Retention time of Crater Ray Materials on the Moon

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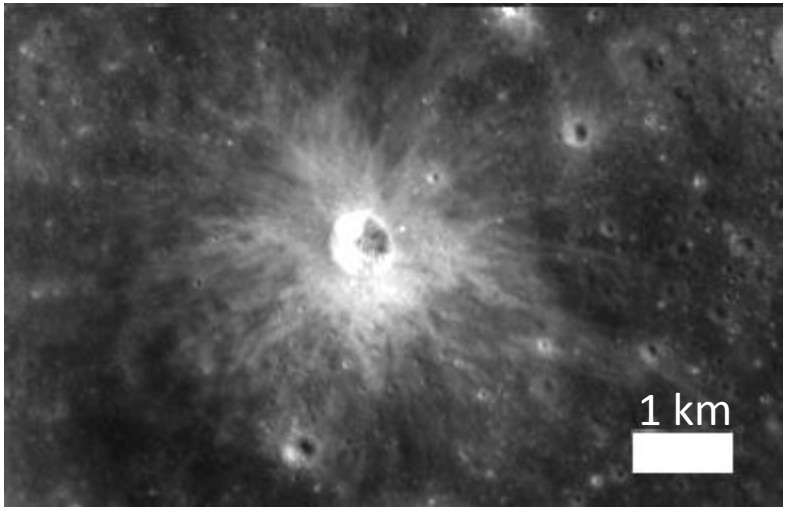
Crater Ray

- **Fresh materials** not be affected by space weathering

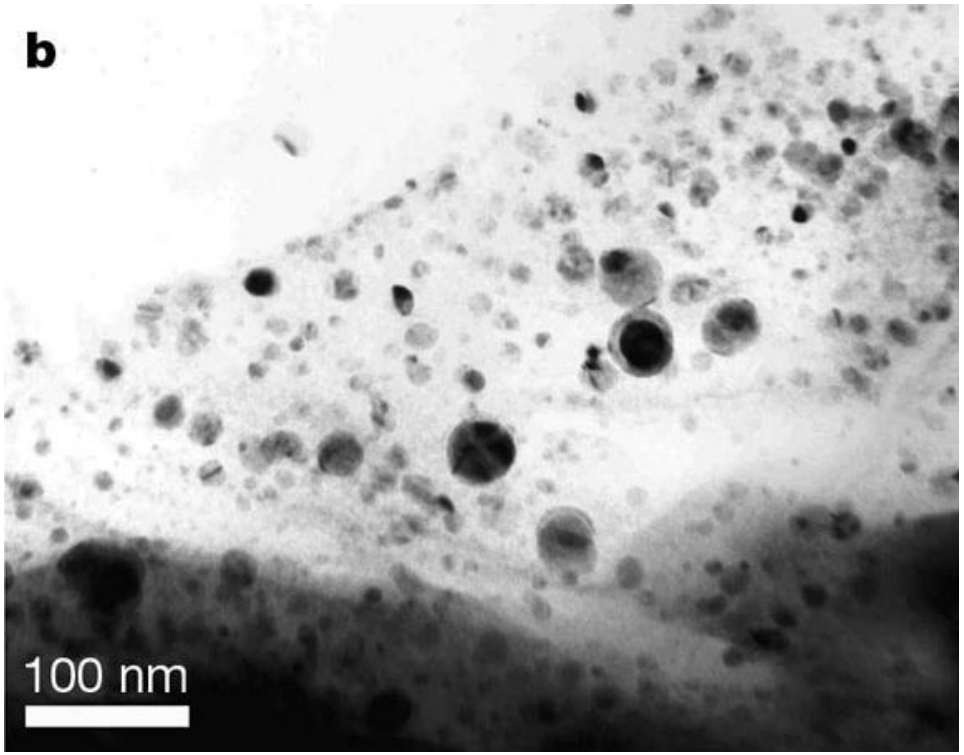
  → Bright compared with the surrounding materials

- Formed by excavation and deposition of fresh materials from both the primary crater and the secondary craters (Hawke et al., 1999, 2000)



Space Weathering (1)

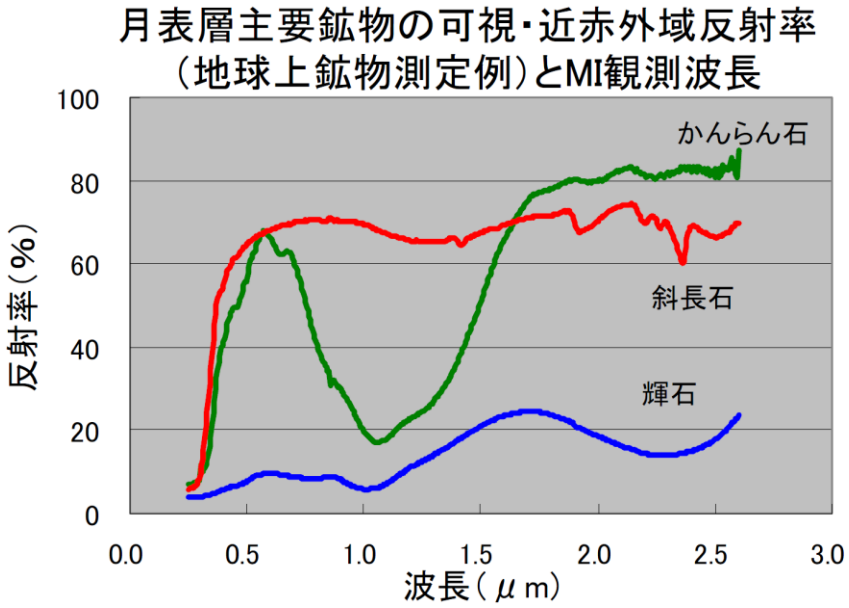
- Surface materials are modified by exposure to **cosmic rays**, **solar wind**, and **meteorite bombardments** (Sasaki et al., 2001)



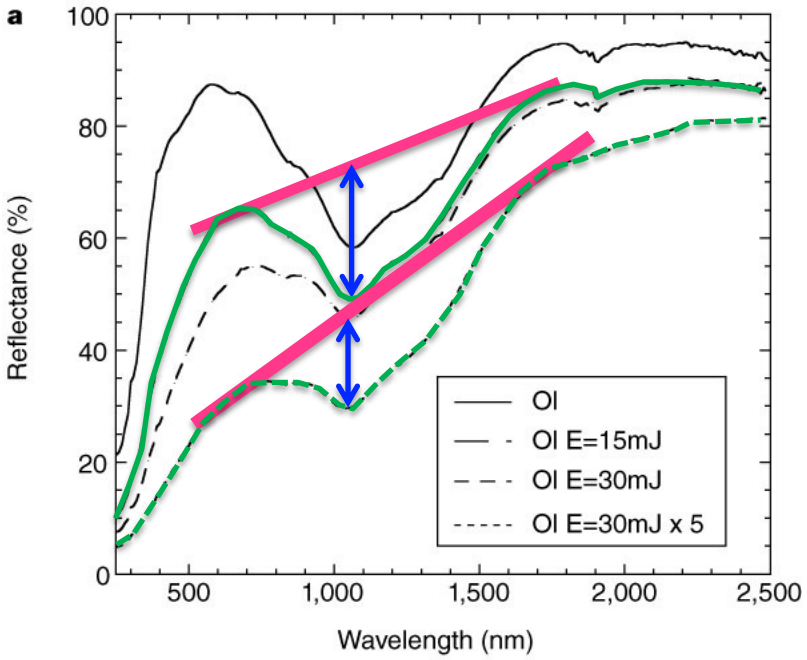
Sasaki et al. (2001)

Space Weathering (2)

- Effects of space weathering
  - Darkening : Surface reflectance becomes low
  - Reddening : Visible range is darker than near infrared
  - Weakening of absorption band depths



大竹さんの講義ファイルより



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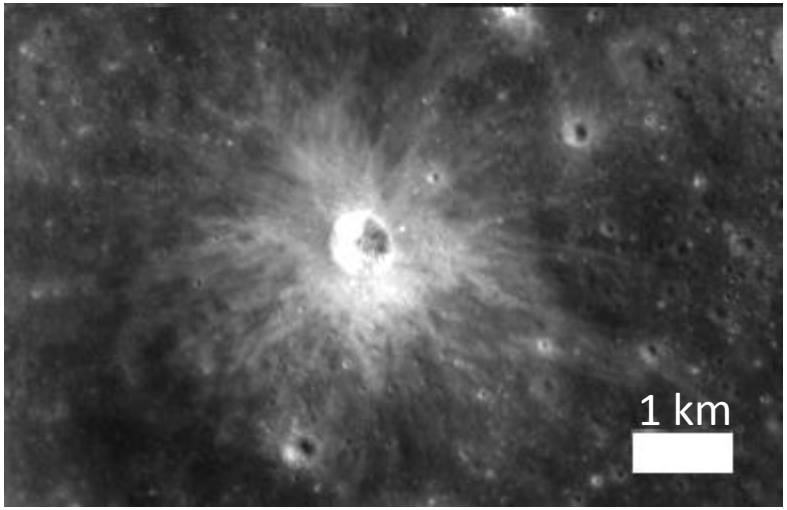
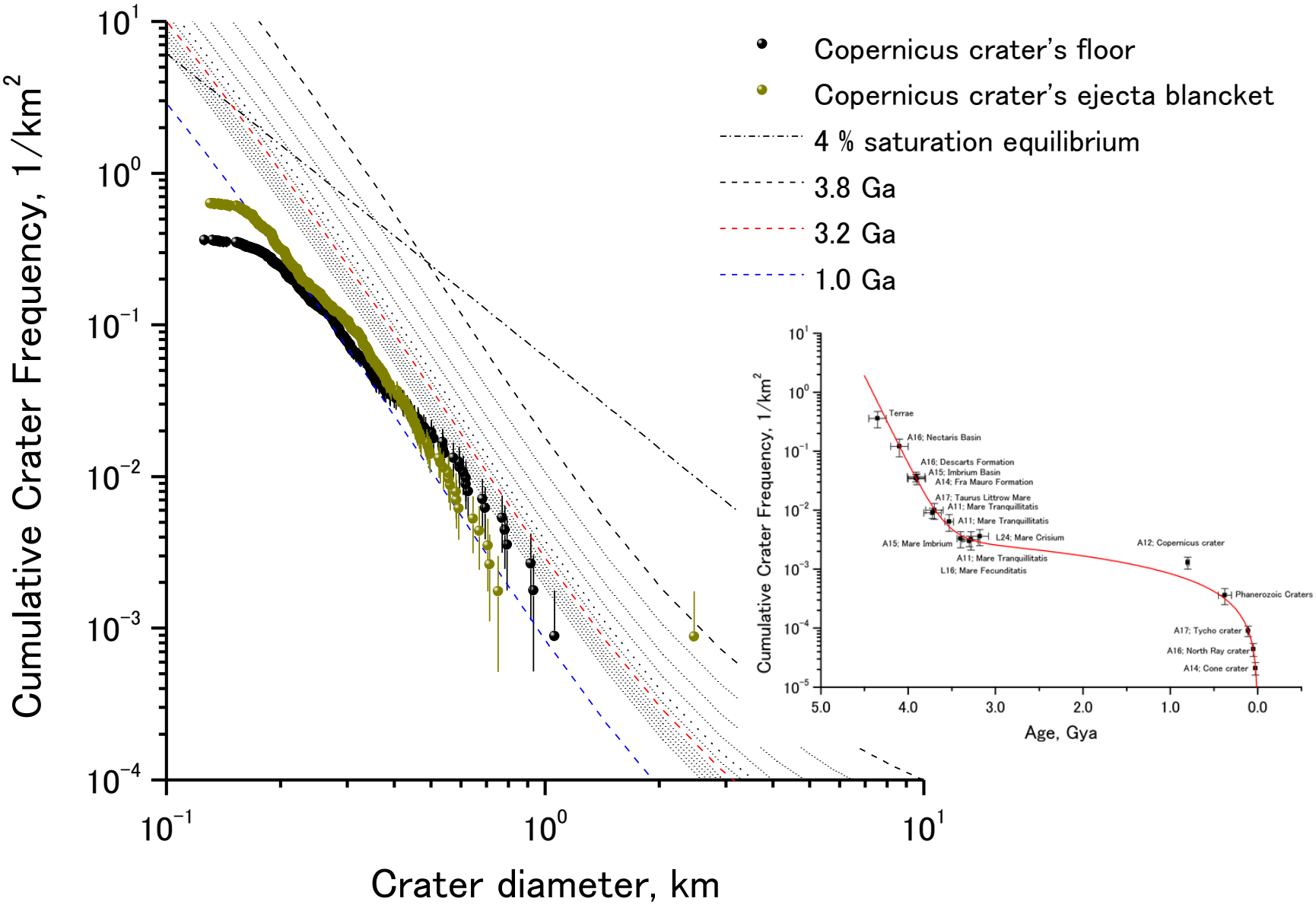


Crater Chronology (NPRF)

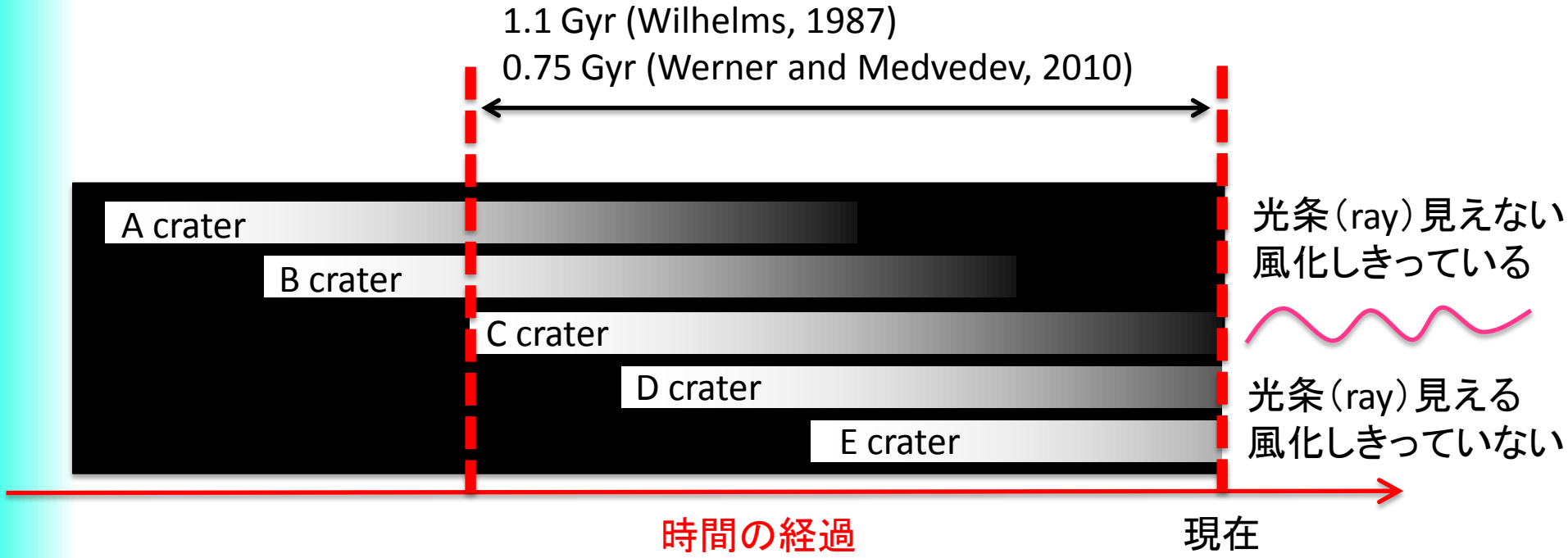


Reasons for Disappearance of Rays

- Rays disappear in **1.1 Gyr (Wilhelms, 1987)** 、**750 Myr (0.75 Gyr) (Werner and Medvedev, 2010)**

- **Space weathering** acts directly on surface materials
- **Gardening**
  - Surface materials are mixed with surrounding space weathered materials by micrometeorite bombardments

ポンチ絵


1.1 Gyr (Wilhelms, 1987)
0.75 Gyr (Werner and Medvedev, 2010)
A crater
B crater
C crater
D crater
E crater
光条（ray）見えない
風化しきっている
光条（ray）見える
風化しきっていない
時間の経過
現在

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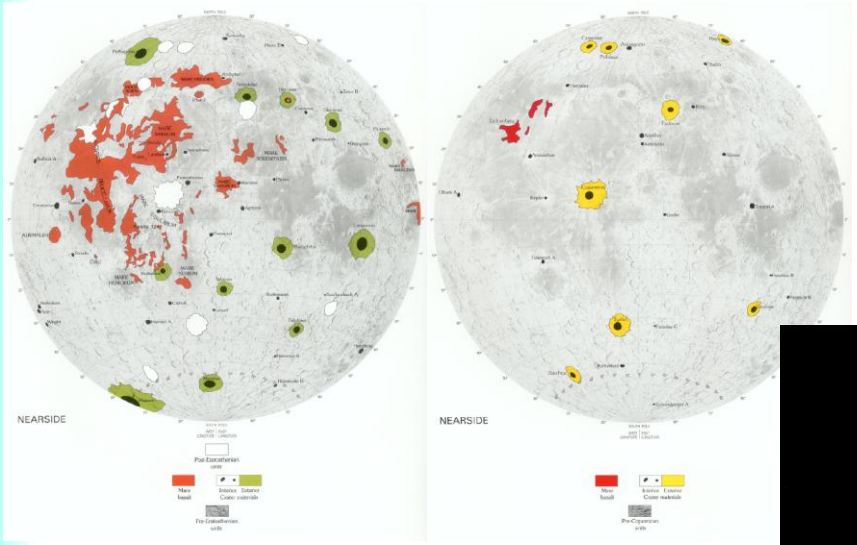
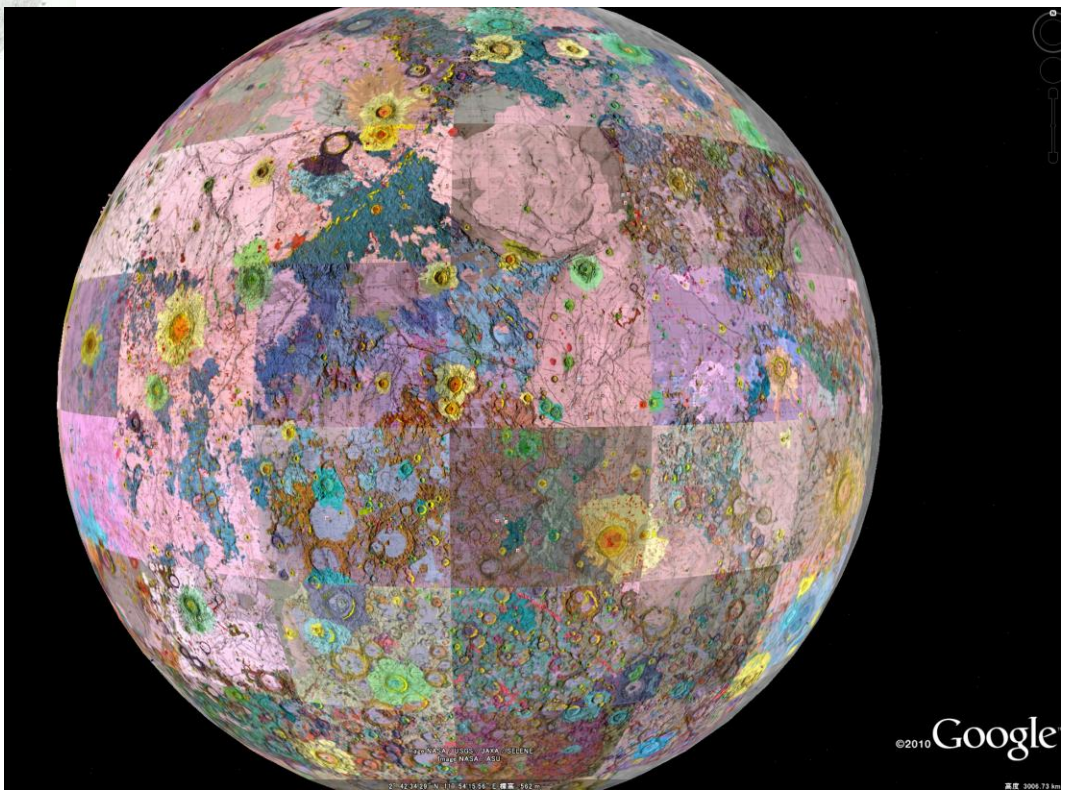
月の地質区分
Eratosthenian - Copernican



Wilhelms (1987)

光条をもつクレーター：Copernican
光条をもたないクレーター：Eratosthenian

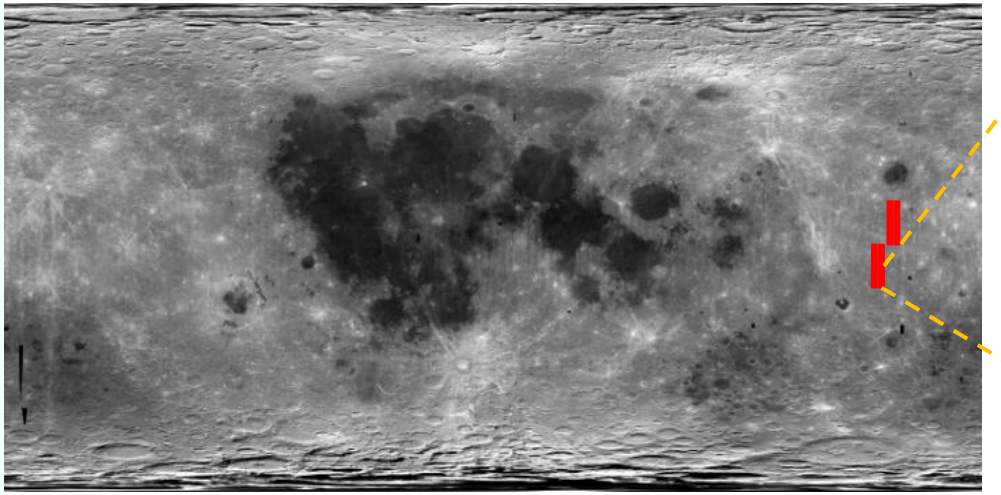
USGS作成の詳細地質マップ

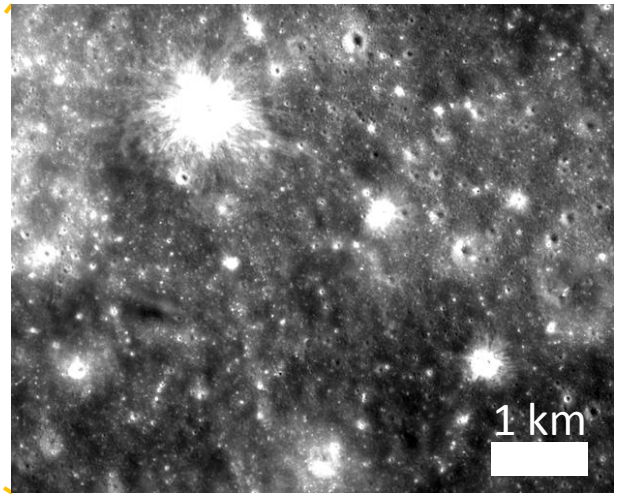


Objective

Investigate retention time of crater rays using high-resolution data from Terrain Camera and Multiband Imager onboard Kaguya

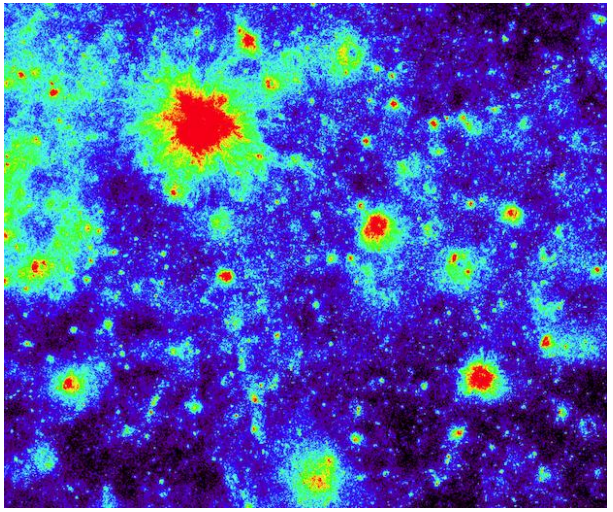
Analysis Areas





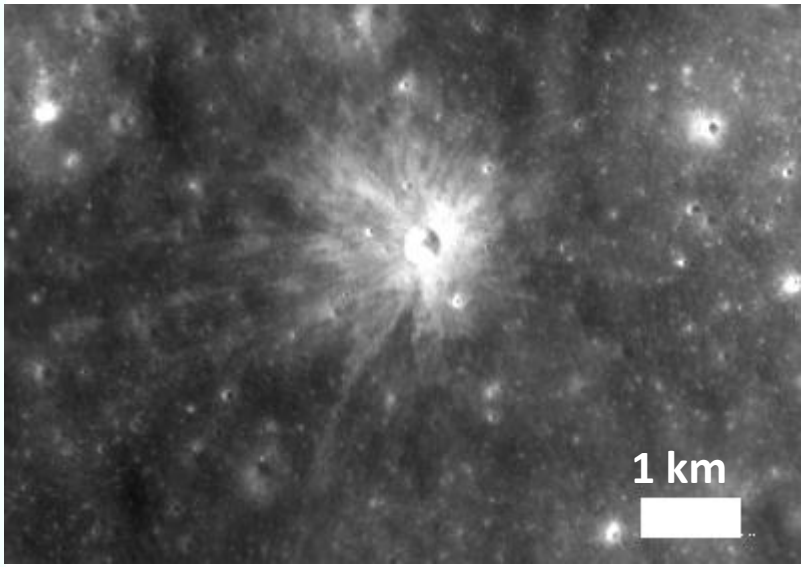
MI 750 nm image

	Longitude	Latitude	Areas [km^2]
1	0° N – 15° N	147.5° E – 148.1° E	8.3×10^3
2	0° N – 15° N	148.5° E – 149.2° E	8.3×10^3
3	15° S – 0° N	143.2° E – 143.5° E	8.1×10^3
4	15° S – 0° N	144.3° E – 145.1° E	8.1×10^3



OMAT

Crater with Bright Ray



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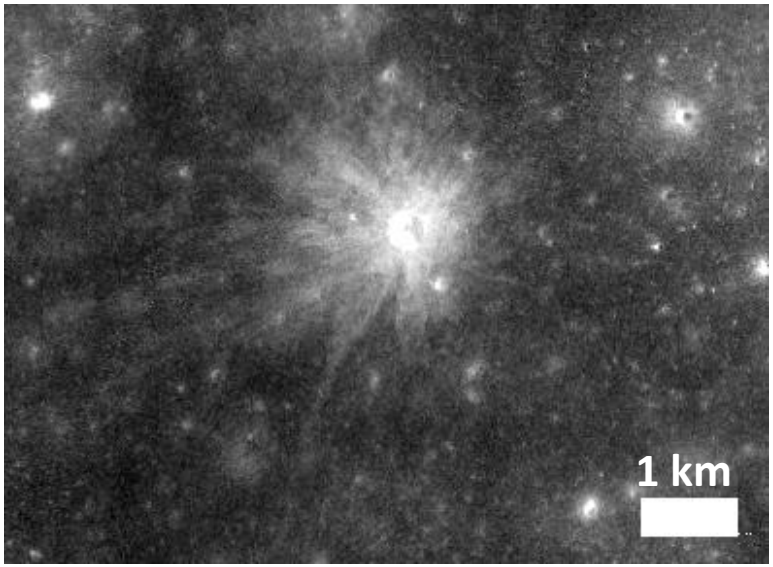
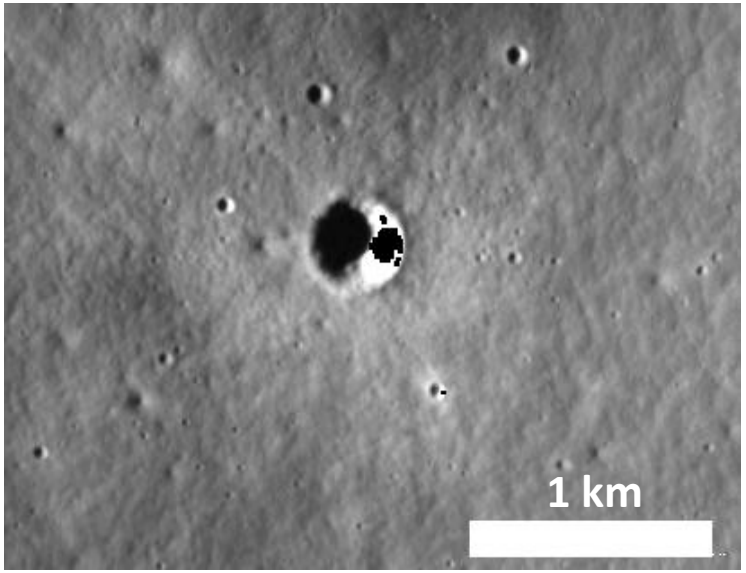
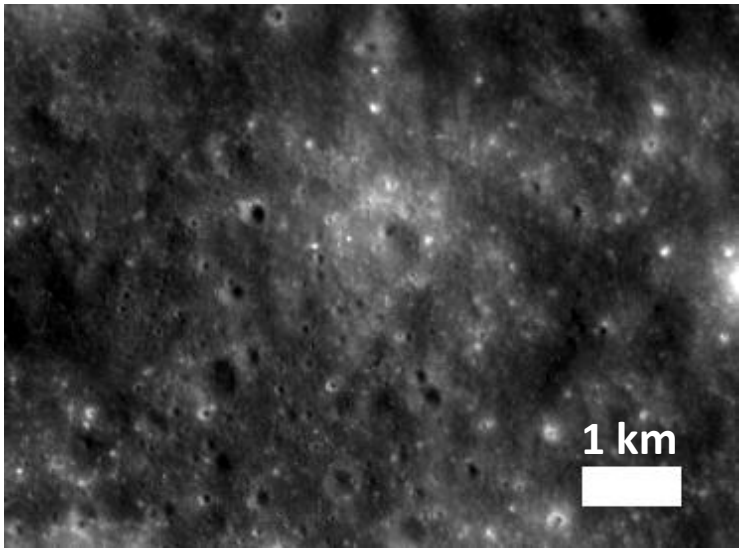


MI-OMAT

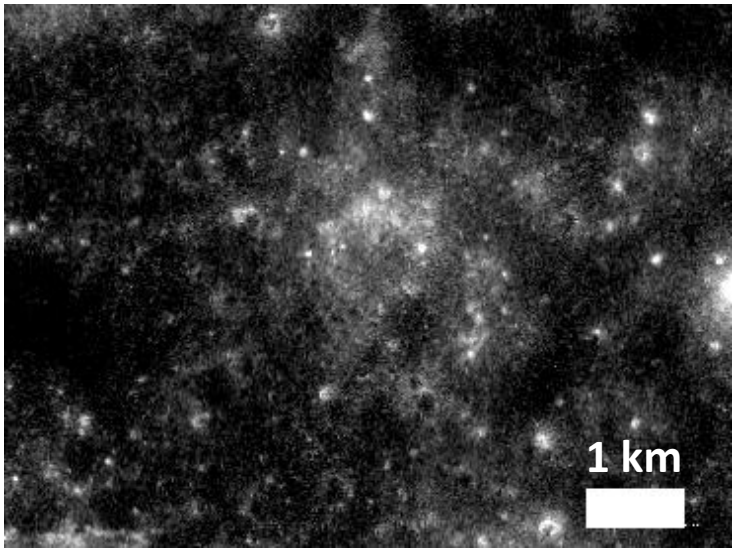


TC

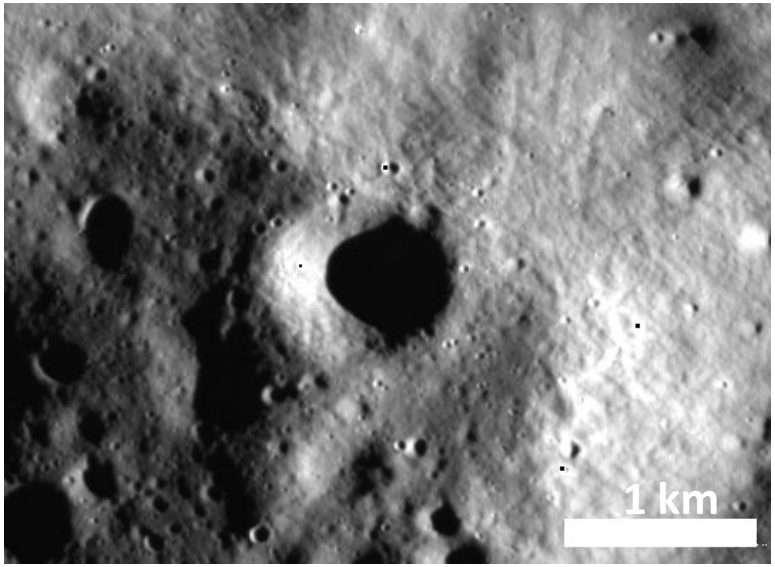
Crater with No Ray



MI



MI-OMAT



TC

Optical Maturity ParameTer (OMAT)

(Lucey et al., 2000)

- Optical index representing the degree of space weathering (Low OMAT value means mature soil)
- Definition :

$$OMAT = \sqrt{(R_{750} - x_0)^2 + \left(\left(\frac{R_{950}}{R_{750}}\right) - y_0\right)^2}$$

R_{750}: Reflectance at 750 nm
R_{950}: Reflectance at 950 nm
$x_0 = 0.08, \quad y_0 = 1.19$

- Calculate from multiband data obtained by MI

Space Weathering (2)

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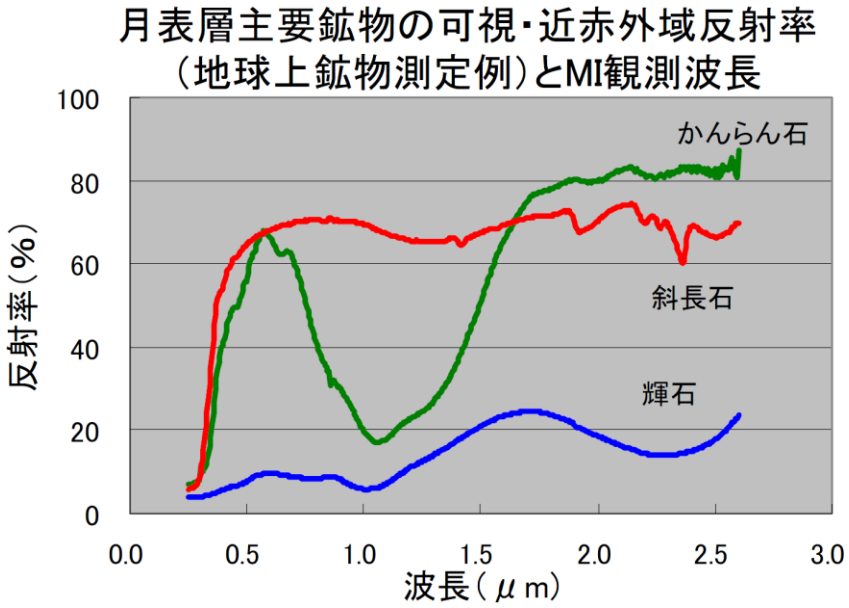
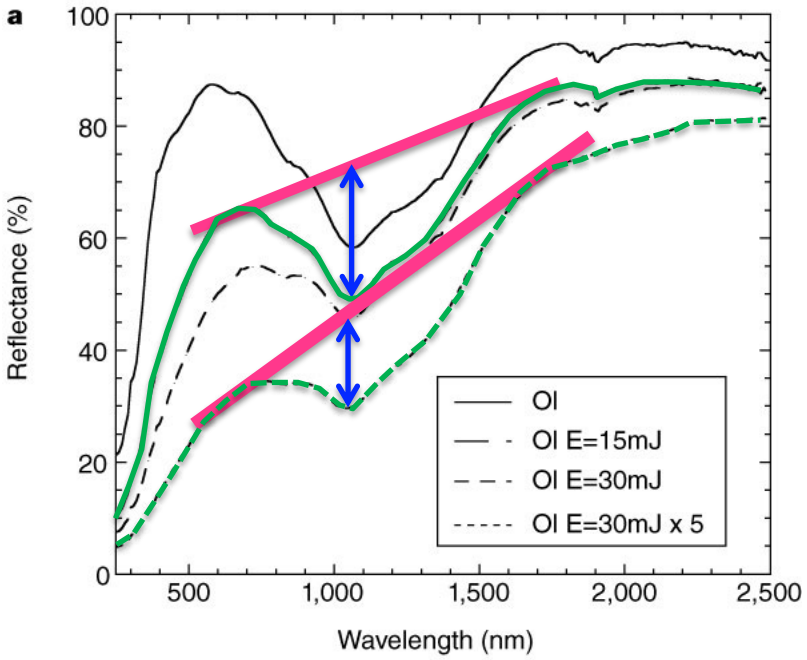


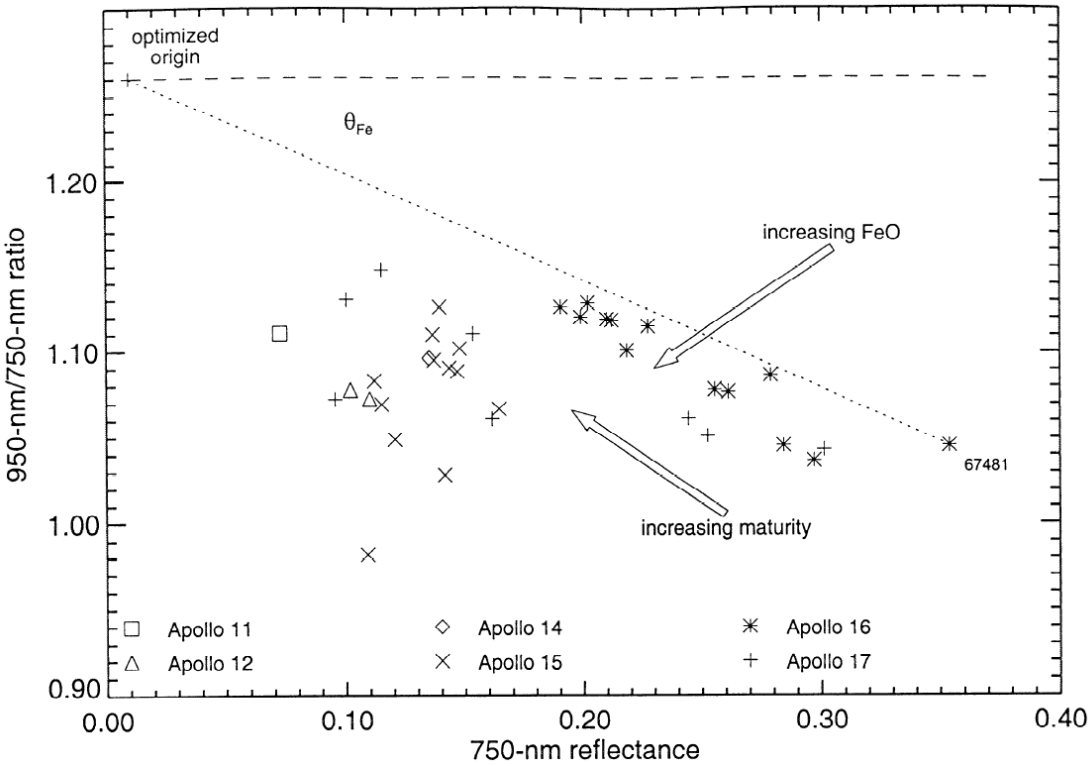
大竹さんの講義ファイルより

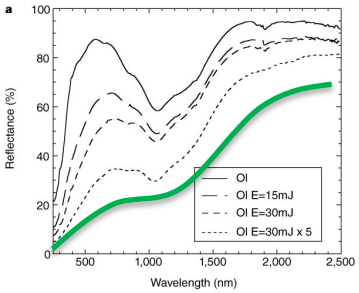


Sasaki et al. (2001)

Space Weathering (2) つづき

吸収深さが浅くなる





Sasaki et al. (2001)

Lucey et al. (2000)

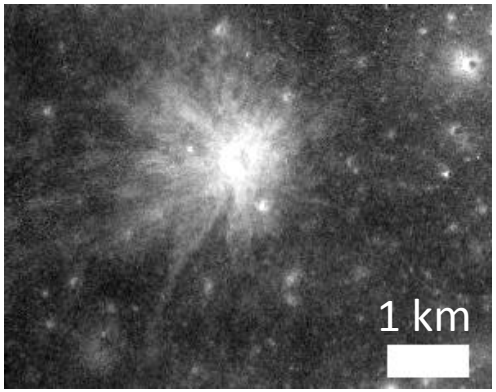
反射率が全体的に低くなる

手順

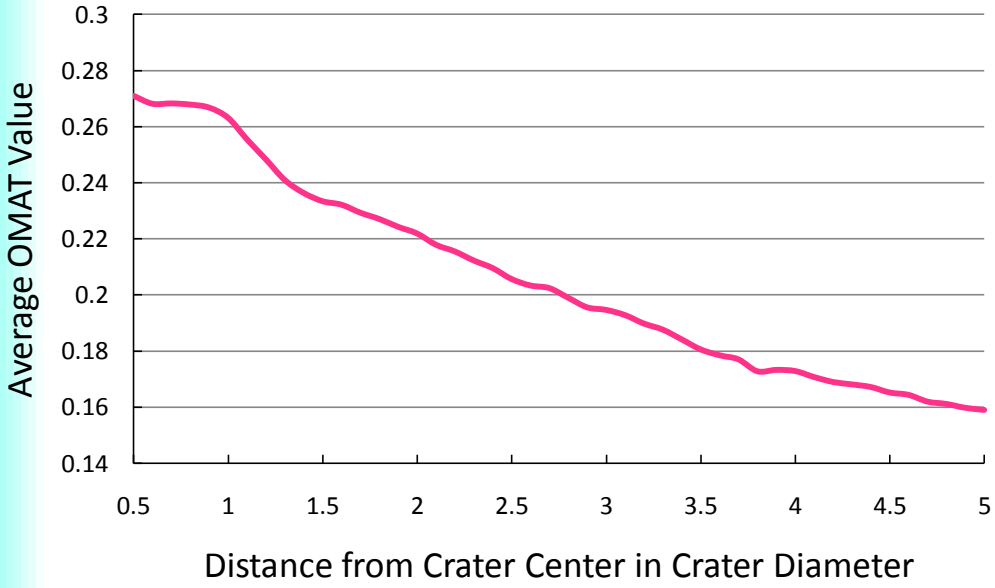
- TCデータ（低太陽高度条件データ）を用いて、計測領域内の直径300m以上の地形の形状から判断して新鮮なクレーターをリストアップ
- MIデータを用いて、リストアップしたクレーターのOMATプロファイルを調べ、光条の有無を判定する

OMAT and Crater Rays

- OMAT value of ray materials is high
- OMAT value of rayed craters
  - High at the crater rim
  - Decreases with the distance from crater rim



OMAT

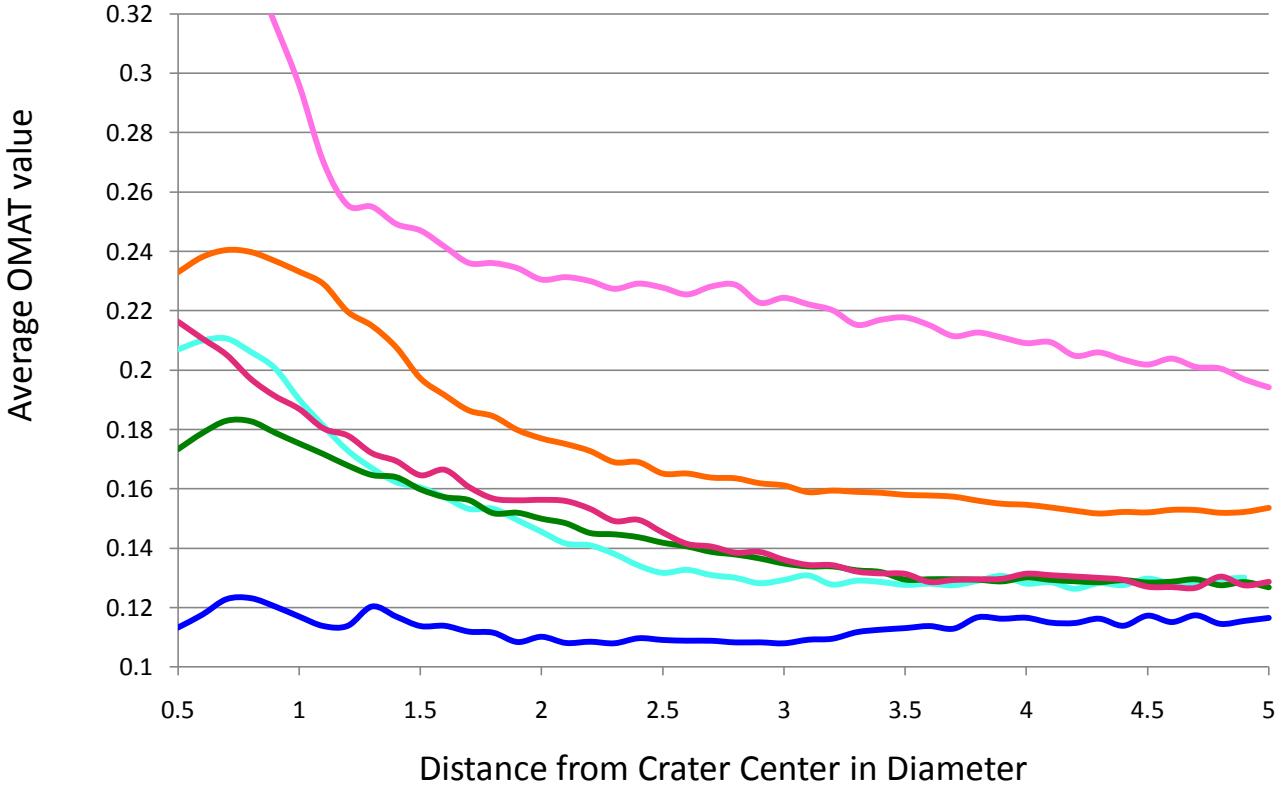


OMAT Profiles

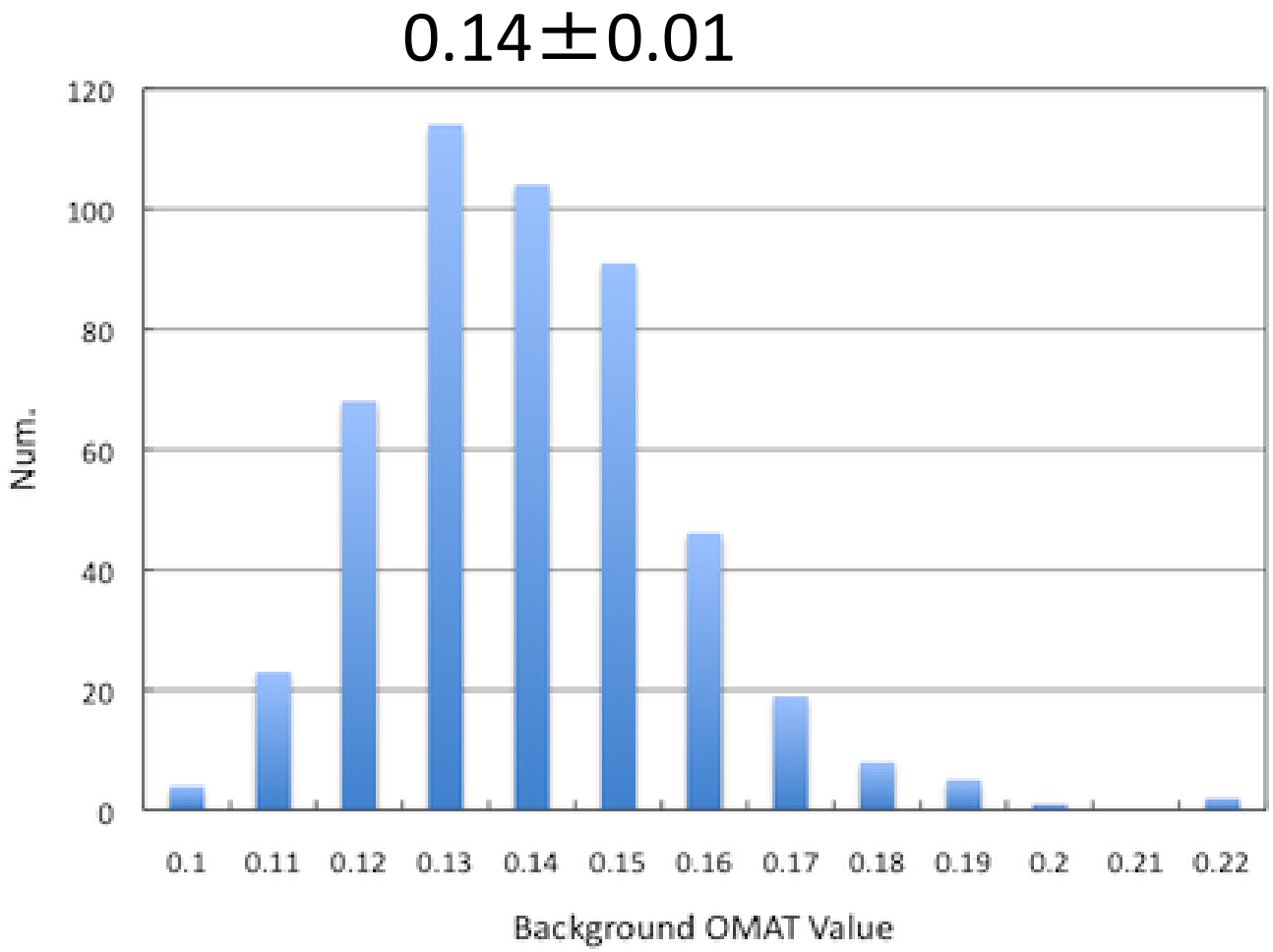
- Calculate **radial average OMAT value**
- Normalized distance from crater center by crater diameter

Rayed Craters Extraction

1. Identify craters larger than 300 m in diameter in TC image
2. Extract rayed craters based on the following criteria:
   - OMAT value at the crater rim is larger than 0.15
   - OMAT value decreases with the distance from crater rim



Background OMAT Value



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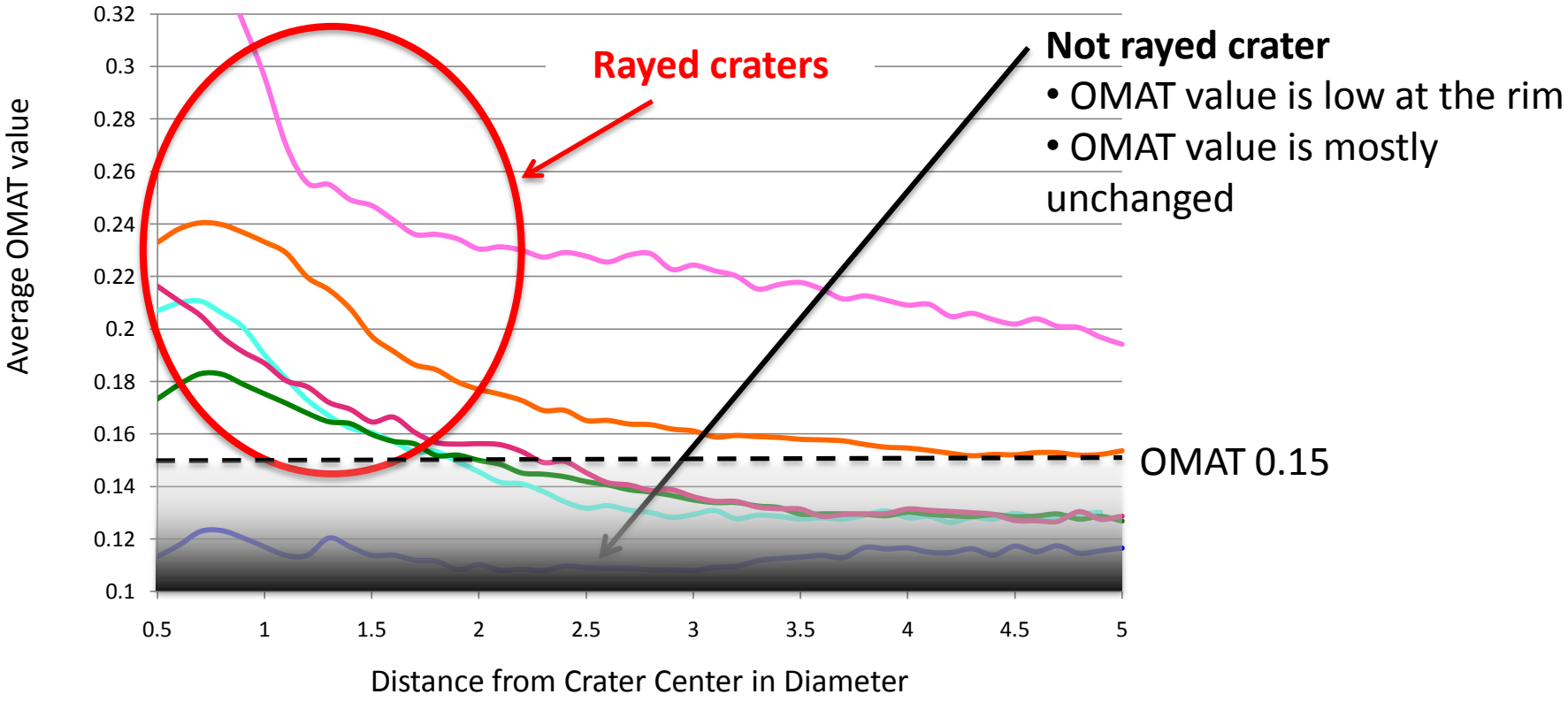
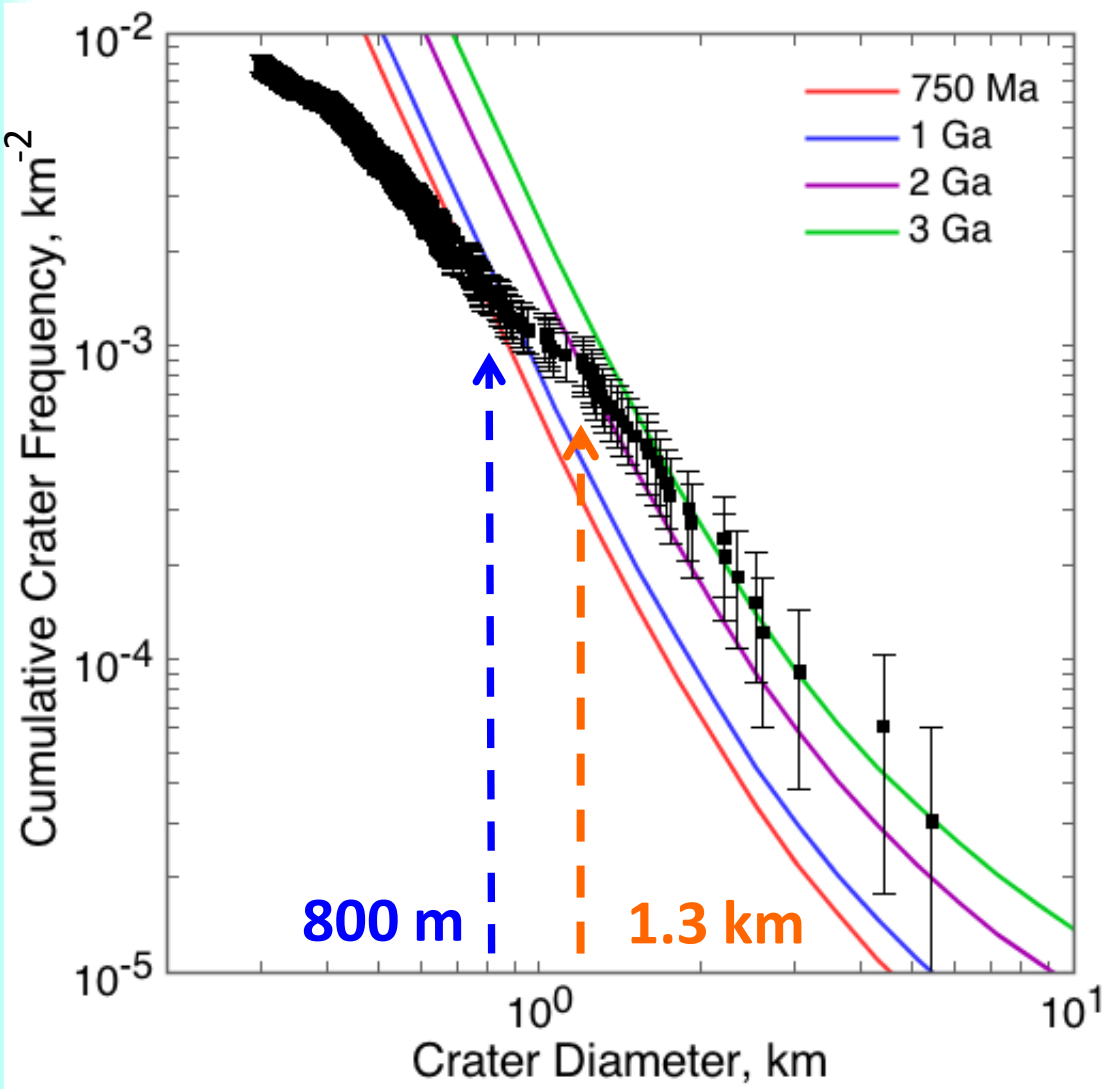


Number of All Craters and Rayed Craters

area	Num. of all craters		Num. of **rayed craters**	
	Total	D > 1 km	Total	D > 1 km
1	124	13	77	11
2	133	18	53	8
3	109	11	56	5
4	151	26	76	12
Total	**517**	**68**	**264**	**36**

Crater Size-Frequency Distribution



- Deviated from 750 Ma isochron (Wener and Medvedev, 2010)

D > 1.3 km

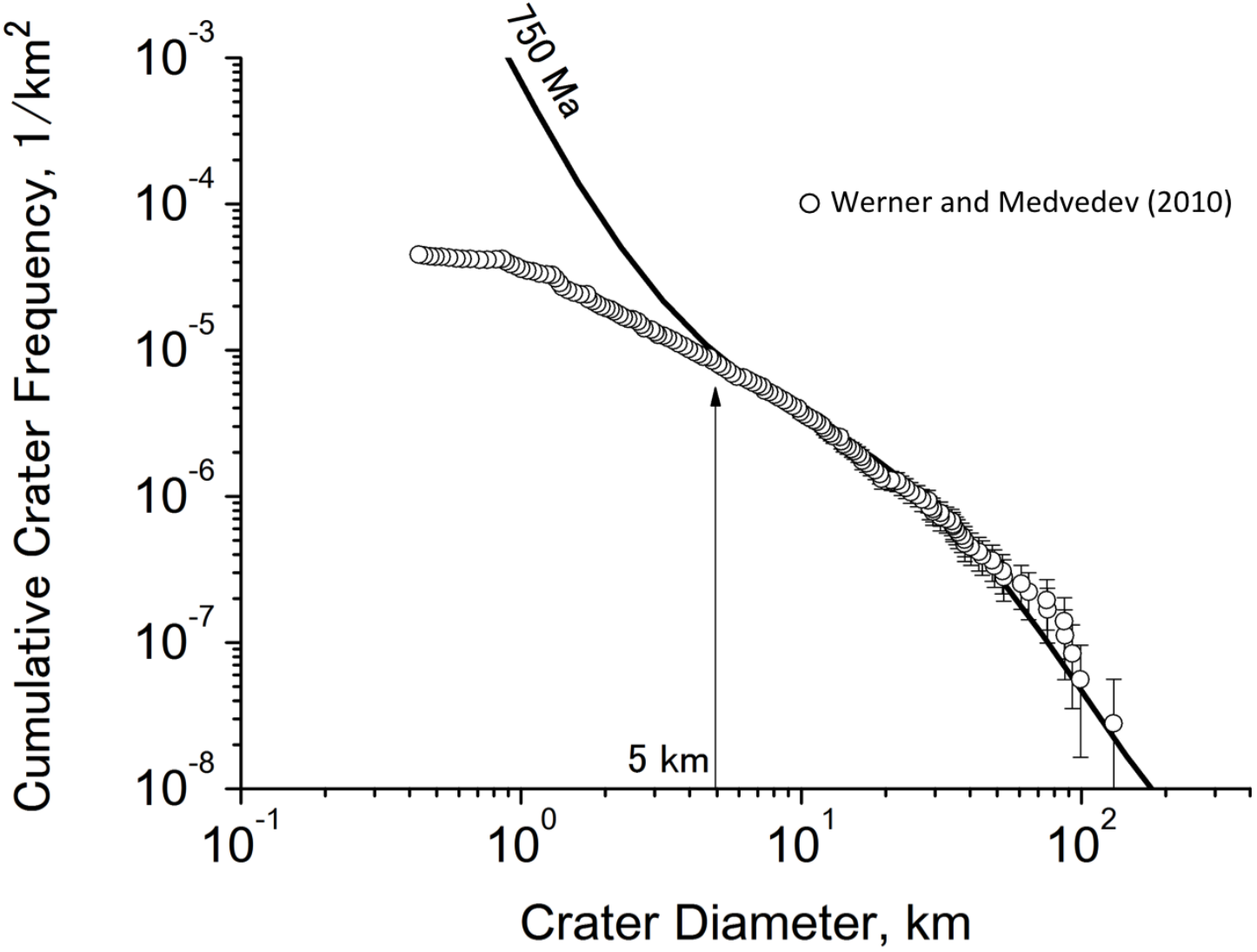
- Distributed between 2 Ga and 3 Ga isochrons

D < 800 m

- Fall below 750 Ma

Inconsistent with previous researches

Werner and Medvedev (2010)



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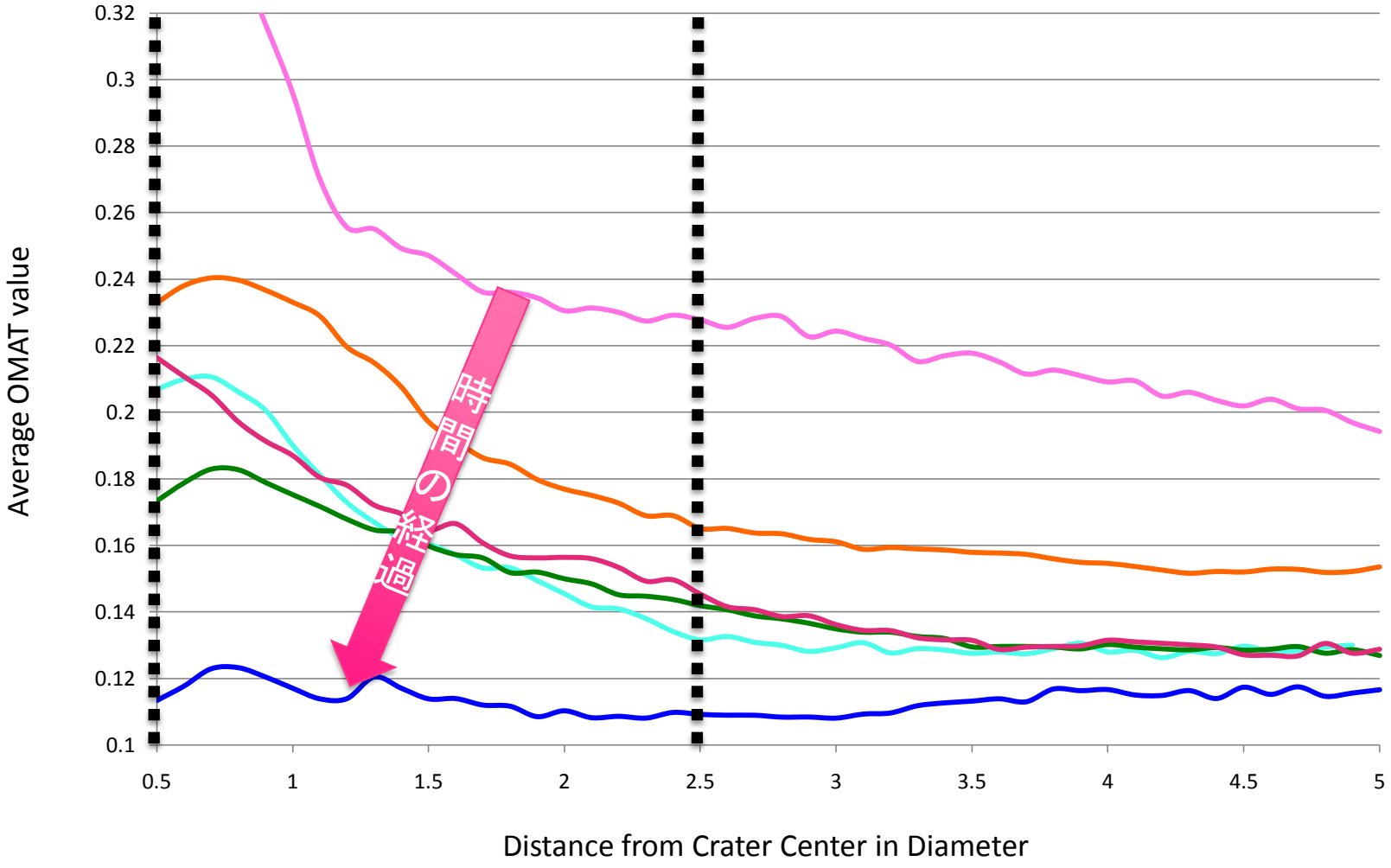
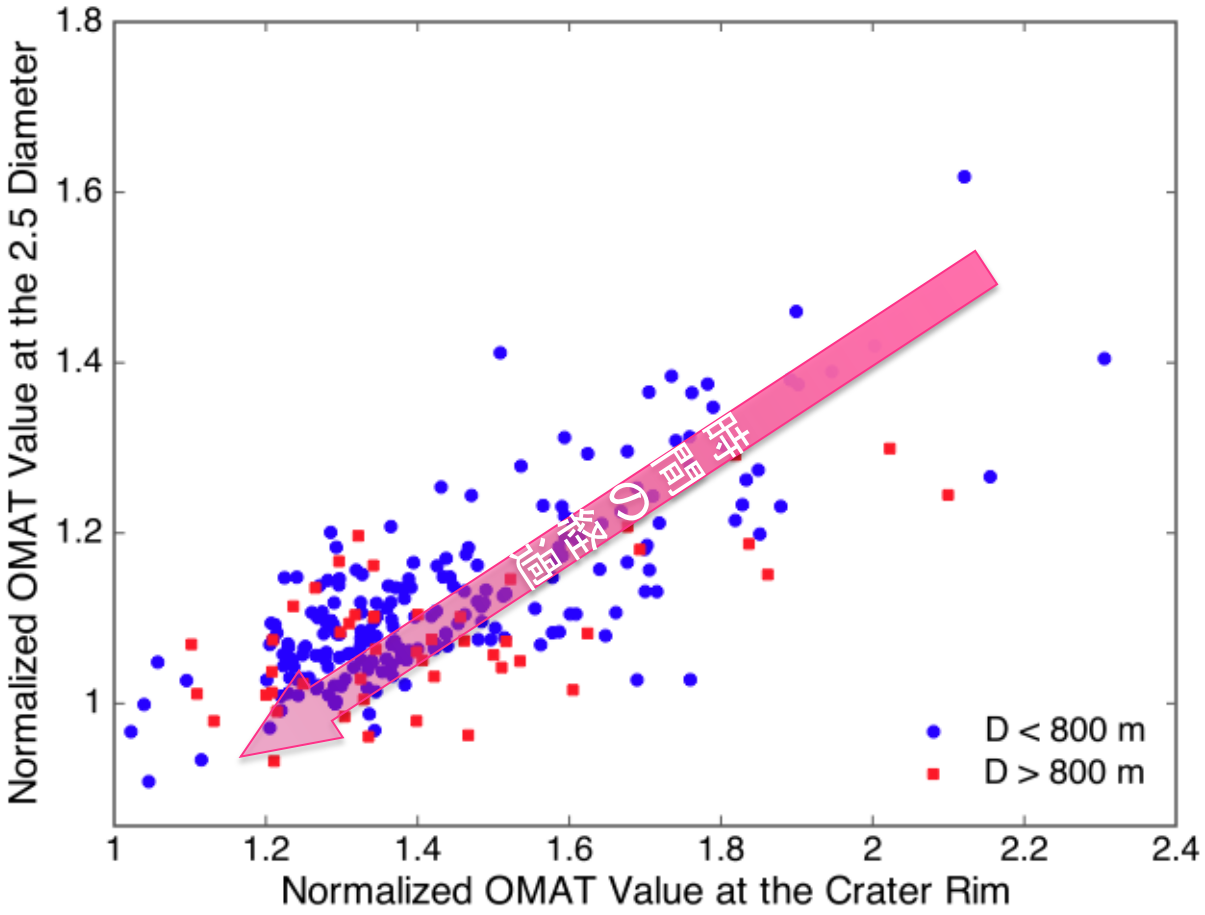


Pattern of Ray Disappearance



Plots of normalized OMAT value

- The craters larger than 800 m in diameter and that smaller than 800 m are plotted.

Num.D<800m : Num.D>800m
≒ 4 : 1

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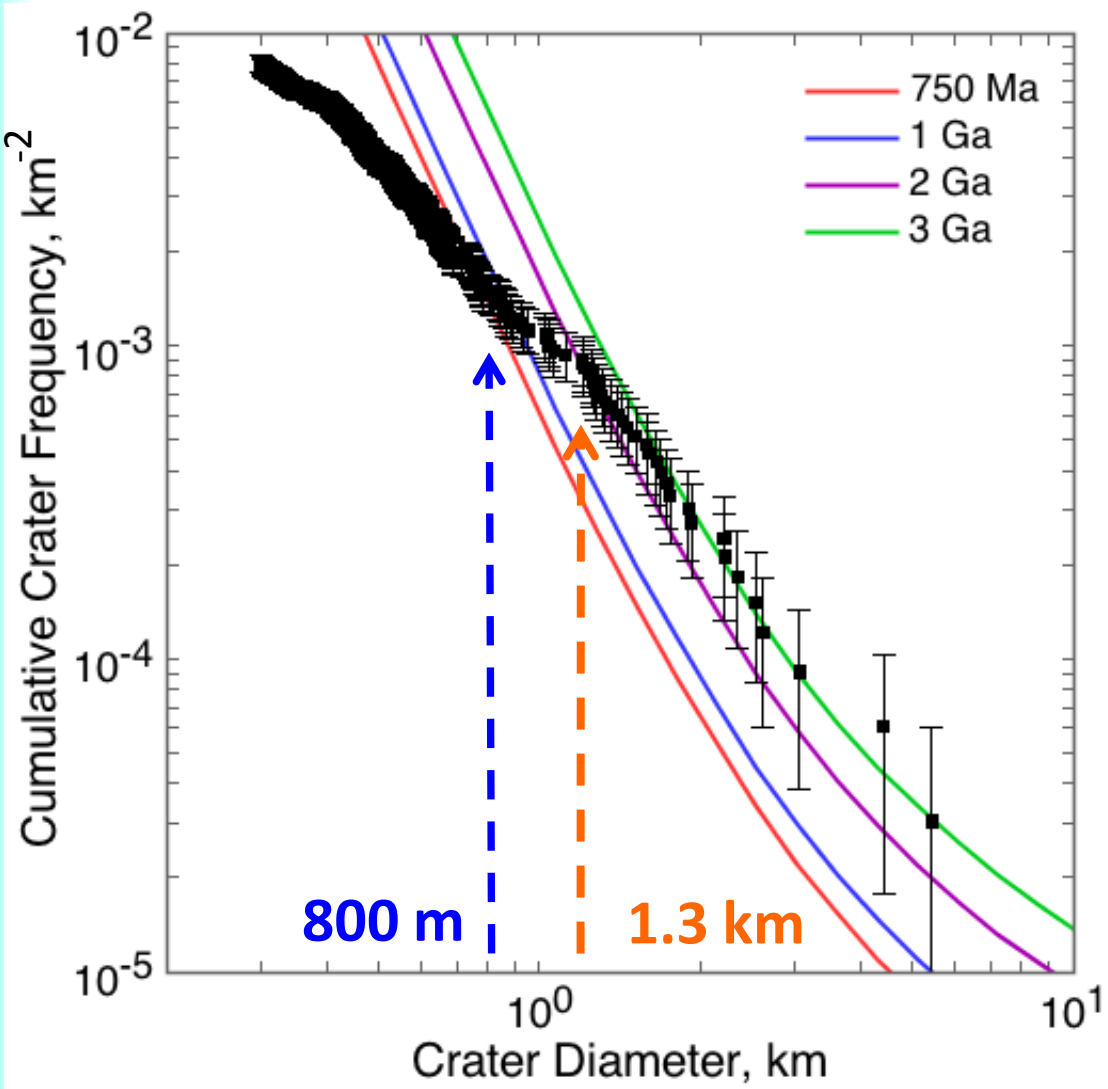

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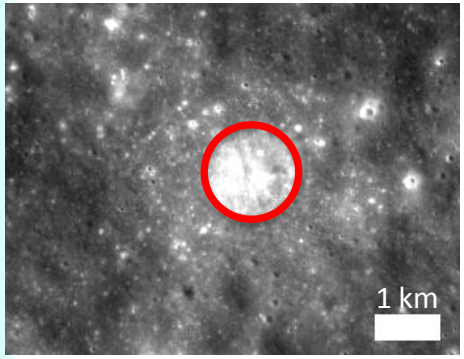
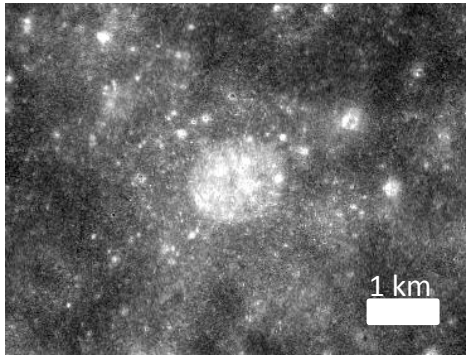
Inconsistent with previous researches

Precise Inspection of Rayed Craters

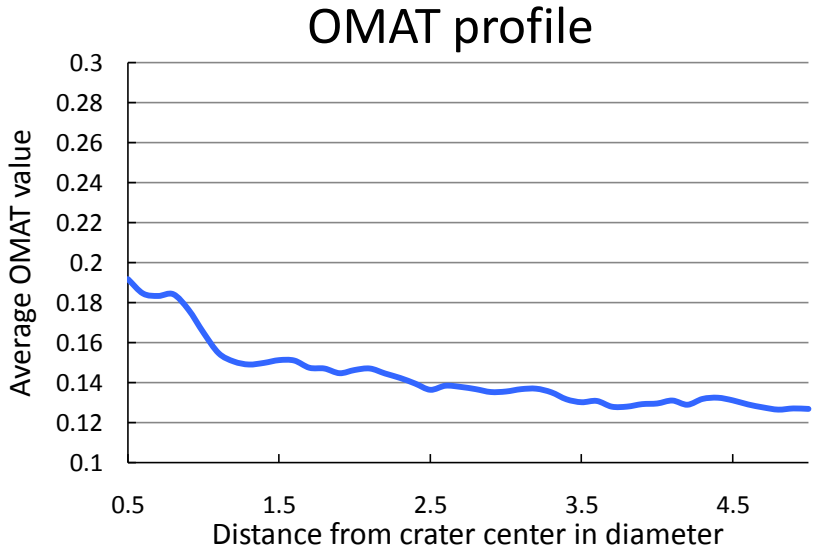
- Confirm existence of rays using image data
- Focus on craters larger than 1 km in diameter
- Investigate based on MI 750 nm image, OMAT, and OMAT profile



MI 750 nm image



OMAT



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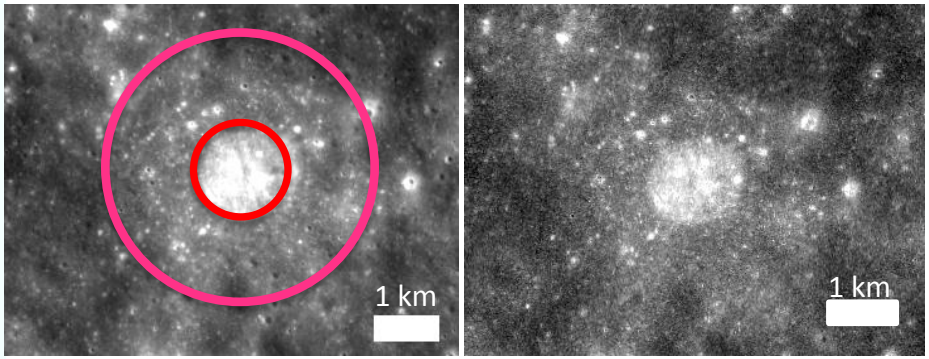
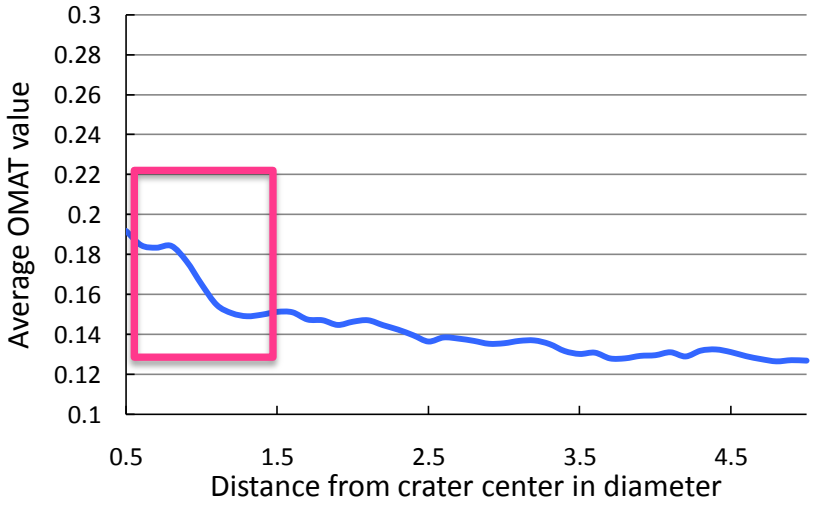


MI 750 nm image　　OMAT

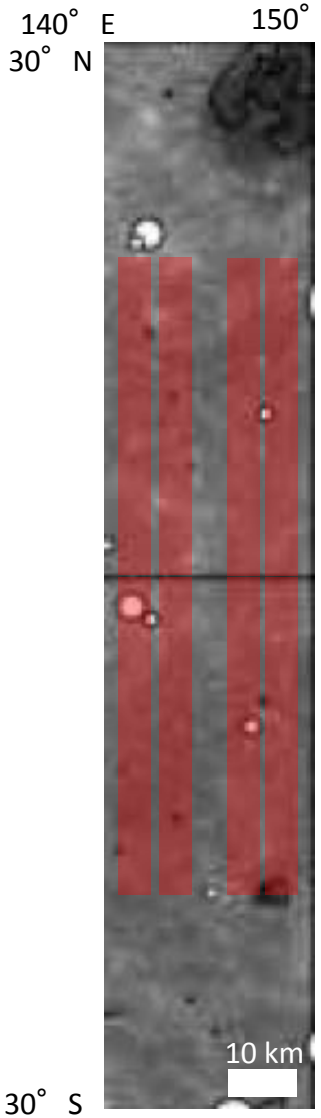


- OMAT values at the rim affect due to tiny fresh craters around a crater
- OMAT values also affect due to overlapped ejecta from a neighborhood rayed crater

➡ Eliminate such craters

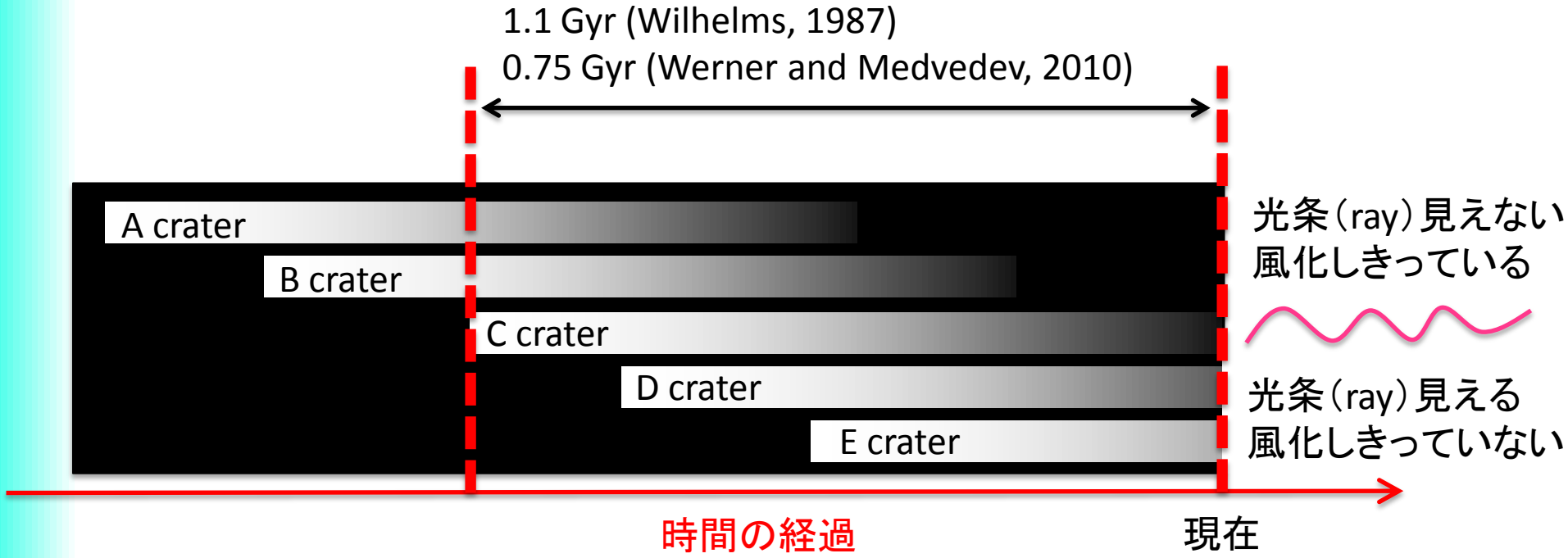
Comparison with Werner and Medvedev (2010)

- Our result obviously shows that there are more rayed craters in these areas than Werner and Medvedev (2010)
- We also strongly suggest that **retention time of rays is substantially longer than 750 Myr**



Werner and Medvedev (2010)

ポンチ絵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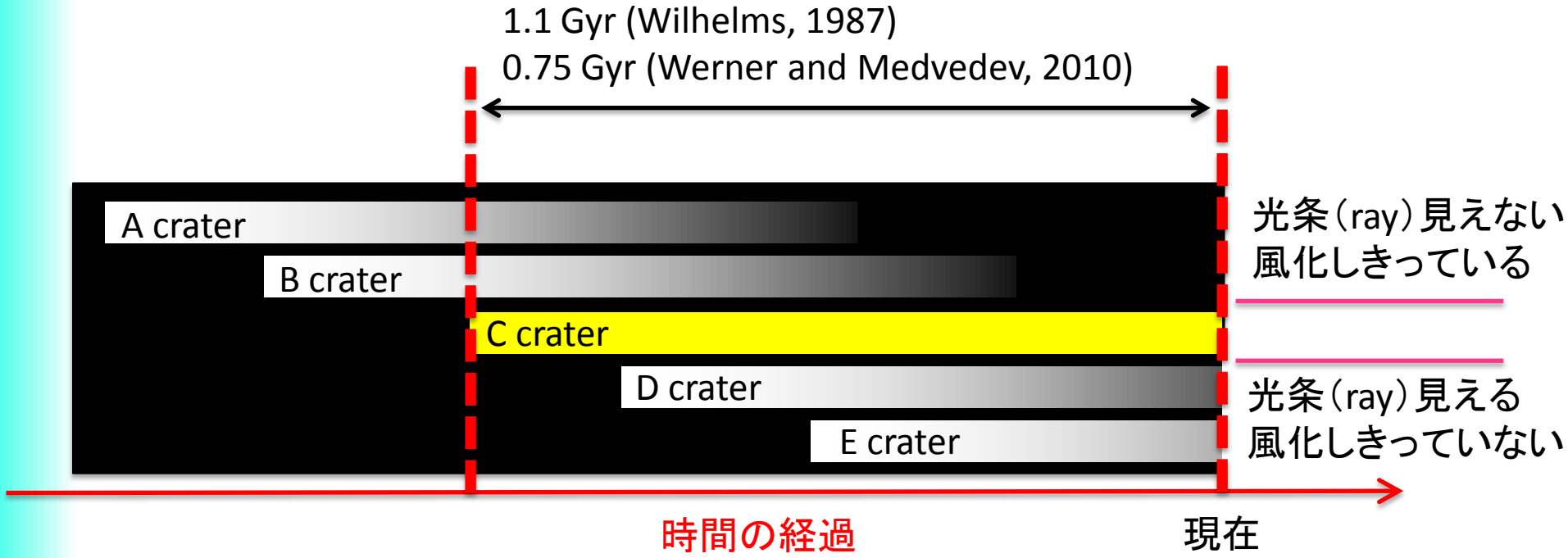
ポンチ絵

Clementine: 8 bit（過去研究）
Kaguya, MI: vis 10 bit, nir 12 bit



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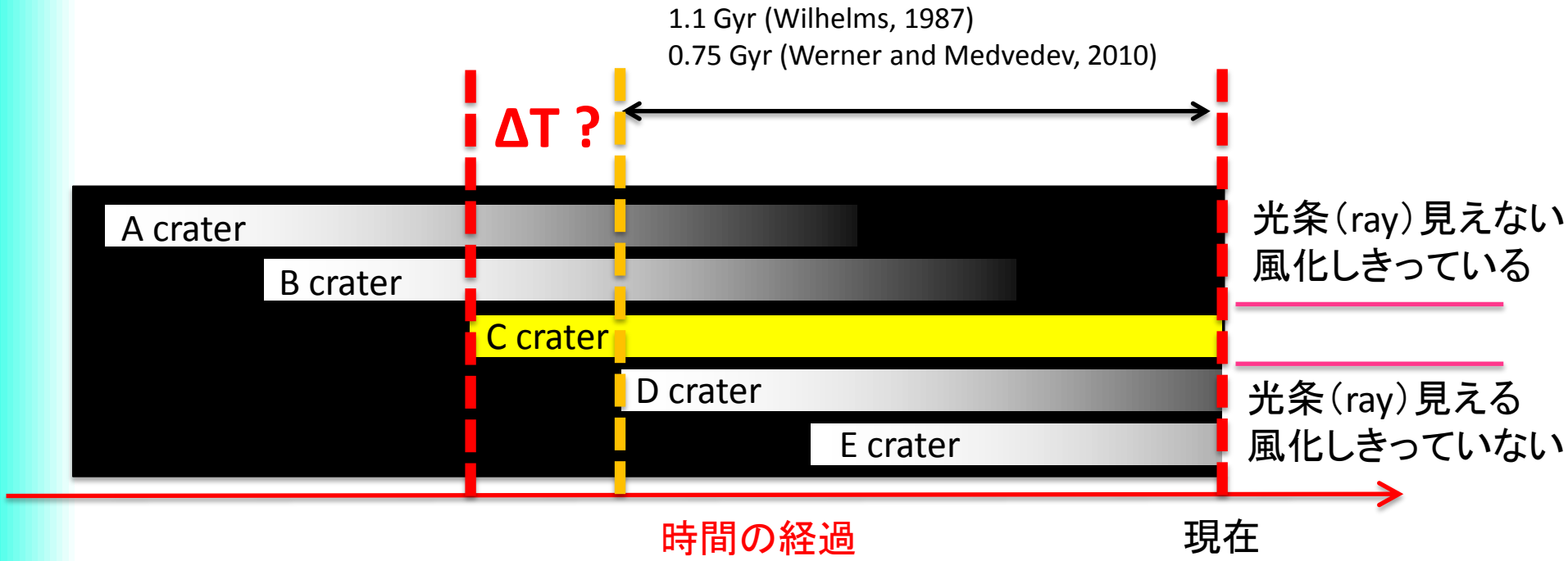

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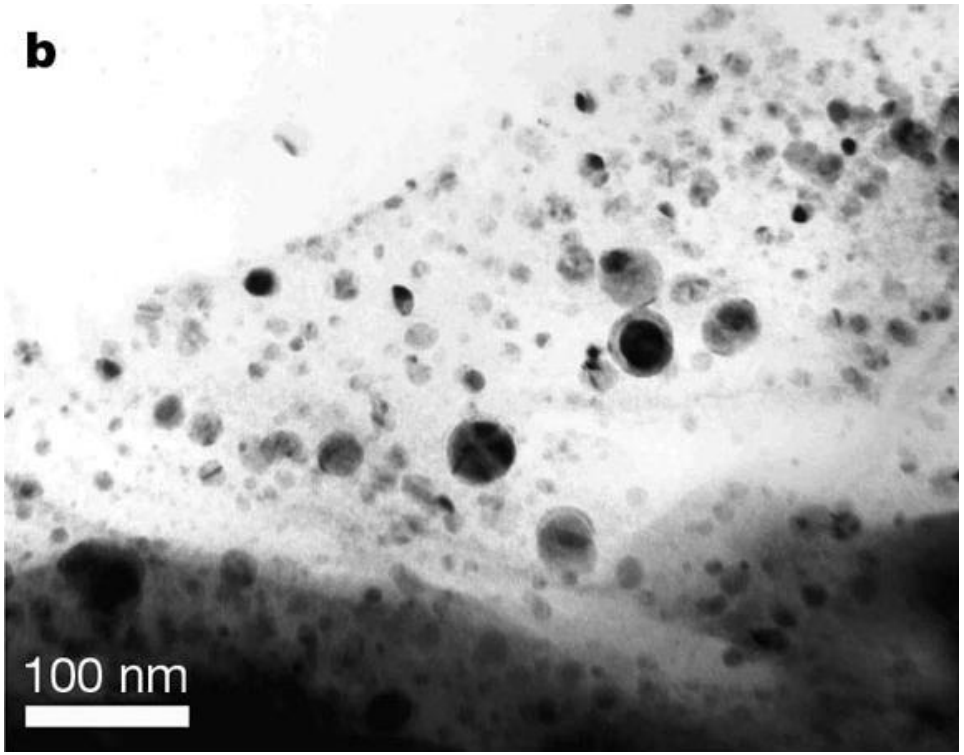
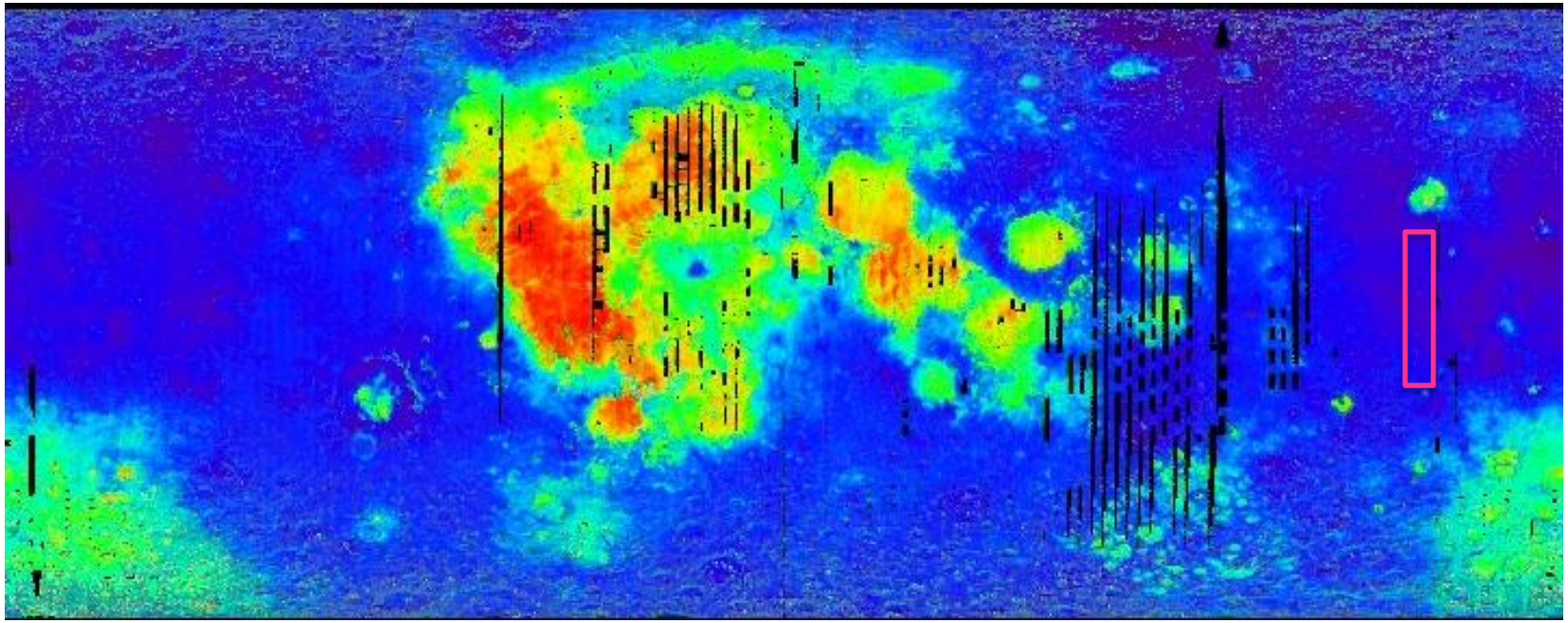


Sasaki et al. (2001)

Lunar Iron Map



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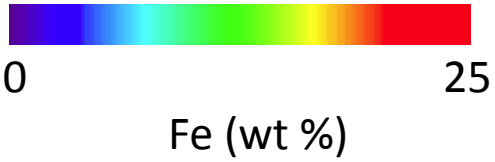
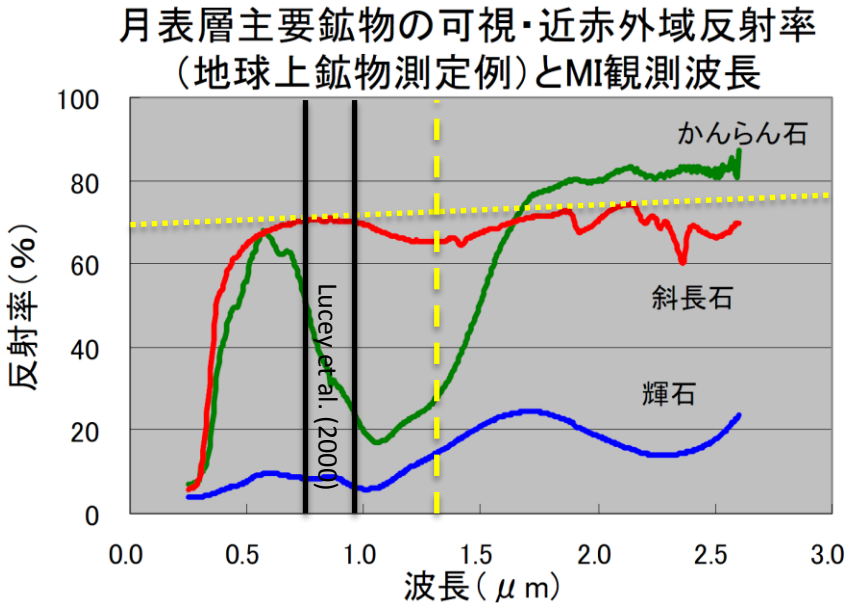


光学的成熟度

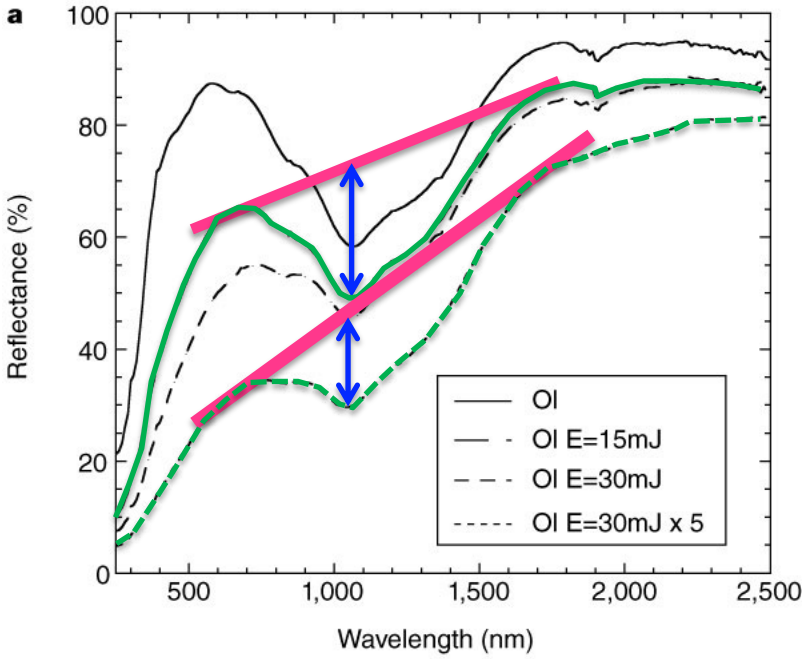
- OMATは反射率スペクトルの1000 nm付近の吸収の深さに着目したパラメータ
- そもそも月高地には、1000 nmに吸収を持つ鉱物（olivine、pyroxene）がほとんど含まれないため、OMATは不適当かもしれない
- OMAT以外に、スペクトルの傾きを利用した光学的成熟度を示すパラメータを作ってみるとよいかも

Space Weathering (2)

- Effects of space weathering
  - Darkening : Surface reflectance becomes low
  - Reddening : Visible range is darker than near infrared
  - Weakening of absorption band depths



大竹さんの講義ファイルより



Sasaki et al. (2001)

Conclusion

- OMAT is useful for ray detection
  - Need to investigate based on not only OMAT profile, but also OMAT map

- Retention time of rays
  - Longer than the previous results
  - Highly depending on crater size

  → Valuable information to understand mechanism of rays disappearance

Thank you for your kind attention.