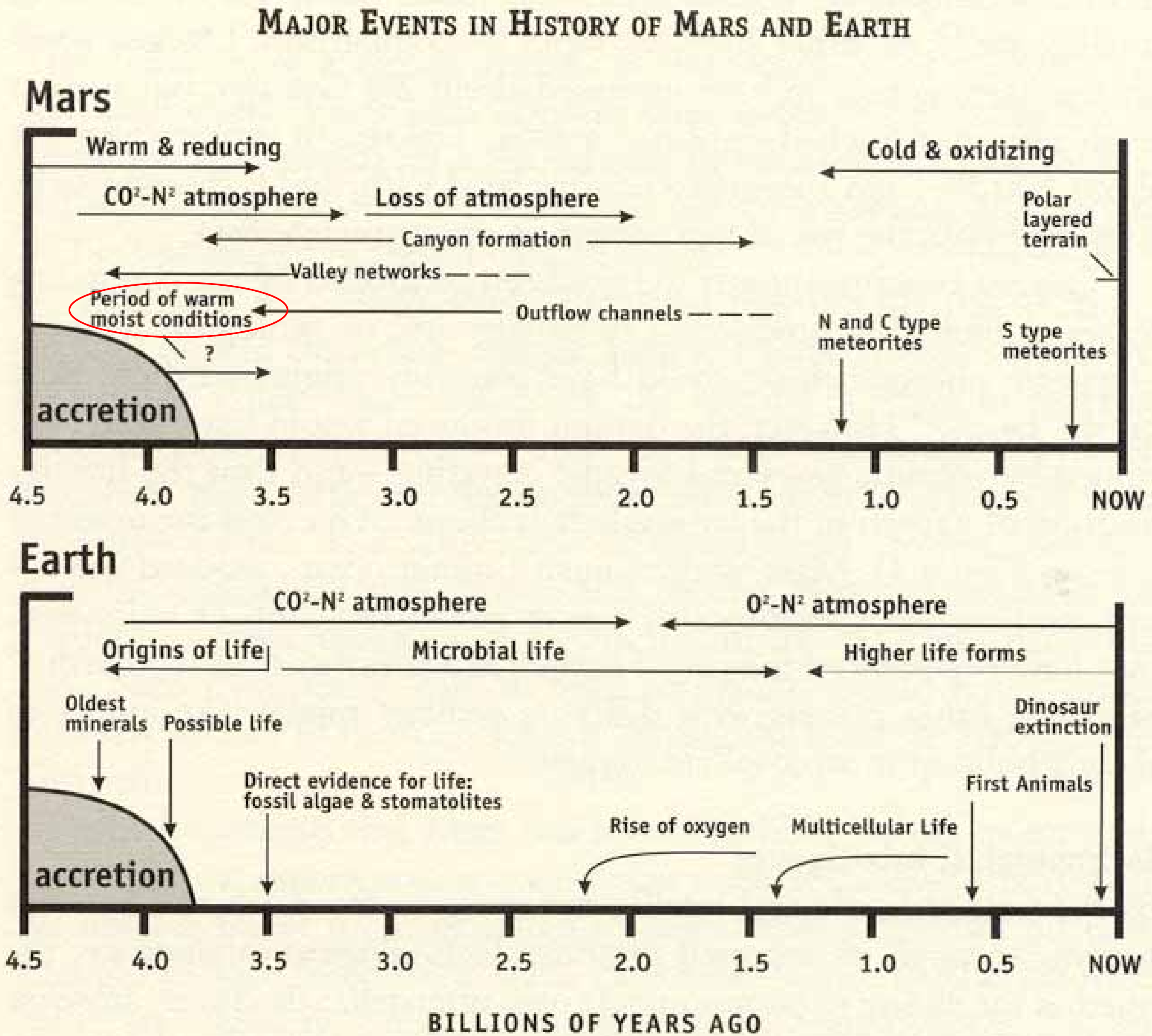


Fig. 6.5 Patterned ground on the floor of an impact crater in the northern plains of Mars. The polygons might have formed by repeated freeze-thaw cycles of subsurface ice. MOC image release MOC2-150 (NASA/JPL/Malin Space Science Systems).


JH
NASA


JH
ESA


ESA/DLR/FU Berlin (G. Neuk
JH
ESA



The period of moist surface conditions on Mars may have corresponded to the time during which life originated on Earth. The similarities between the two planets at this time raises the possibility of the origin of life on Mars.

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Icarus **146**, 326–342 (2000)
doi:10.1006/icar.2000.6398, available online at http://www.idealibrary.com on IDEAL®

White Mars: A New Model for Mars' Surface and Atmosphere Based on CO_2

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A new model is presented for the Amazonian outburst floods on Mars. Rather than the working fluid being water, with the associated difficulties in achieving warm and wet conditions on Mars and on collecting and removing the water before and after the floods, instead this model suggests that CO_2 is the active agent in the "floods." The flow is not a conventional liquid flood but is instead a gas-supported density flow akin to terrestrial volcanic pyroclastic flows and surges and at cryogenic temperatures with support from degassing of CO_2-bearing ices. The flows are not sourced from volcanic vents, but from the collapse of thick layered regolith containing liquid CO_2 to form zones of chaotic terrain, as shown by of a "warm and wet" early Mars can be discarded in favor of a more consistent cold ice world model. In this paper we develop an explanation for the "flood" channels as cold and dry surface density flows, supported by CO_2 vapor. The source of the vapor is liquid CO_2 and solid CO_2-bearing ices from the regolith.

SURFACE OBSERVATIONS

Mars' surface displays a complex and extended geologic history with at least two major episodes of fluid erosion and/or sedimentary transport: first in the Noachian when dendritic val-

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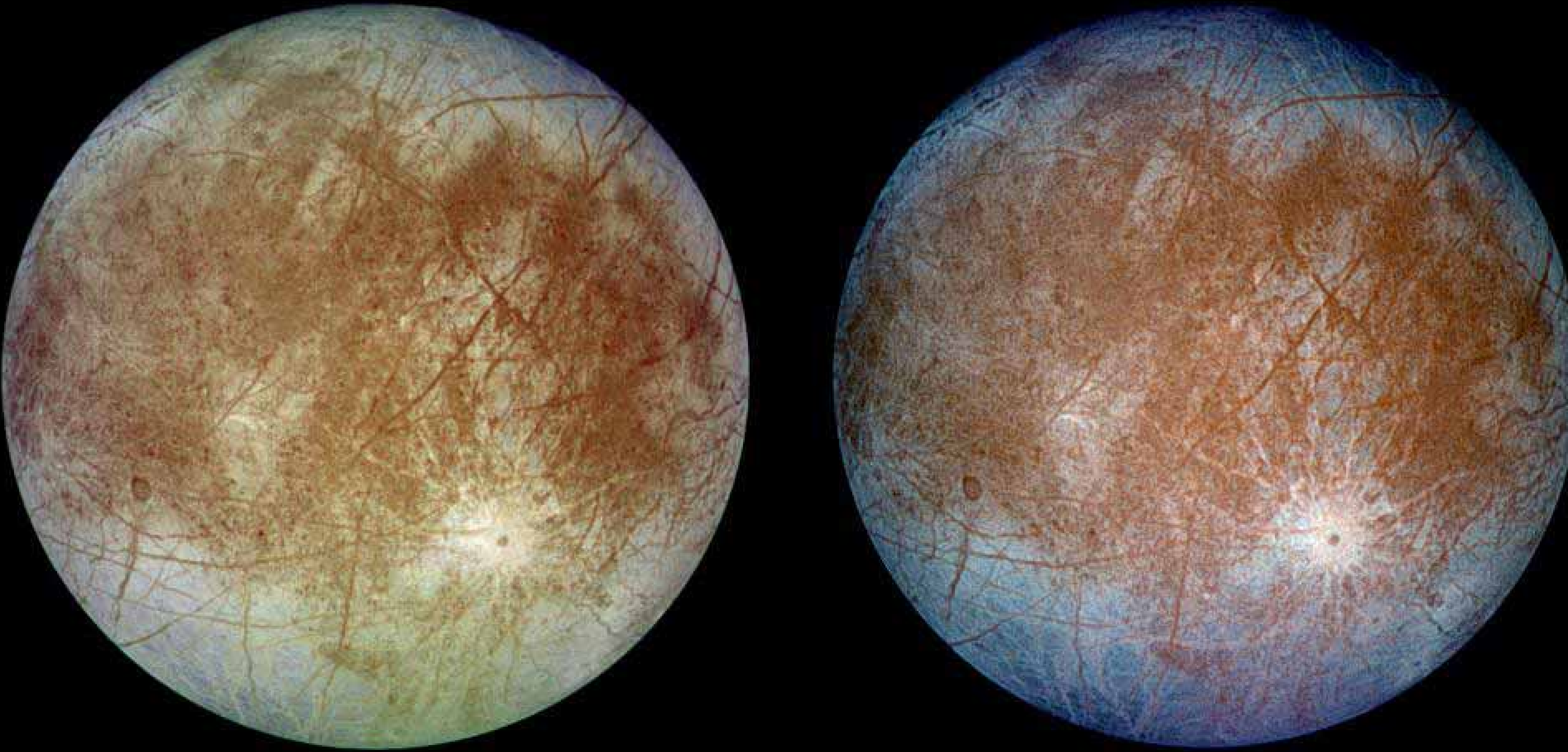
Europan déjà vu

- 달 크기, 얼음표면
- 충돌자국 거의 없음, 표면 최근 형성
- 유체바다 위에 균열이 간 얇은 얼음 층
- 얼음층 밑의 tectonic 활동, 조석력
- 수백km에 달하는 어름이 흐른 자국
- Icepick: Europan ocean explorer project


Io
Europa
Earth's Moon
Ganymede
Callisto
JH



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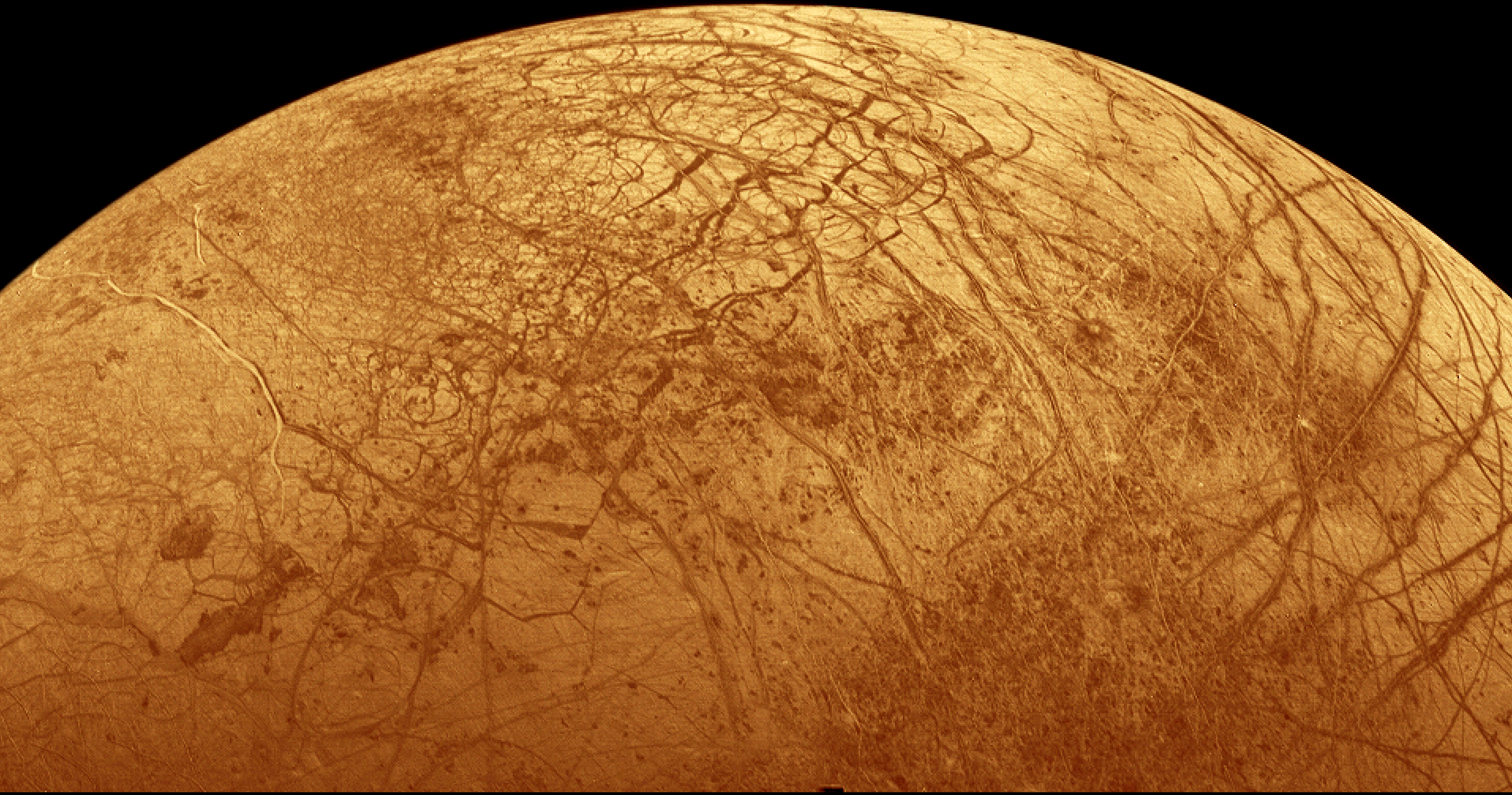

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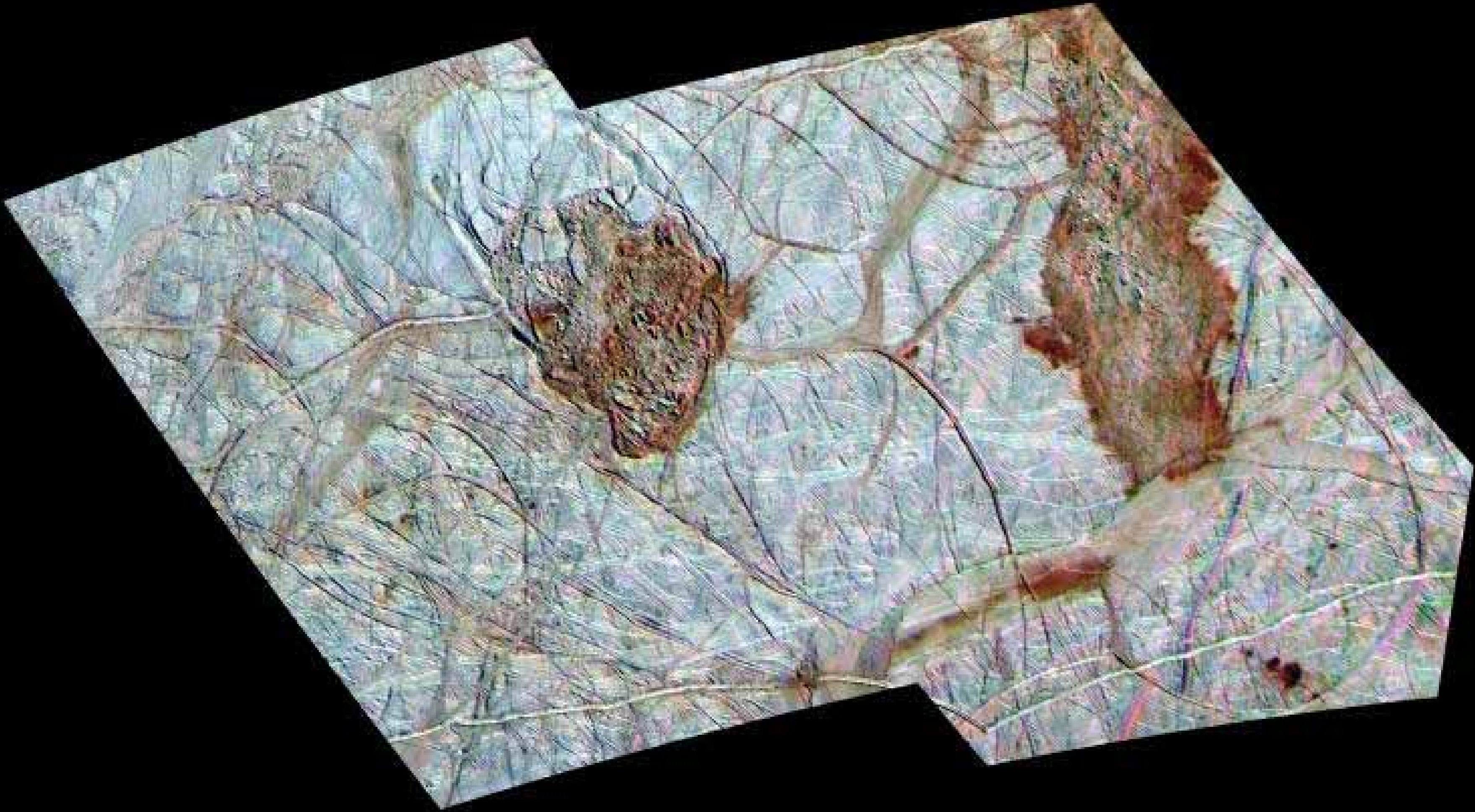

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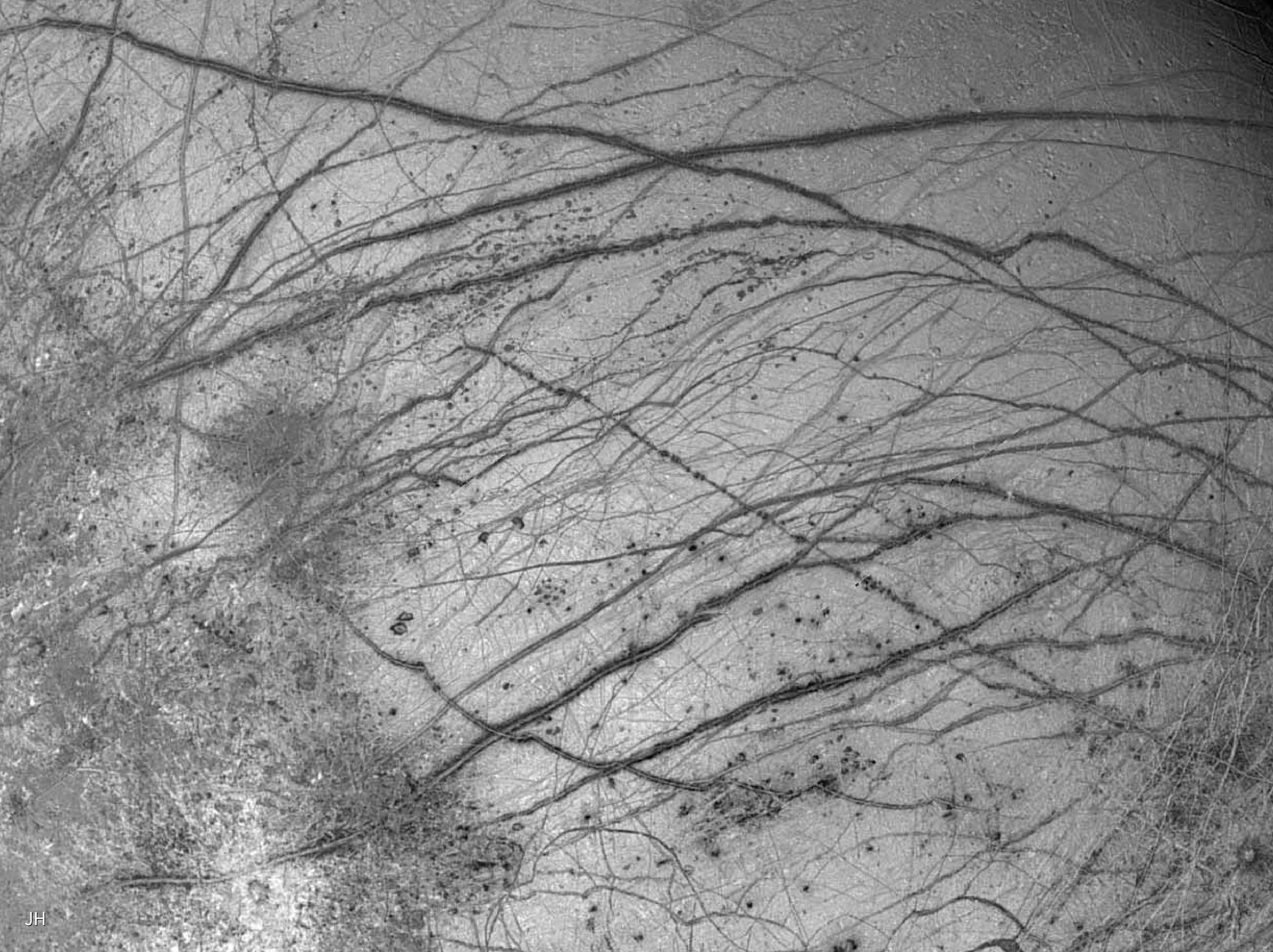
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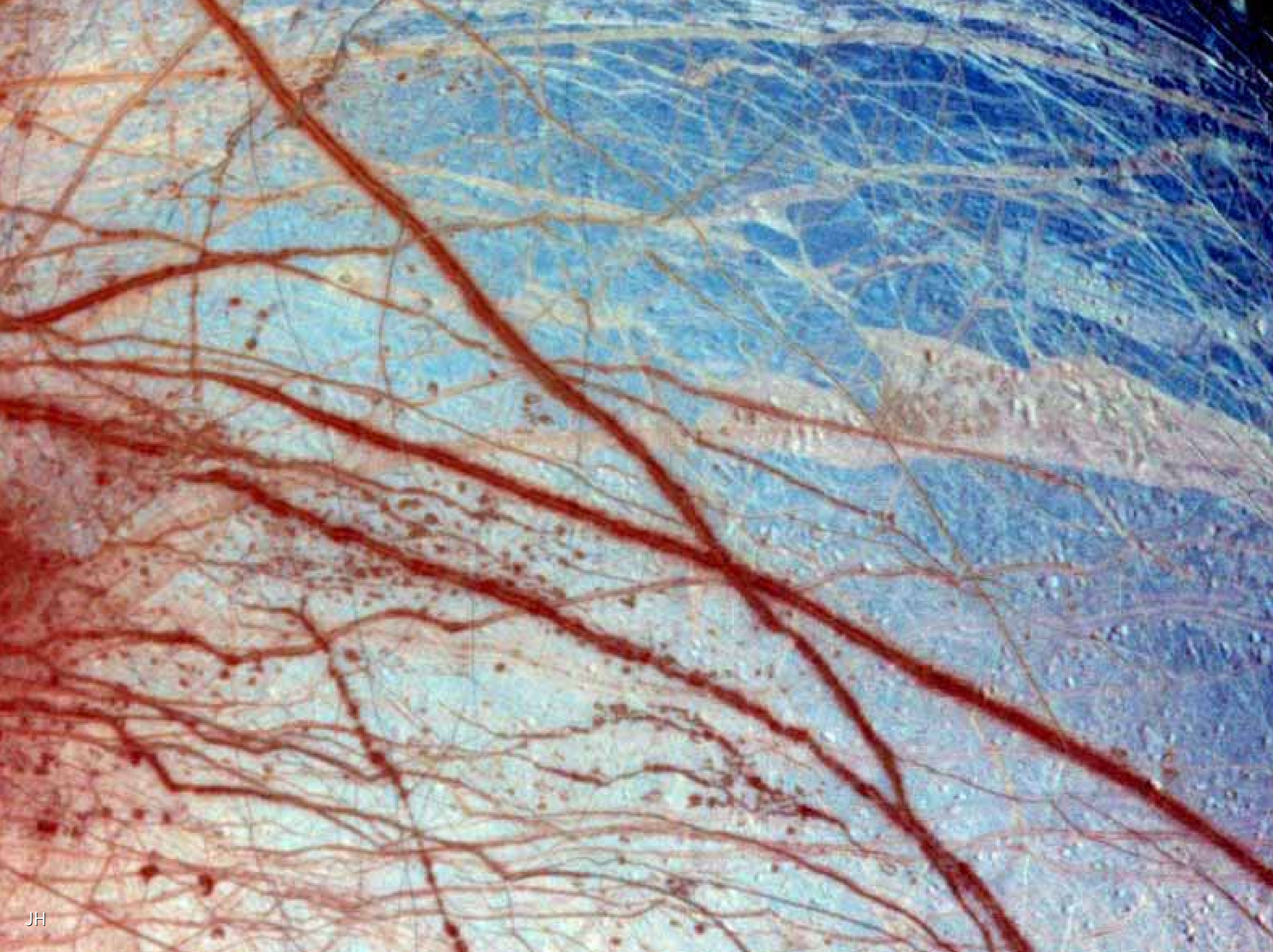
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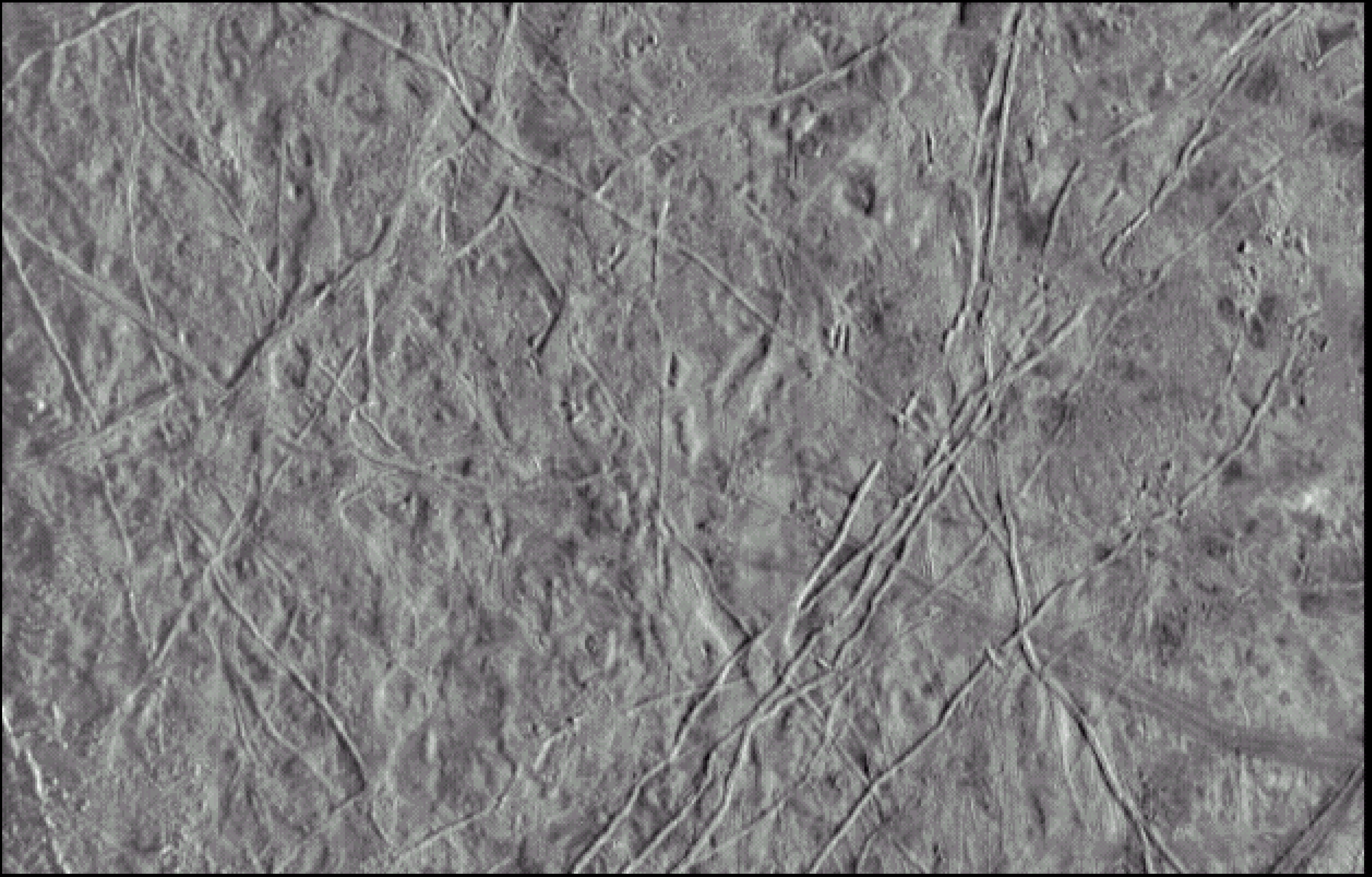

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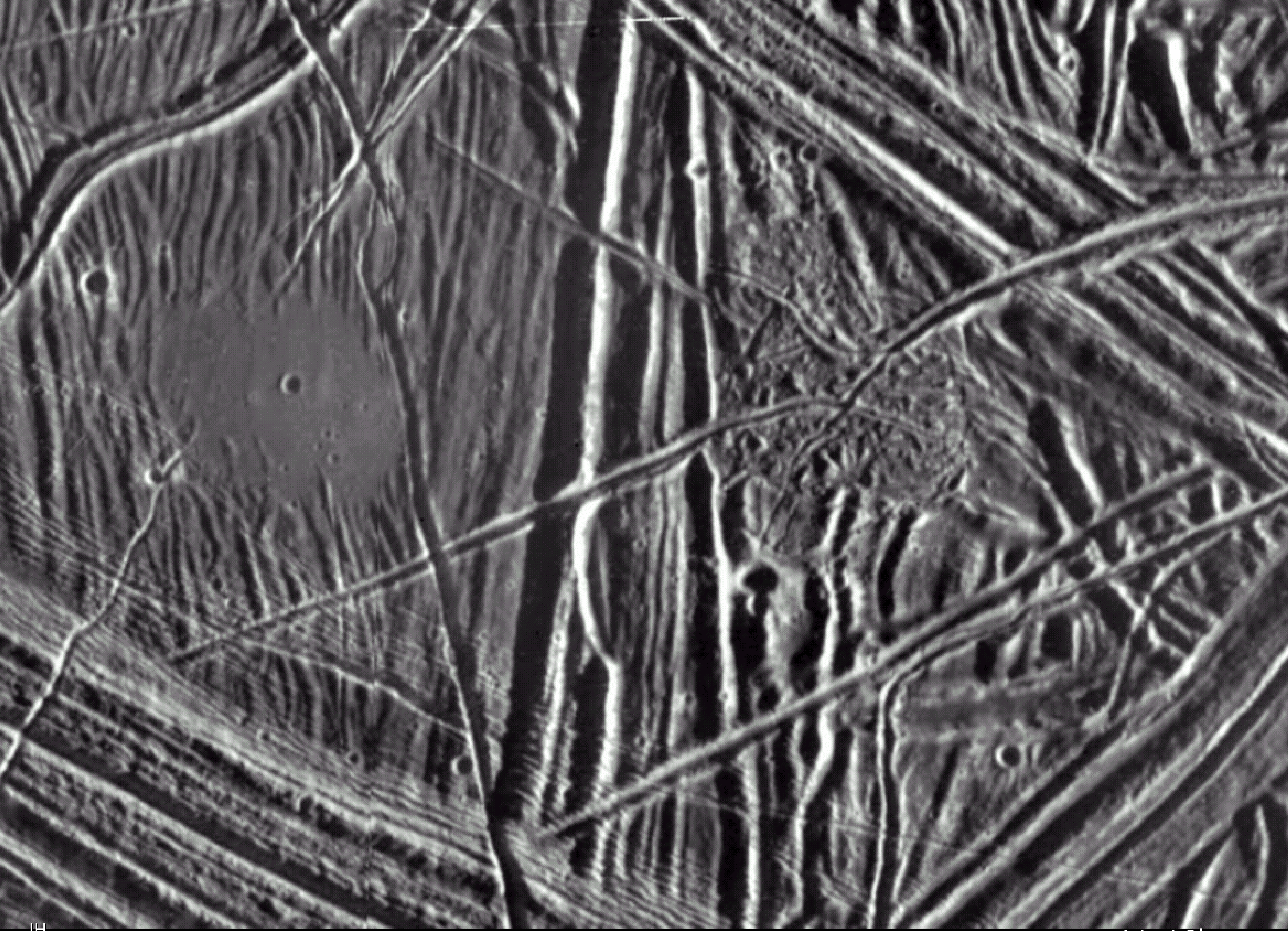
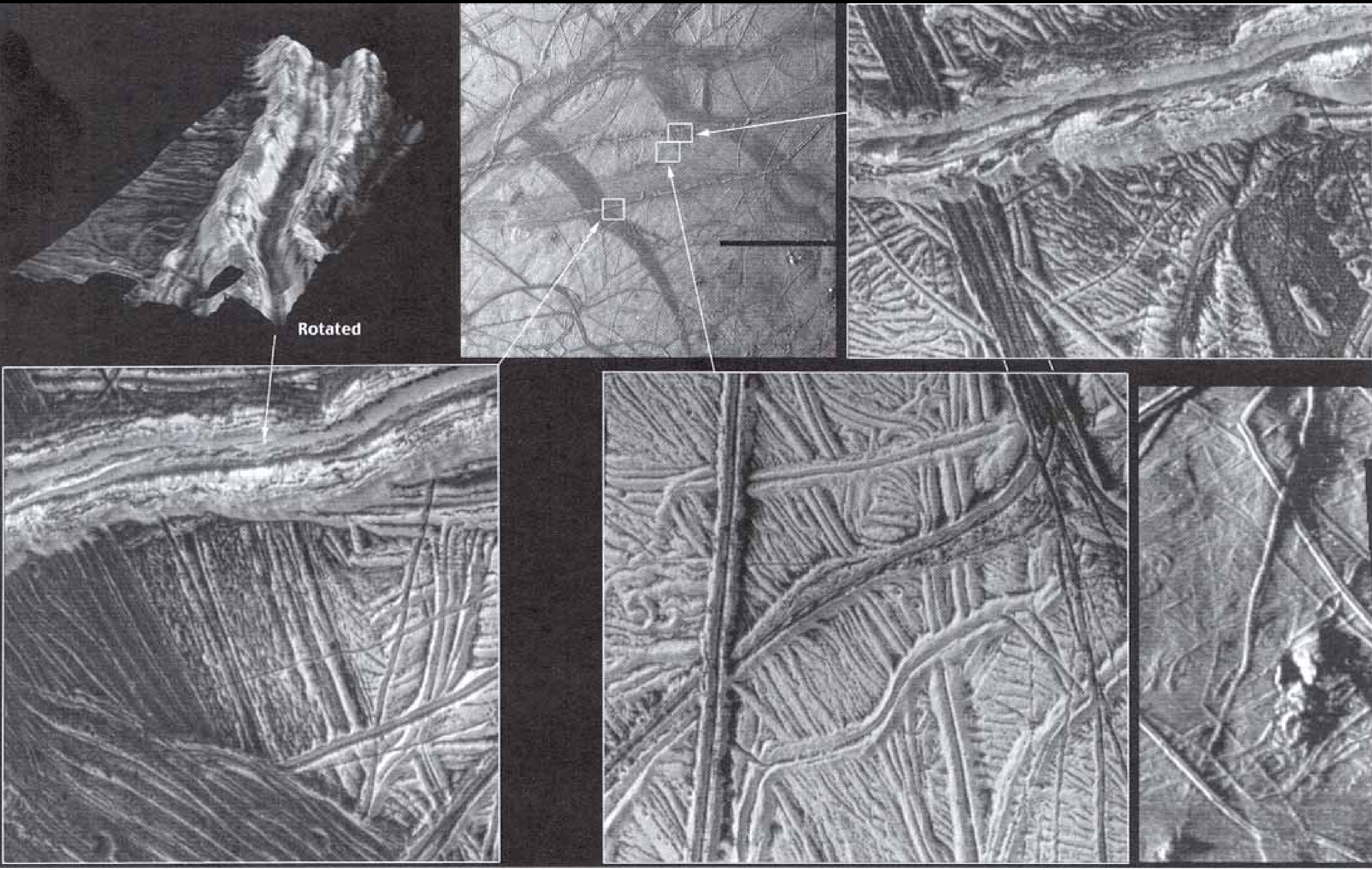
252x393km

Fig. 7.3 A portion of Conamara Chaos (at 40 m/pixel). Here we see rafts of older tectonic terrain which have been slightly displaced in a lumpy frozen matrix, giving the appearance of a site of melting of the crust followed by refreezing. Two examples of cracks with double ridges have formed subsequently, providing examples of a widespread process by which tectonics have obliterated chaotic terrain to various degrees.

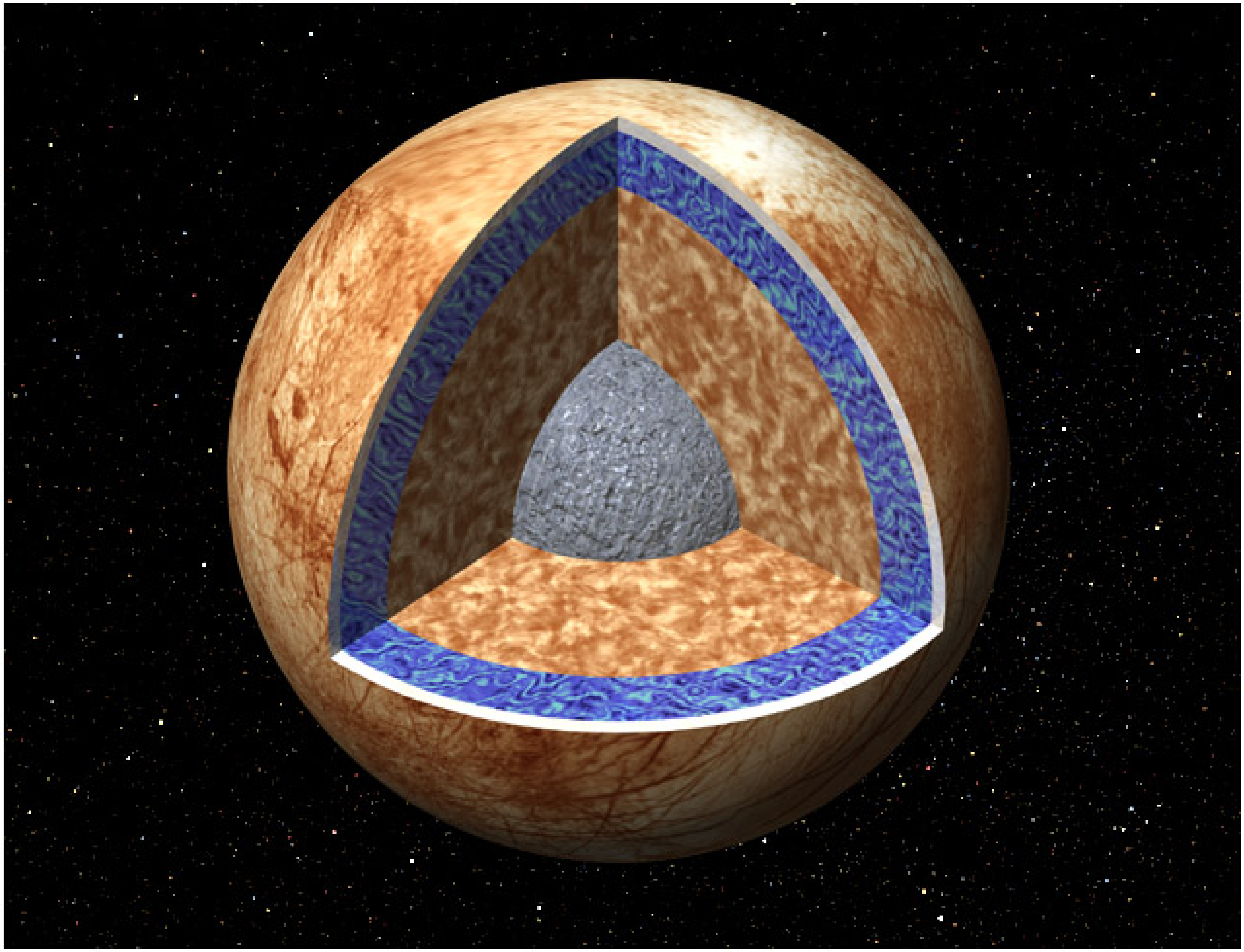


JH

11x16km



JH



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The Interior of Europa

Titan

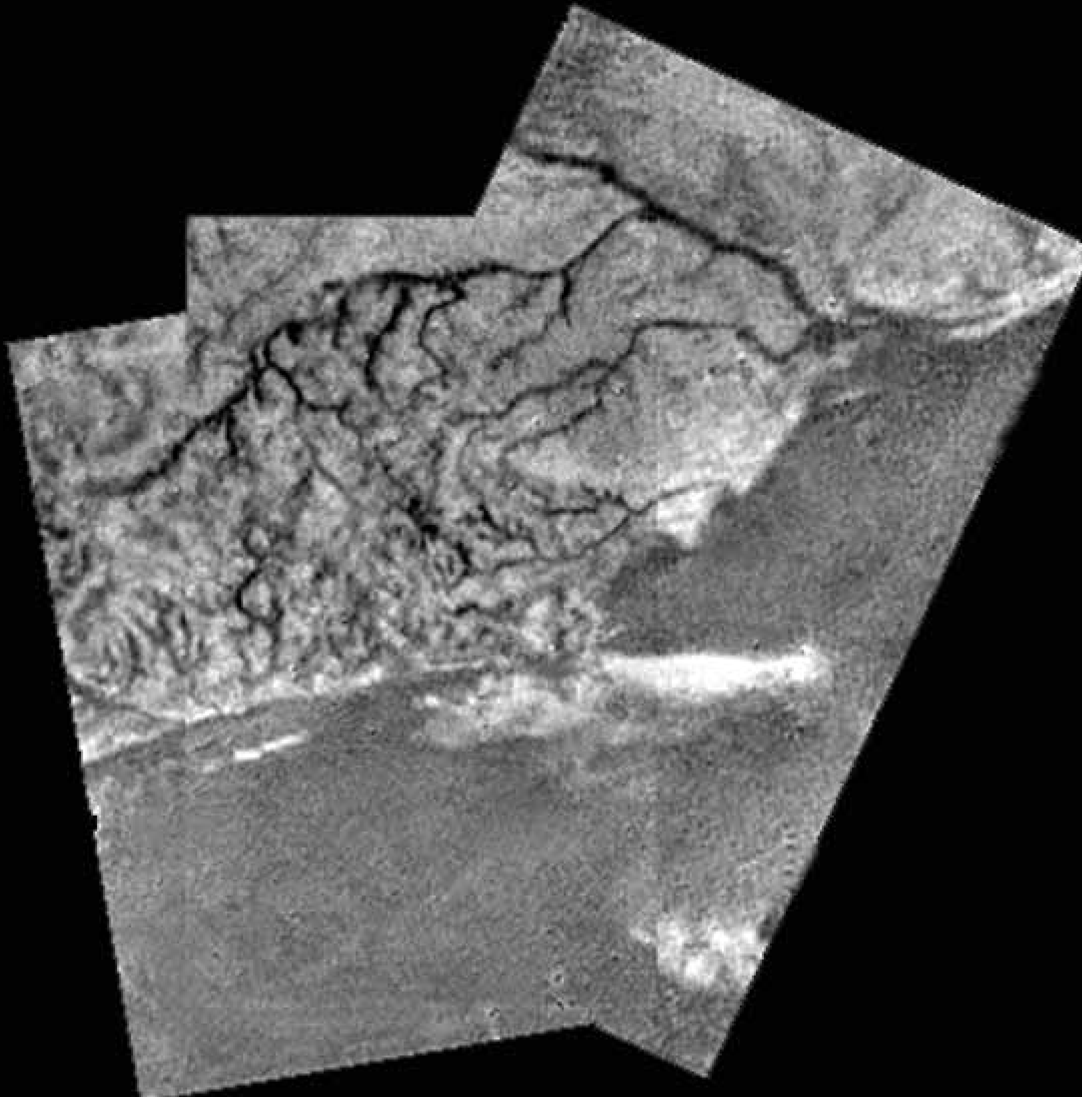
- Prebiotic 지구대기와 비슷함
- 유기물이 풍부한 대기
- 유체 ethane (C_2H_6) 바다 methane-ice (CH_4) 섬 가능
- 90K 온도에서 화학반응은 아주 느림
- Huygens Probe (2005.01.14 진입)

Titan

JH

LEFT **Artist's impression of Titan's surface, showing the Huygens probe entering the atmosphere.**

JH



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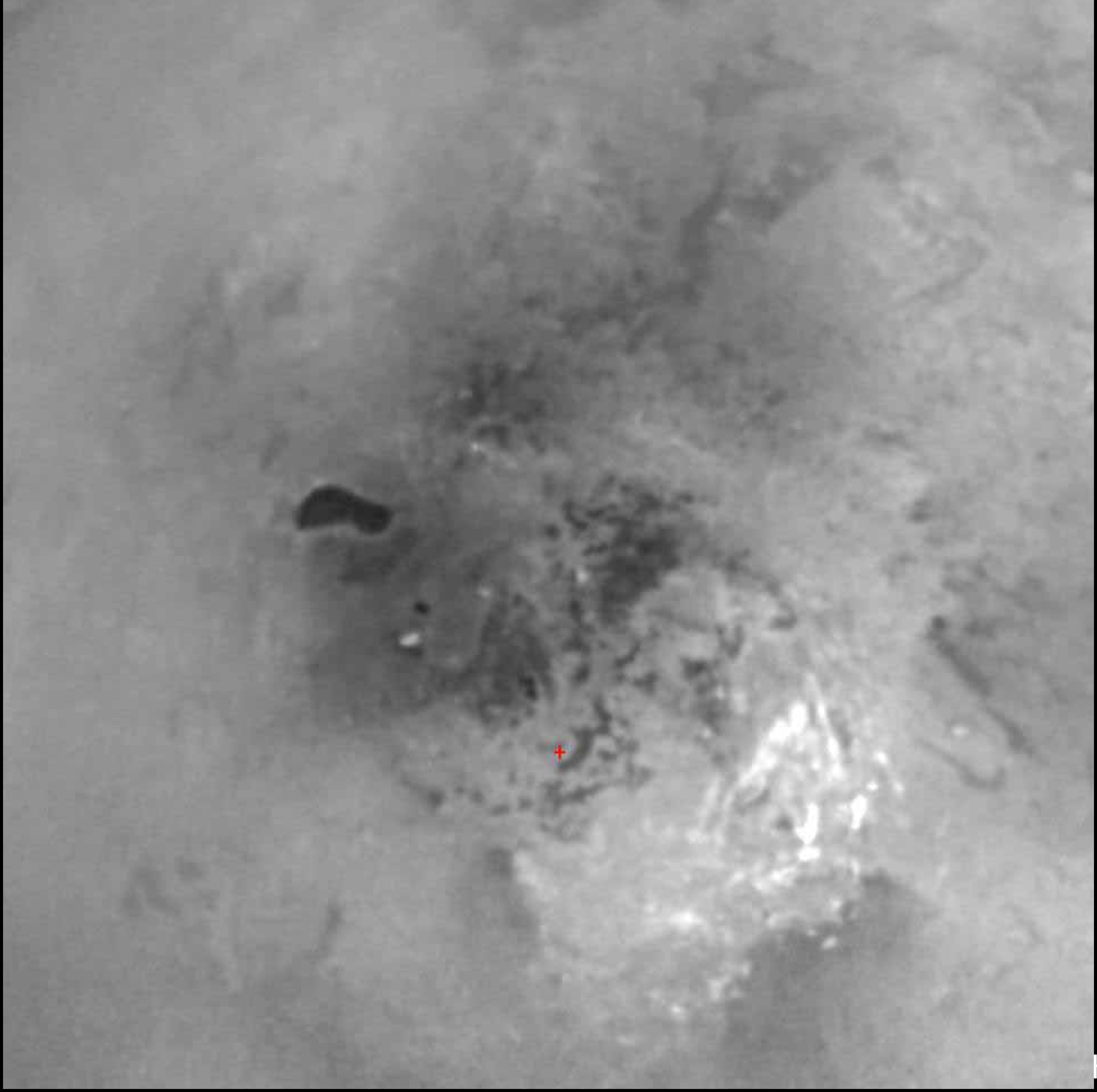
Huygens probe



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Huygens

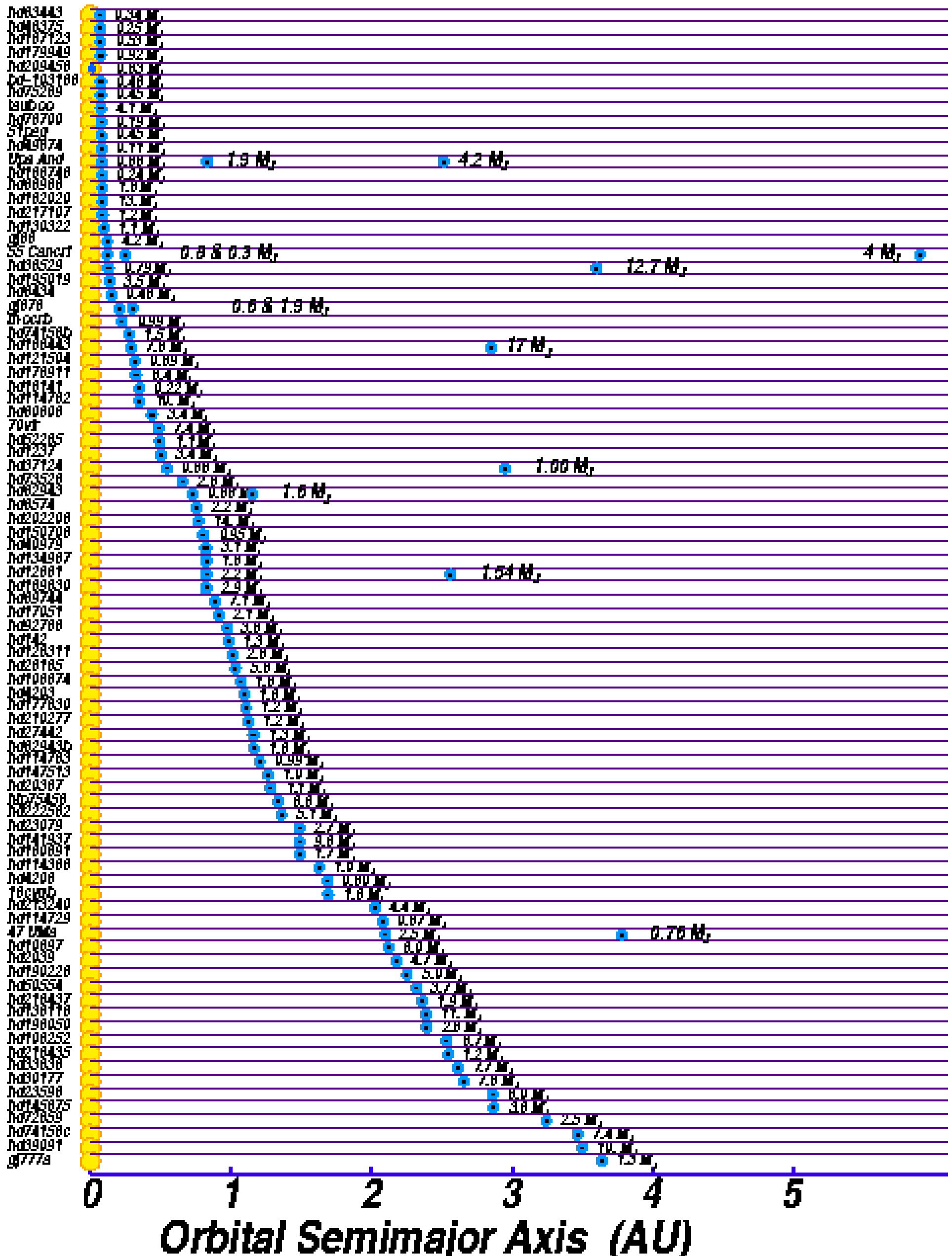
다른 가능성

- 목성 토성의 1 대기압 지역.
- 금성 대기 상부.
- 혜성, 소행성, 위성 표면.
- ...

외계행성

- 1995년 처음 발견됨.
- 주로 별 가까이 있는 목성형 행성.
  관측방법(스펙트럼 도플러효과)이 선호.
- 미리 알았다면 25년 전에도 관측가능!
- 지금까지 100ly안에 있는 ~1000개 별에서 ~130개이상 발견, 계속 발견...
- 실재질량이 너무 커 brown dwarf들일 가능성.

110 extrasolar planets: masses and orbitial radii



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http://exoplanets.org/massradiiframe.html

Habitable zone

- 액체상태 물이 존재하는 지역.
- 별의 온도-크기와 행성의 대기압-성분에 관련됨.
- 별 빛 뿐 아니라 행성이나 위성의 내부열에 따른 지역도 고려해야 함.

  예, Europa.

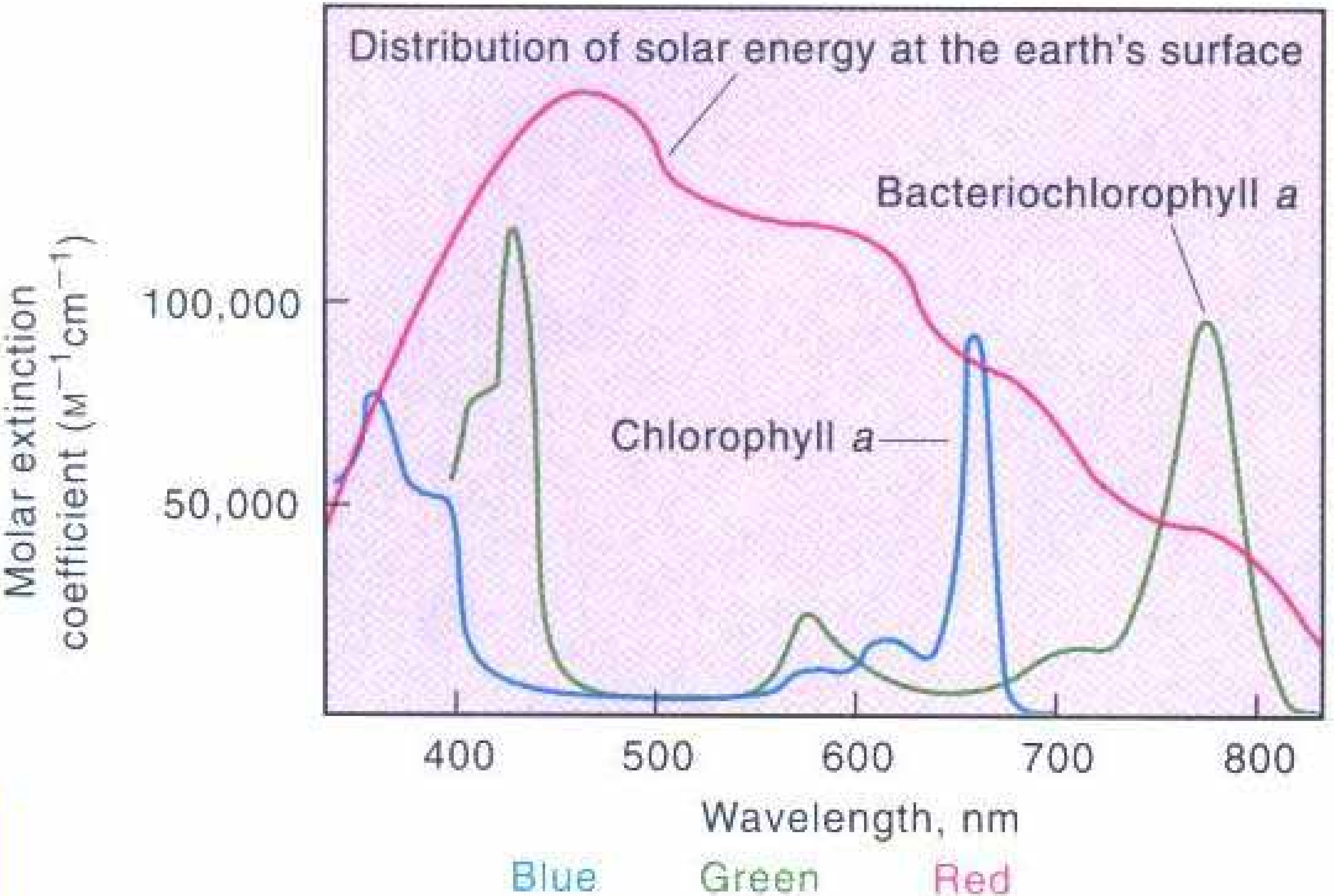
다른 조건

- 별빛의 질: 스펙트럼.
- 별의 수명: 생명의 탄생과 진화에 충분해야함.
- 중력: 대기허용, 생명허용.
- 별에서 거리: tidal 힘의 크기.
- 자전: 낮과 밤의 기온차.
- 자전축 기울기: 적절한 계절.
- 공전 궤도 이심율: 별빛의 강도 변화.

외계생명의 특성

- 물리-화학 조건만 맞으면 생명은 출현.
- 생명이 얼마나 다를 수 있나?
- 아미노산은 외계에서도 만들어지지만 지구생명은 오직 20개 아미노산만 활용. 필연적인가?
- 엽록소(chlorophyll)는 햇빛을 충분이 활용하지 못함.

필연적인가?



G. L. Zubay “Biochemistry”376p

단순한 생명, 복잡한 생명?

- 간단한 유기물은 태양계와 성간에 흔함.
- 단순한 박테리아는 지금도 지구를 지배.
- 화성, 유로파에서는 단순한 생명 기대.
- 단순한 생명이 있으면 복잡한 생명의 출현은 필연적일 가능성.
- 따라서, 복잡한 생명이 흔한지 드문지는 모름.

Exotica

- 환경(중력)에 따른 형태 제약.
- Silicon based.
- Black cloud.
- Neutron star life.
- 2001 Space Odyssey; Solaris; ...
- ...

ETI 찾기

- 무슨 의미가 있나? : 우리뿐인가?
  우주에서 우리의 위치.
- 어떻게 찾나? : SETI (Search for ExtraTerrestrial Intelligence)
  -> SETT (Technology)
- Drake 식: 우리의 무지를 대변
- If we insist in looking for life which is like our own, why do we looking for … INTELLIGENT LIFE?

F. Giovannelli (1999)

ET intelligence 의 존재 가능성

- 우주에 생명은 흔하더라도 intelligence 는 흔하지 않을 가능성: 지구의 경우!
- Intelligence가 그렇게 좋고, 생존에 유리하고, 쉽게 출현하는 것이라면, 왜 우리가 아는 한 지구생명의 역사에서 우리가 유일한 intelligent species 일까?

Stephen Jay Gould

ET civilization 의 존재 가능성

- 오래된 외계문명은 현재 80-90억년까지도 가능!
- Kardashev's super-civilizations

I. 행성에 온 별빛을 모두 활용, 10^{20} erg/s

II. 별빛 에너지를 모두 활용, 10^{33} erg/s

III. 은하의 빛 에너지를 모두 활용, 10^{44}erg/s

Nikolai Kardashev (1964)

- Dyson sphere

Type II. 문명은 IR 방출가능성

Freeman Dyson

우주규모에서 진화의 끝은?

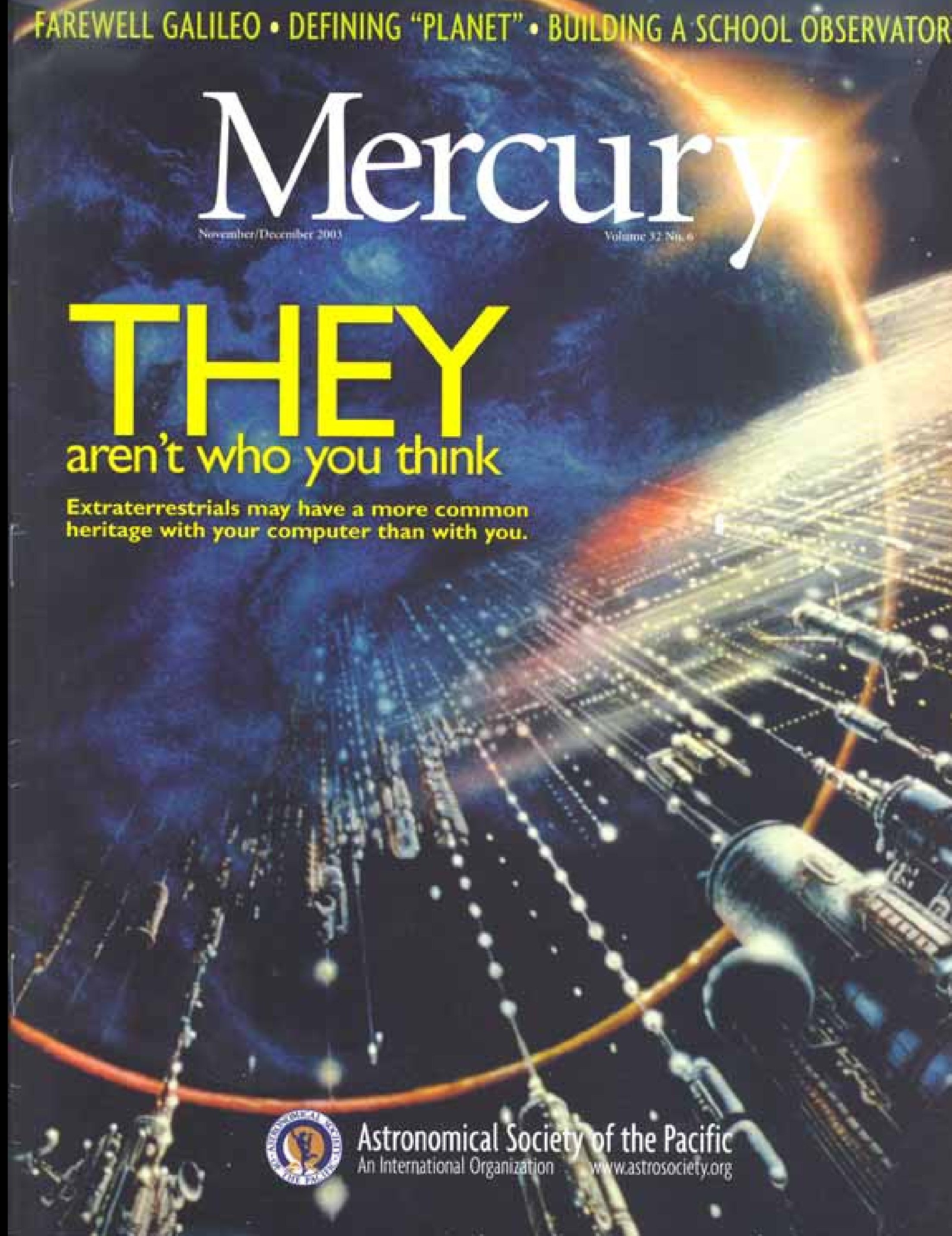
I. Physical evolution
II. Chemical evolution
III. Biological evolution, genetic takeover
IV. Cultural evolution, robotic (AI) takeover

Hans Moravec (1988)

III. 과 IV. 의 끝은?

❑ "If we ever encounter extraterrestrial intelligence, they're likely to be machines, not creatures of flesh and blood.''

Steven J. Dick (2003)

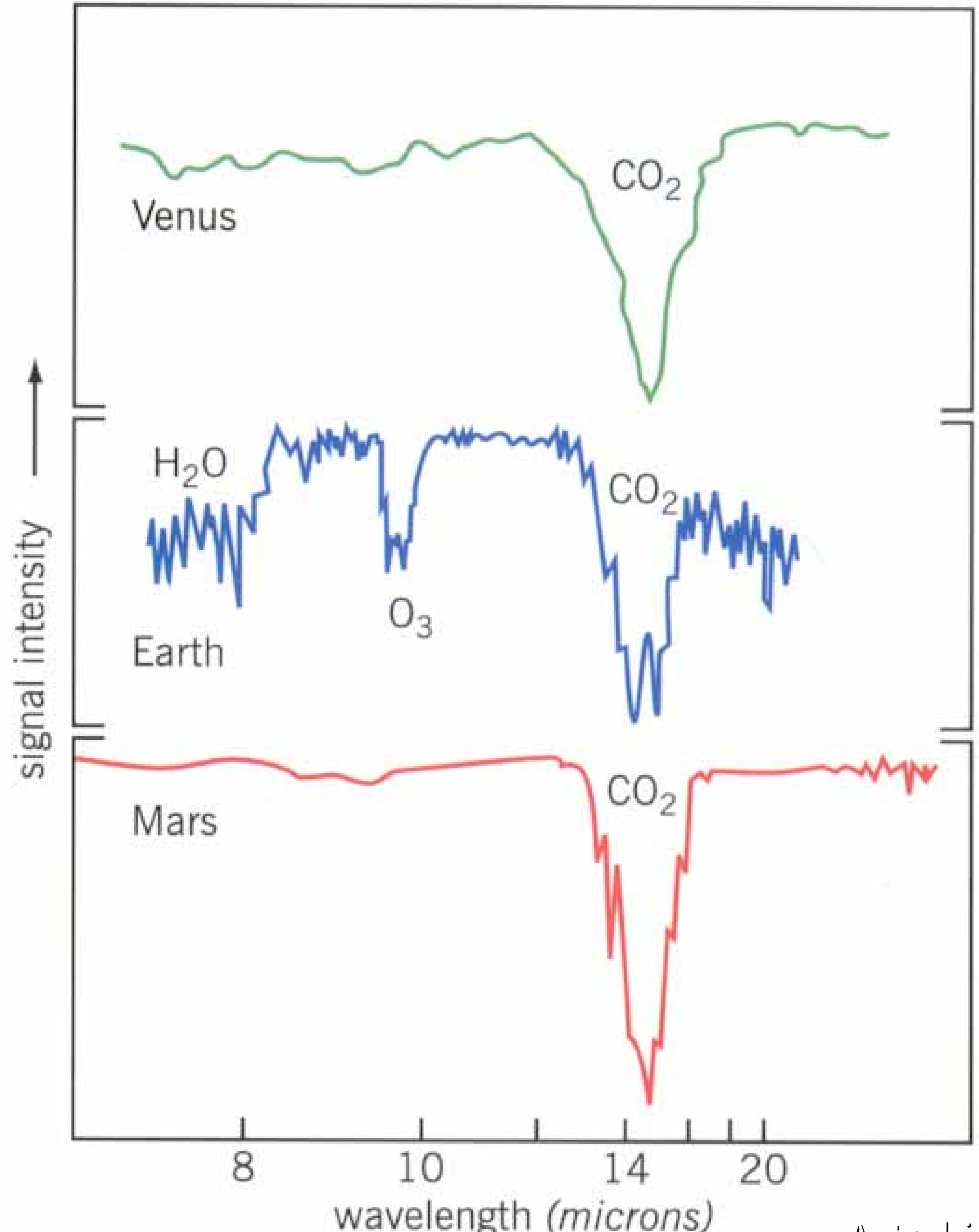

FAREWELL GALILEO • DEFINING "PLANET" • BUILDING A SCHOOL OBSERVATORY
Mercury
November/December 2003
Volume 32 No. 6
THEY
aren't who you think
Extraterrestrials may have a more common heritage with your computer than with you.
Astronomical Society of the Pacific
An International Organization
www.astrosociety.org

JH

외계행성에서 찾기

- Terrestrial Planet Finder (NASA)
- 지구형 행성 직접 imaging (10-15년)
- Oxygen 대기관측

RIGHT **Comparison between the spectral signatures of Venus, Earth and Mars. Earth is the only one to show the signal for oxygen (as ozone).**



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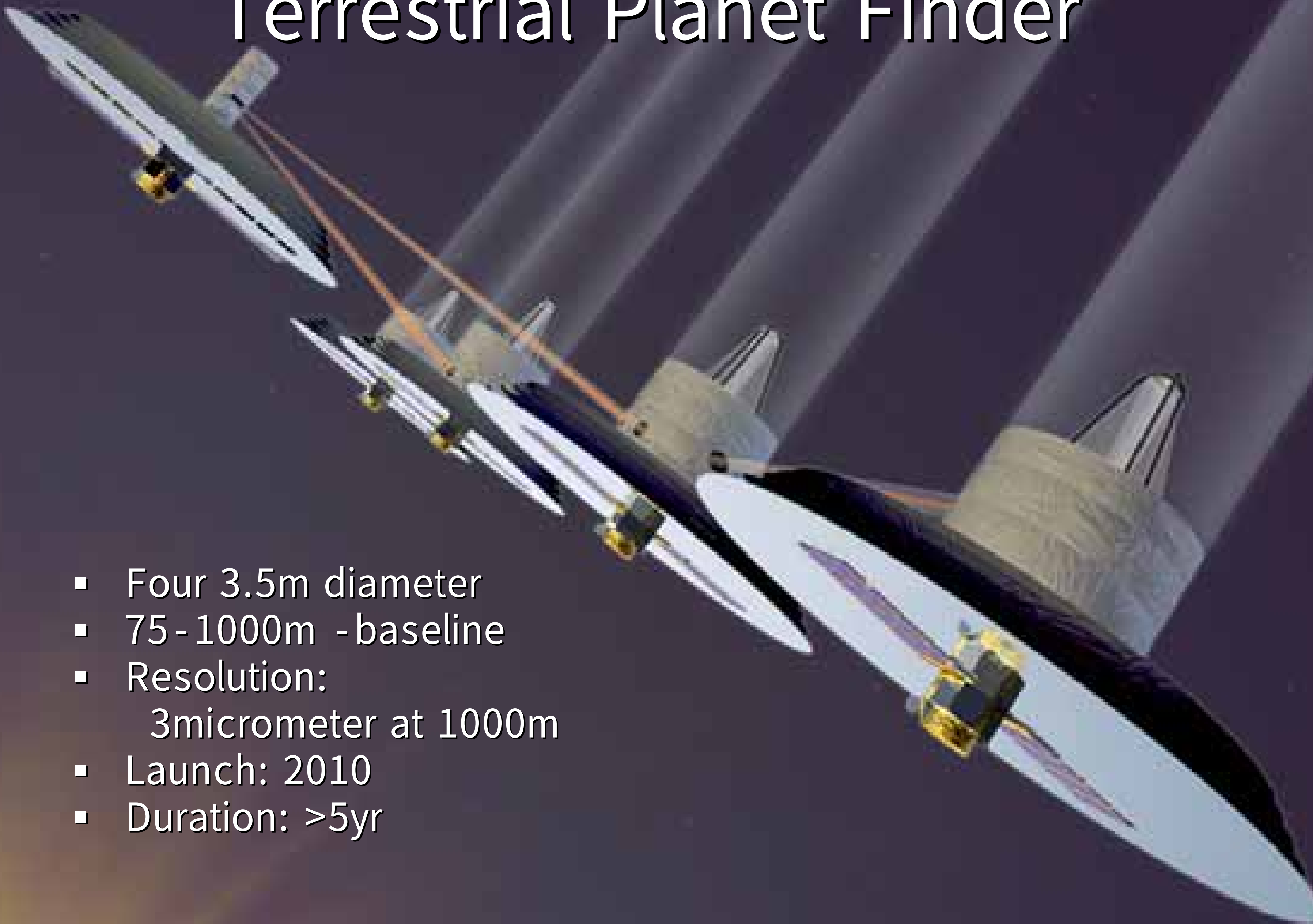
Terrestrial Planet Finder



- Four 3.5m diameter
- 75-1000m -baseline
- Resolution:
  3micrometer at 1000m
- Launch: 2010
- Duration: >5yr

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혹시 와 있는 것은 아닐까?

<u>Close encounters</u> (Ufologists):

- CE1: 150m 이내에서 UFO 관측
- CE2: 잔해, 착륙흔적 따위 증거 발견
- CE3: 외계생명 관측, UFO 근처에서
- CE4: 외계생명 접촉, UFO탑승, 납치
- (CE5): 국제적 상호교신

우리가 외계인을 만난다면

- 진화에 성공적인 지구 생명들은 대부분 호전적
- 예, 인간

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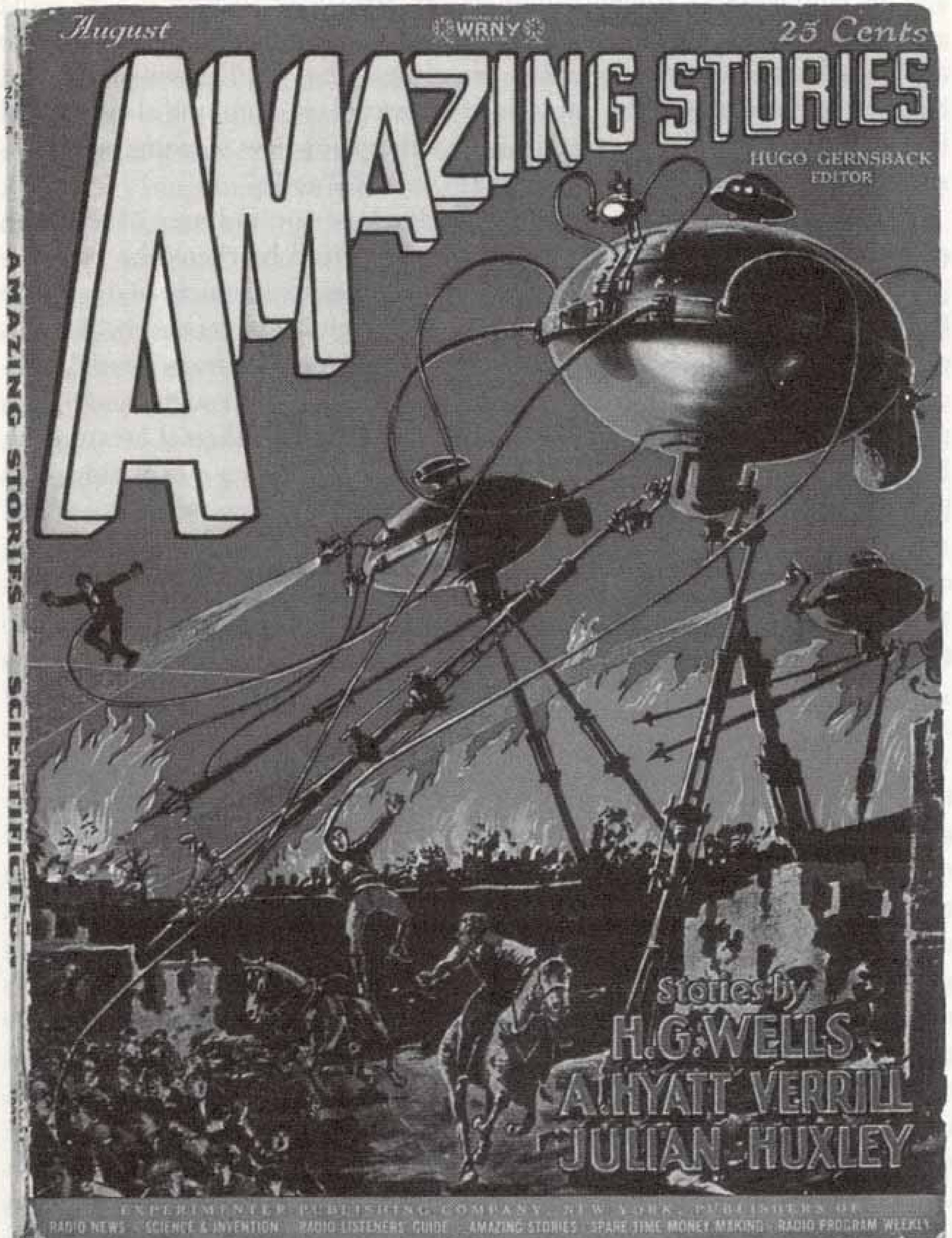

Fig. 4.3. Cover from *Amazing Stories* of August 1927, illustrating H. G. Wells's *War of the Worlds.* Copyright 1927 by Experimenter Publishing Co.

JH

Dick

The Battle of Omdurman. "The maxims and infantry annihilated them. Whole battalions vanished under the withering fire."
The Graphic. *September 24, 1898.*

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"Exterminate all the brutes"

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