Size-frequency statistics of boulders on global surface of asteroid 25143 Itokawa

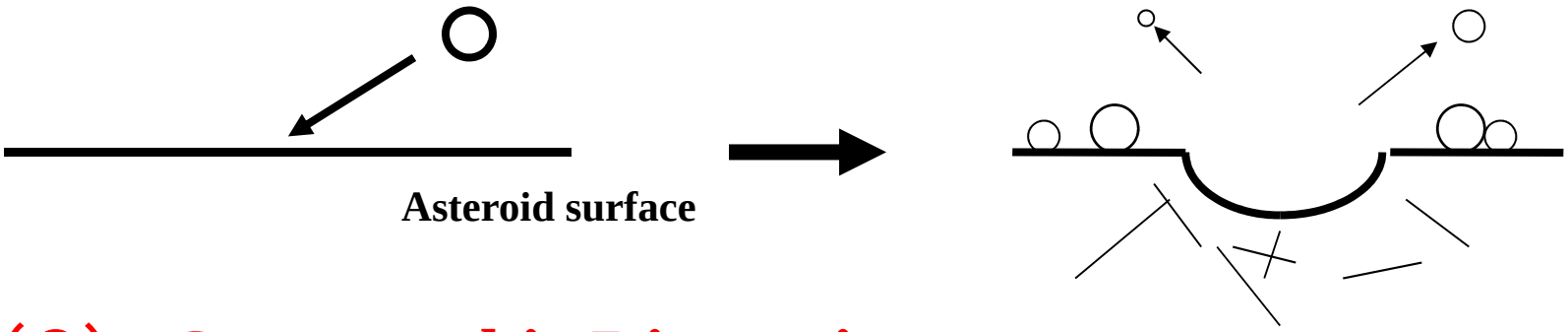
T. Michikami et al., (2008) Earth Planets Space, 60, 13-20.

Size-Frequency Statistics of Boulders

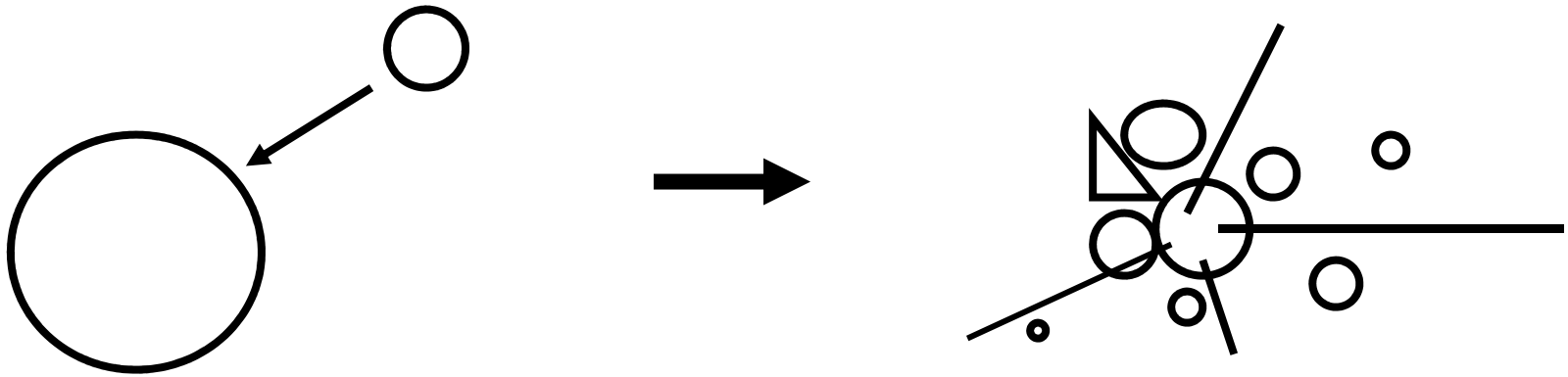
→ It reflects the history of an asteroid

Origin of a Boulder

（1） Cratering

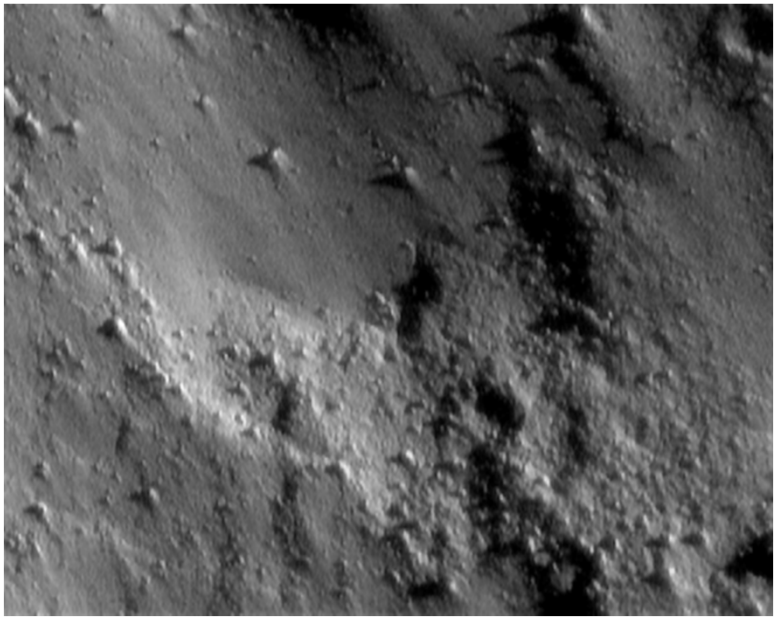


（2） Catastrophic Disruption



Surface of Itokawa

Surface of Eros



100m

Impact Crater Origin

The surface of Itokawa is covered with numerous boulders.

Can we explain these boulders originated from the craters ?

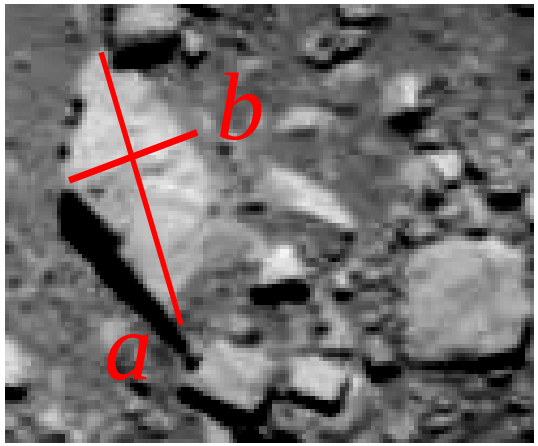
◆Purpose

In order to examine the origin of boulders on the surface of Itokawa, we investigate the size-frequency statistics of the boulders and compare the observed number with the calculated value using a model based on impact cratering experiments.

◆Analysis

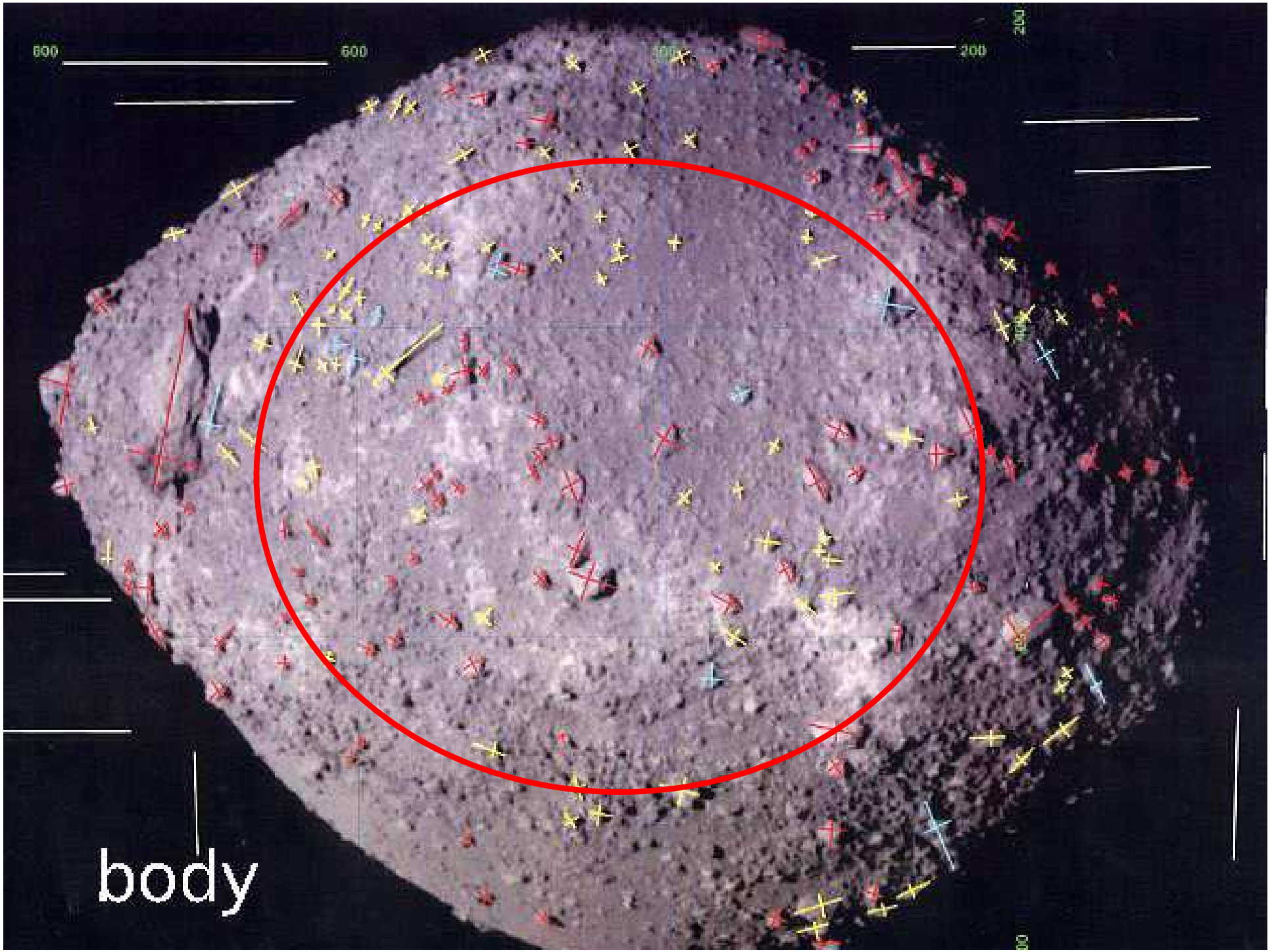
Global mapping of boulders with size of 5-30m

Eight images acquired from AMICA data,
19-26th, October 2005
(1pixel ~ 0.4 m)



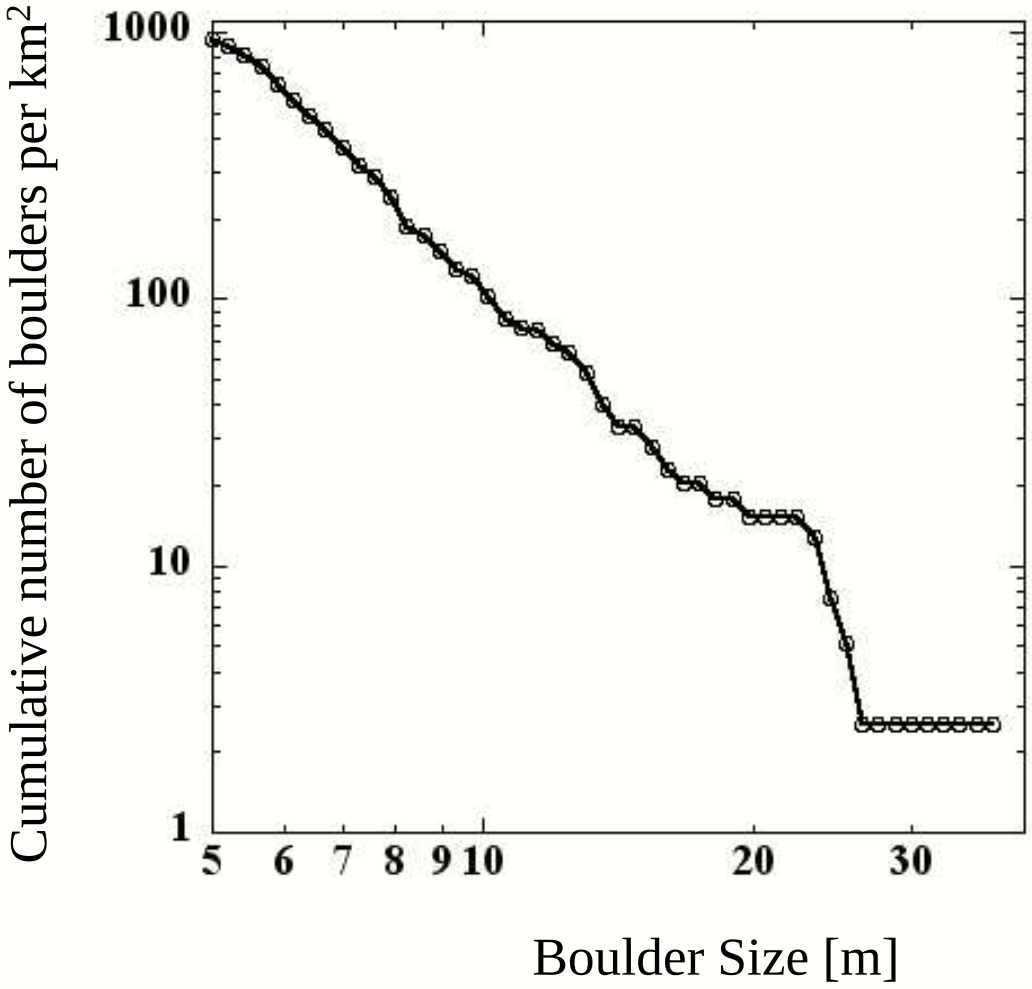
- Positive relief feature is defined as boulder.

- We have measured the apparent axes *a* and *b*, which represent the maximum dimensions of the boulder in two orthogonal planes ($a \geq b$).


600
600
200
200
body

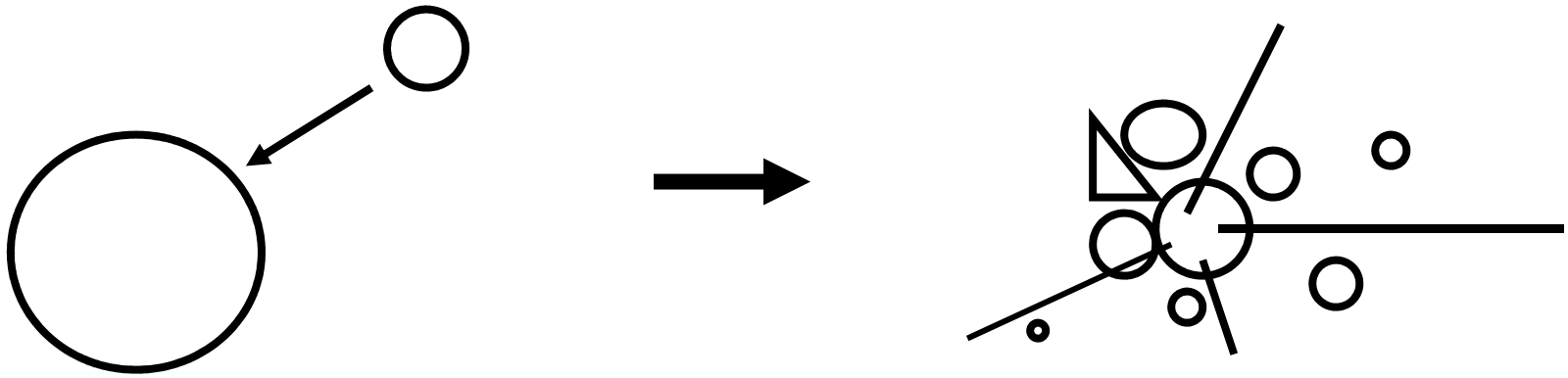
◆ Size distribution of boulders (>5m)

The number density of boulders of Itokawa is larger than that of Eros.

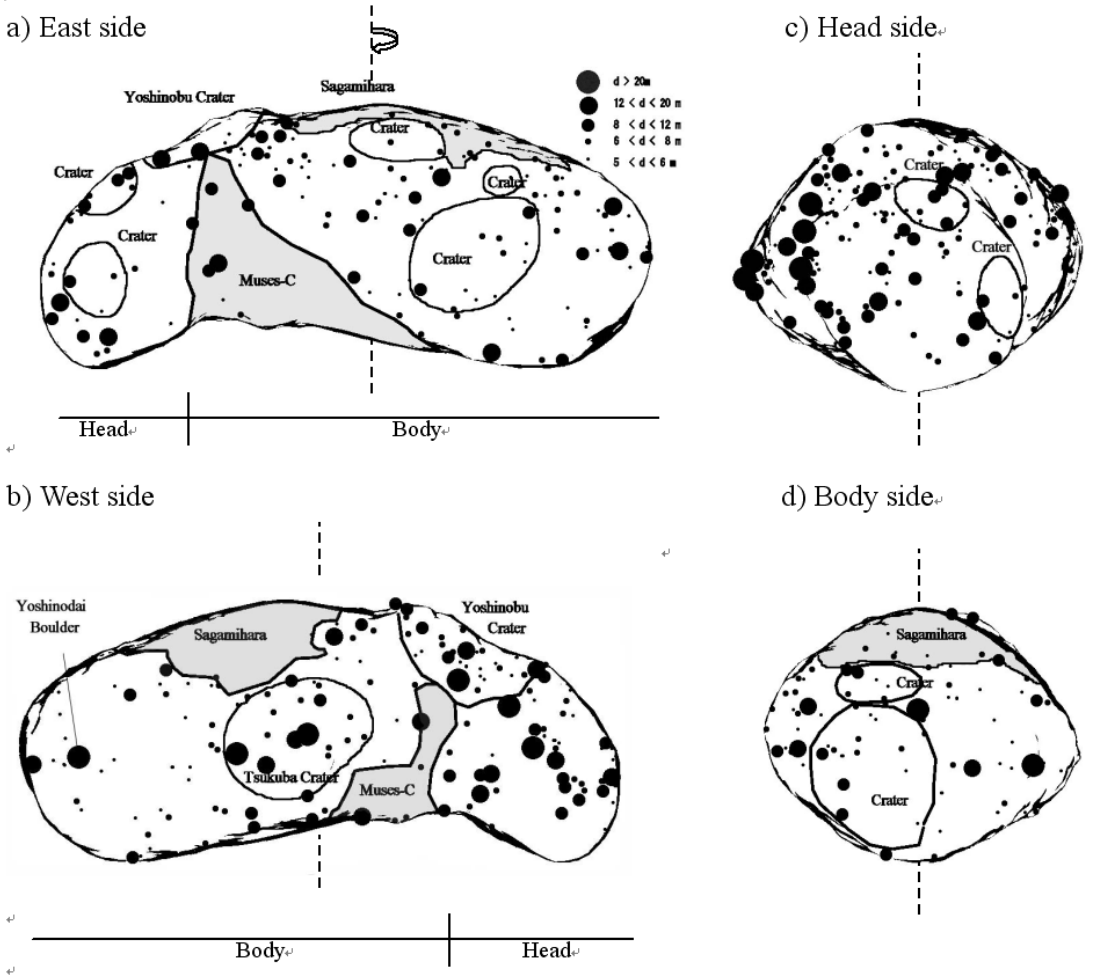


Boulders of Itokawa would be produced by the disruption of the larger parent body.

Catastrophic Disruption



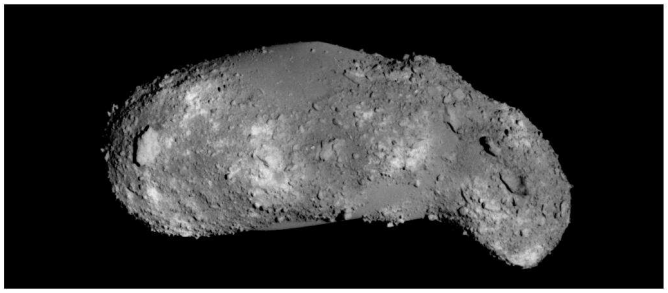
Relation between craters and boulders



The boulders on Itokawa exist regardless of the position of the craters.

Largest Boulder

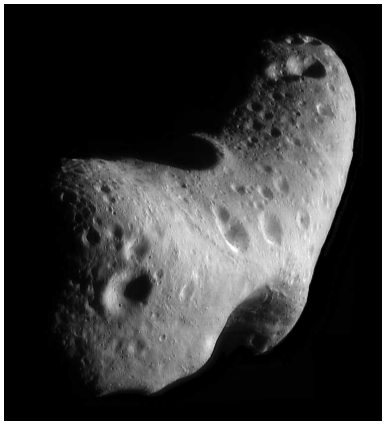
Itokawa



Largest Boulder 40 m

Largest Crater 134 m

Eros

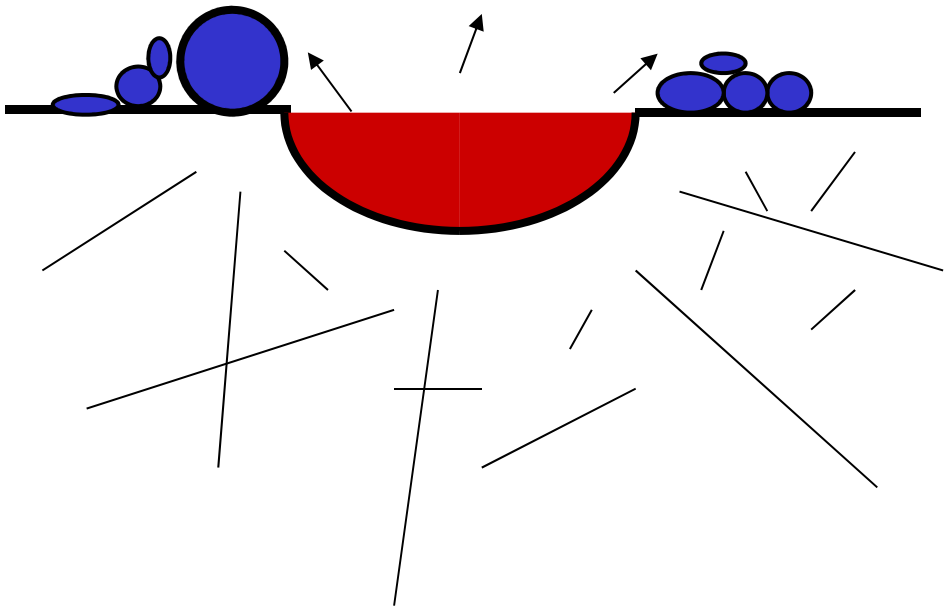


Largest Boulder 130 m

Largest Crater 5500 m

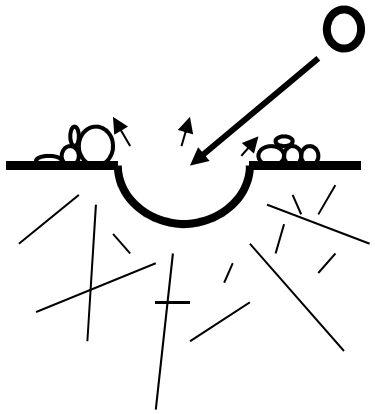
On Itokawa, there are extremely large boulders relative to the size of the largest craters.

The ratio of the the total volume of the boulders to the total excavated volume of the craters on Itokawa is ~ 25%, which is extremely higher than those of Eros (< 1%) and Moon (~5%).



◆Model (Michikami et al.2008)

The number of boulders was estimated by a model based on impact cratering experiments.



The fraction of depositing ejecta mass to total ejecta mass was estimated from laboratory experiments (Michikami et al. 2007).

Result : The estimated number of boulders (>5m) is less than several tens, which is much smaller than the observed number (373).

◆Summary

The numerous boulders on Itokawa cannot solely be produced from the impact craters.

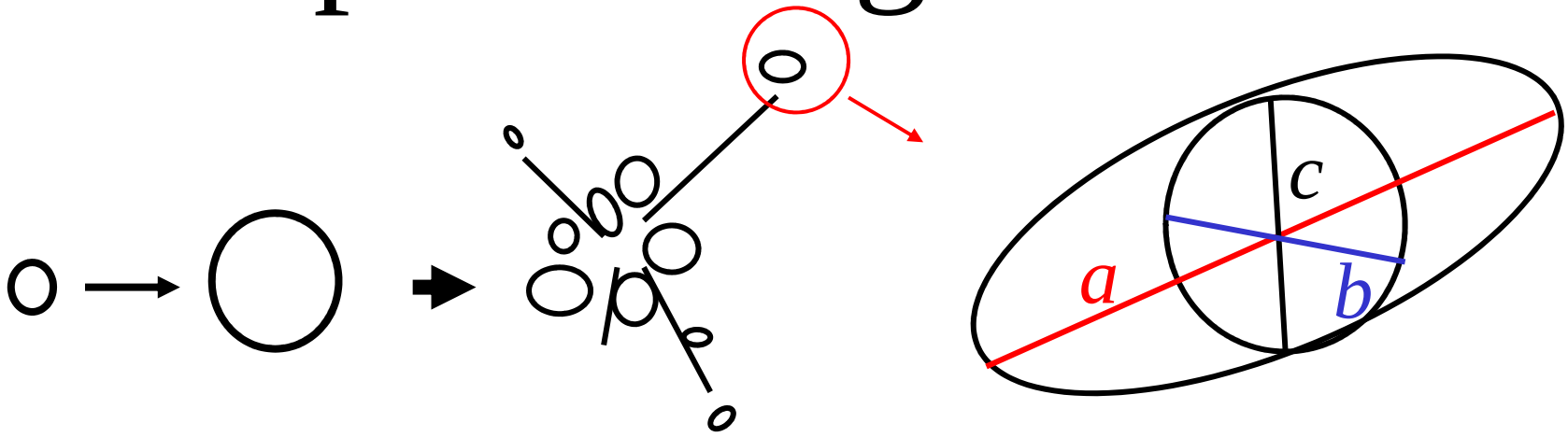
↓

Boulders of Itokawa would be produced by the disruption of the larger parent body.

The axial ratios of boulders on asteroid 25143 Itokawa: Comparison with fragments from impact experiments.

T. Michikami, A. M. Nakamura, N. Hirata. “The shape distribution of boulders on asteroid 25143Itokawa: Comparison with fragments from impact experiments”. ***Icarus.*** 207, 277-284. 2010.

◆Shape of Fragments



Laboratory Impact Experiment

Size ~ less than 0.1 m

$b / a \sim 0.7$

$c / a \sim 0.5$

=

Axial Ratio (mean)

$a : b : c = 2 : \sqrt{2} : 1$

(Fujiwara et al. 1978, Capaccioni et al. 1984, Bianchi et al. 1984)

◆Shape of small asteroid

Mathilde Gaspra Ida Eros Itokawa

Light curve observation

(Catullo et al. 1984, Binzel et al. 1989, Harris and Pravec 2007)

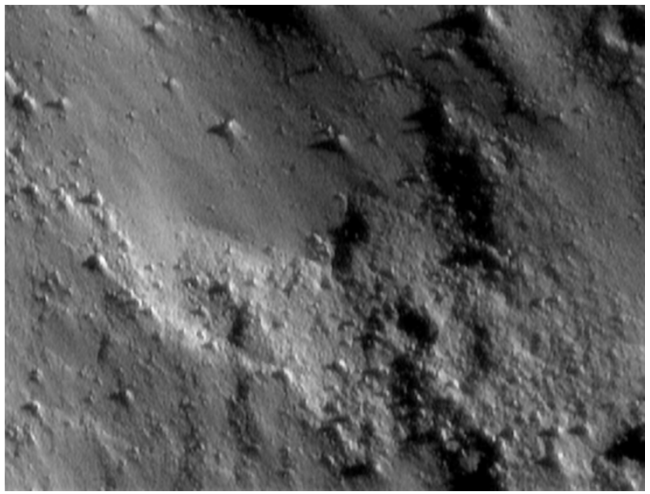
The shape of small asteroid with size of **10^2 – 10^4 m**

||

The shape of fragments in laboratory impact experiments

◆Boulders on asteroids

Surface of Eros



100m

The number of boulder (>15m) is 6760. (Thomas et al. 2001)

Surface of Itokawa

The number of boulder (>5m) is 373. (Michikami et al. 2007)

Numerous boulders were discovered.

→ We can estimate the shape distribution of fragments with size of **0.1- 100 m.**

◆Purpose

In order to investigate whether the shape distribution of boulders is similar to that of the fragments in laboratory impact experiments,
we report the shape distribution of boulders with size of 10^{-1} to 10^{2} m on the surface of Itokawa.

	Size[m]
Fragments in laboratory	10^{-4}-10^{-1}
Boulders on asteroids	10^{-1}-10^{2}
Small asterorids	10^{2}-10^{4}

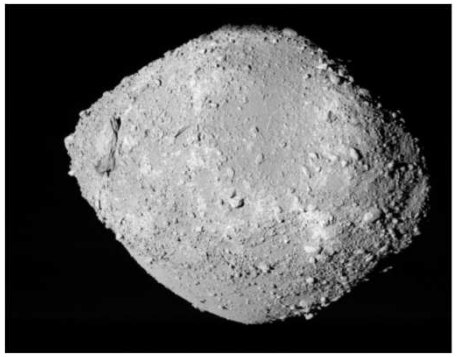
◆Analysis

(I) Global mapping of boulders with size of 5-30m

Eight images acquired from AMICA data, 19-26th, October 2005 (1pixel ~ 0.4 m)

(I) Global mapping of boulders with size of 5-30m

Eight images acquired from AMICA data, 19-26th, October 2005
(1pixel ~ 0.4 m) Distance from Itokawa 3.78-4.91km



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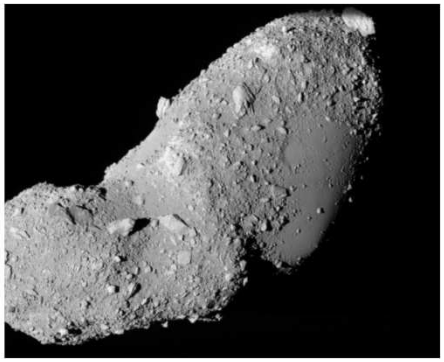

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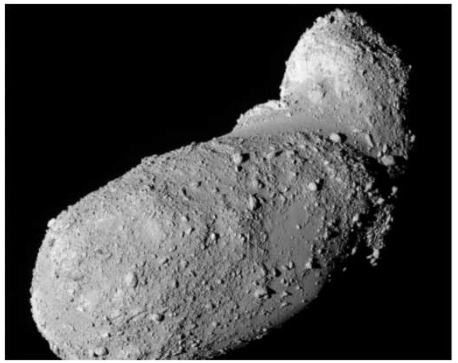

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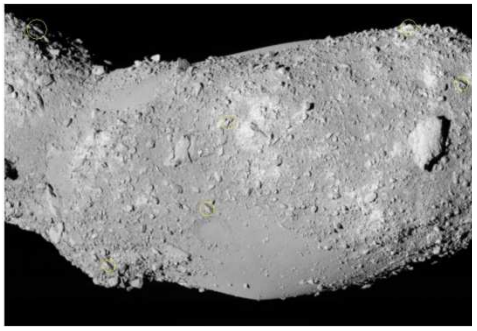

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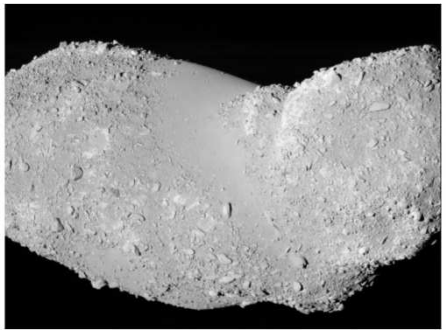

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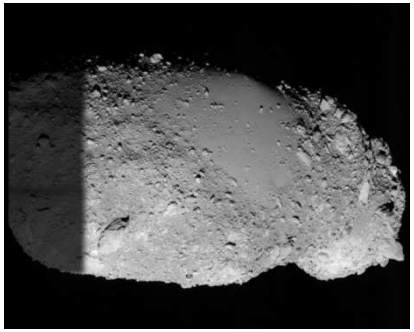

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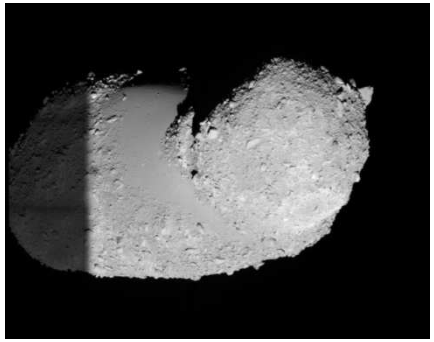


ST2473604354

◆Analysis

(I) Global mapping of boulders with size of 5-30m

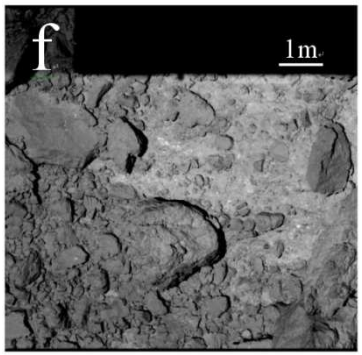
Eight images acquired from AMICA data,
19-26th, October 2005 (1pixel ~ 0.4 m)

(II) Small boulders with size of 0.1-5m

Six close-up images acquired from AMICA data, 9-12th,
November 2005 (1pixel ~ 0.6–6 cm)

(II) Small boulders with size of 0.1-5m

Six close-up acquired from AMICA data, 9-12th,
November 2005 (1pixel ~ 0.6–6 cm) Distance from Itokawa 60-600 m



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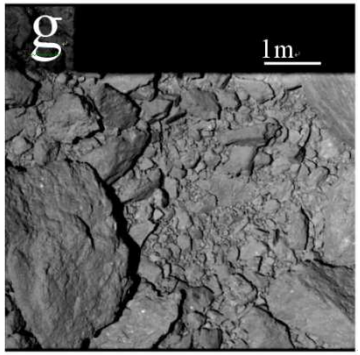

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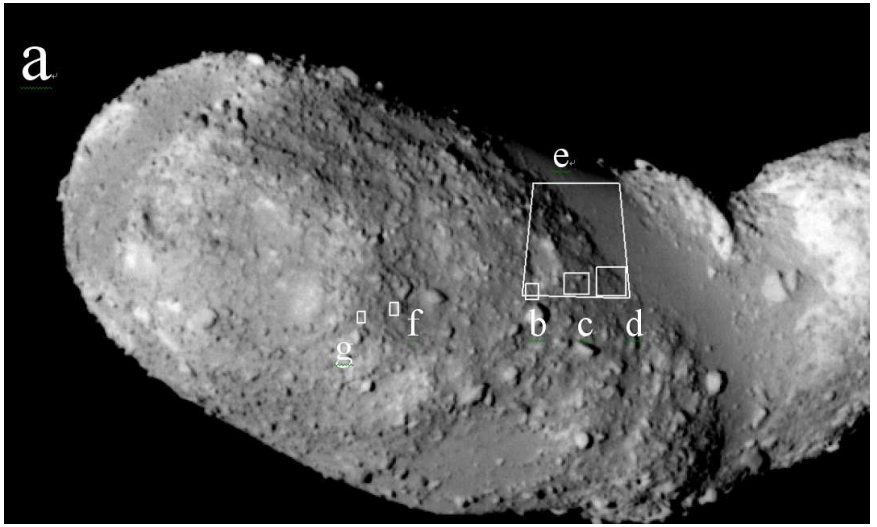

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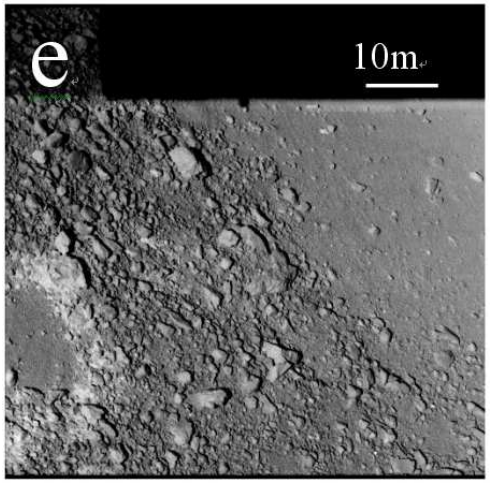

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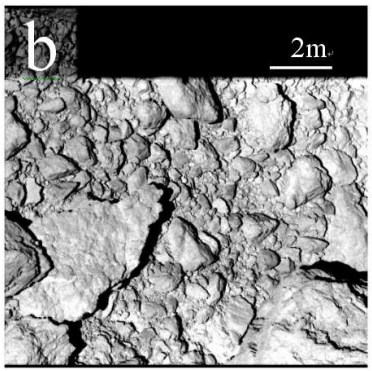
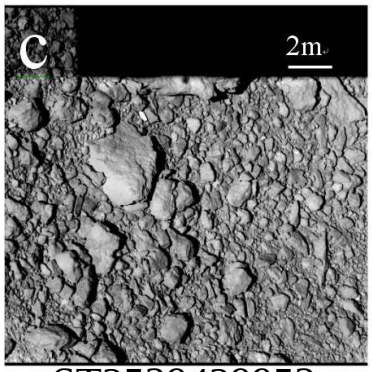


ST2539437177



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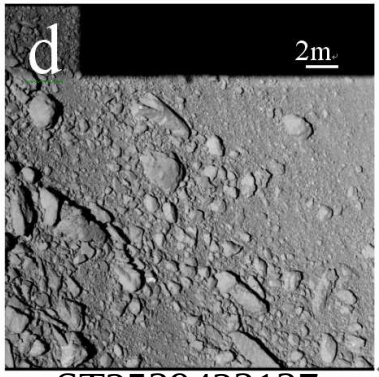
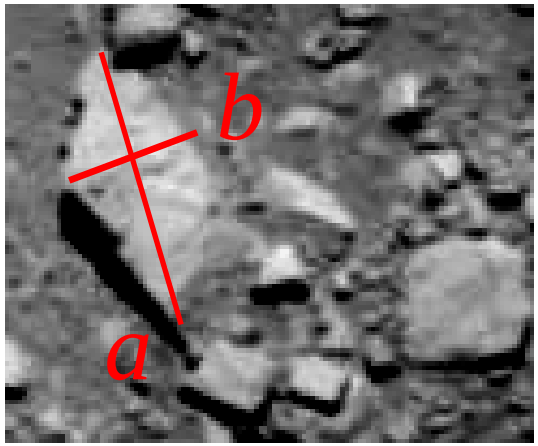


ST2539423137

◆Analysis



(I) Global mapping of boulders with size of 5-30m

Eight images acquired from AMICA data, 19-26th, October 2005 (1pixel ~ 0.4 m)

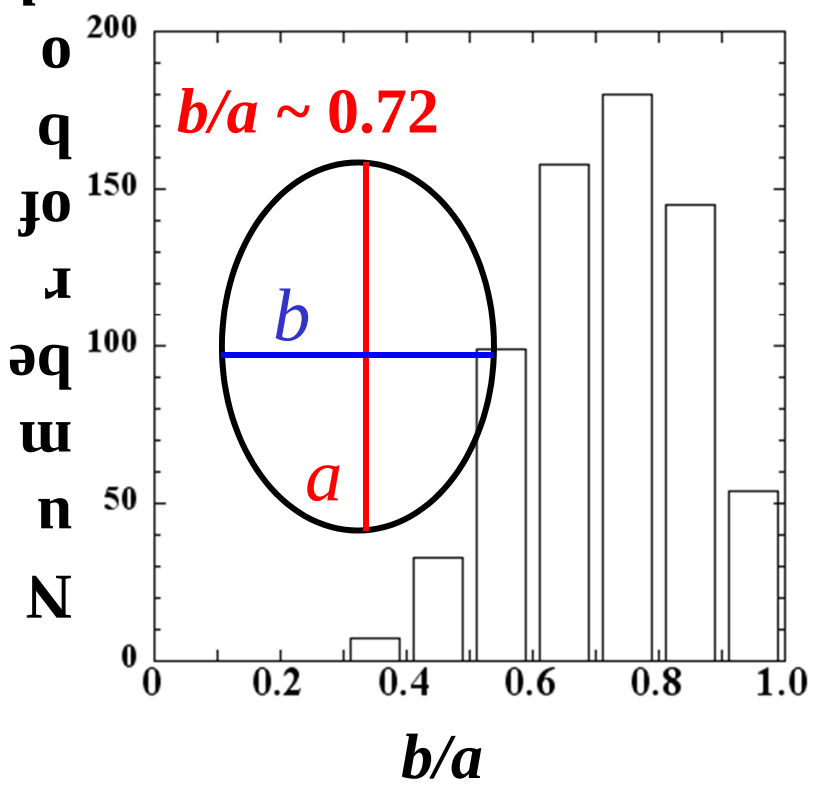
(II) Small boulders with size of 0.1-5m

Six close-up acquired from AMICA data, 9-12th, November 2005 (1pixel ~ 0.6–6 cm)

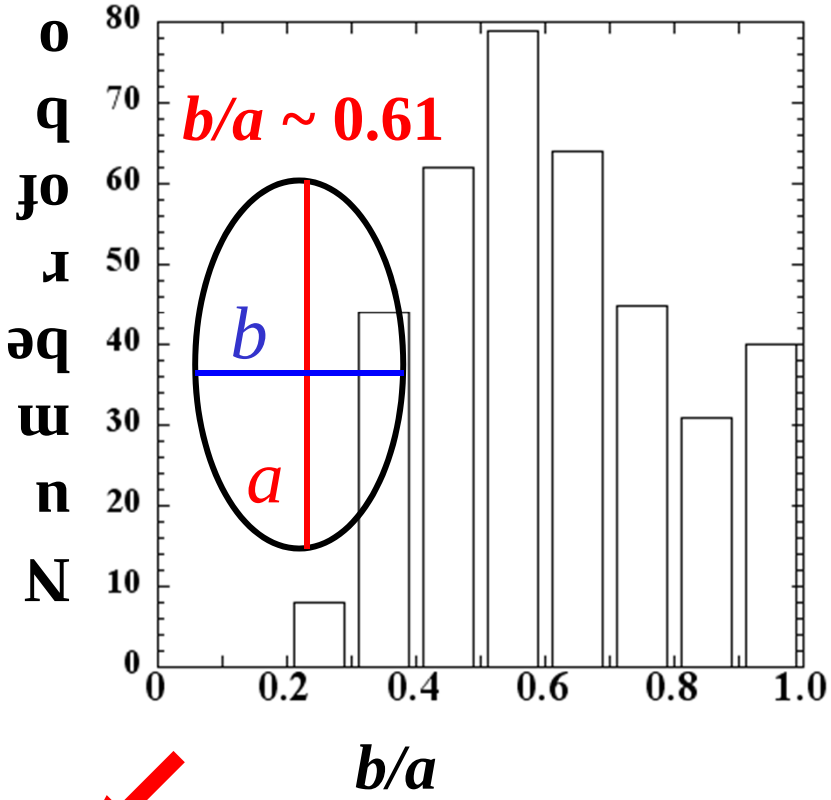
- Positive relief feature is defined as boulder.
- We have measured the apparent axes a and b, which represent the maximum dimensions of the boulder in two orthogonal planes ($a \geq b$).

The shape distribution of boulders

Fragment (<0.1m) in laboratory



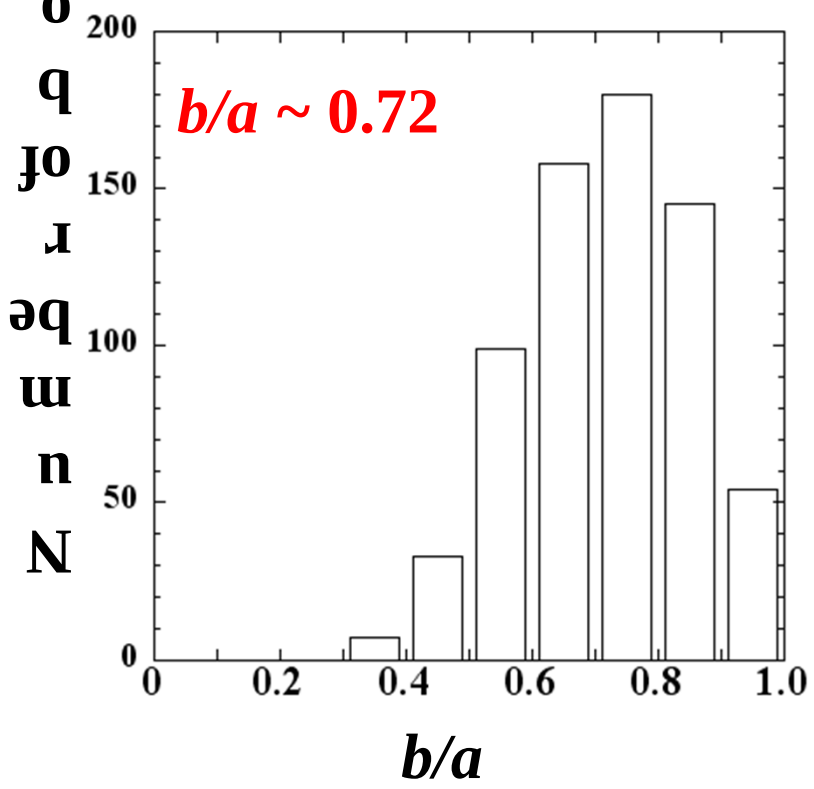
Boulder (5-30m) of Itokawa



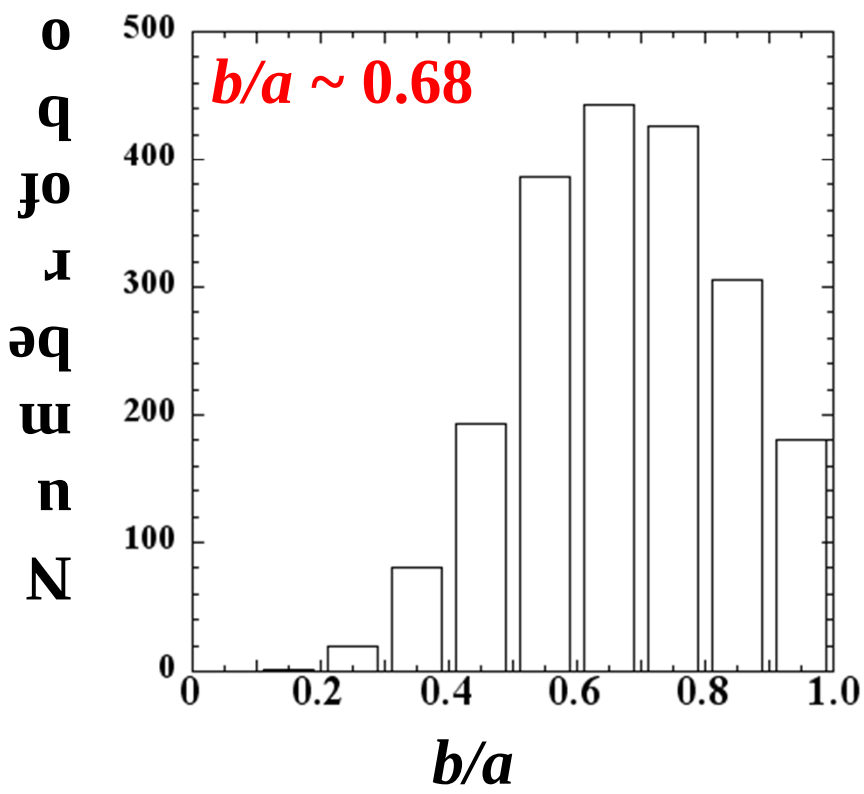
It looks like the typical boulders of Itokawa have more elongated shapes as compared with that of fragments in laboratory.

The shape distribution of small boulders

Fragment (<0.1m) in laboratory



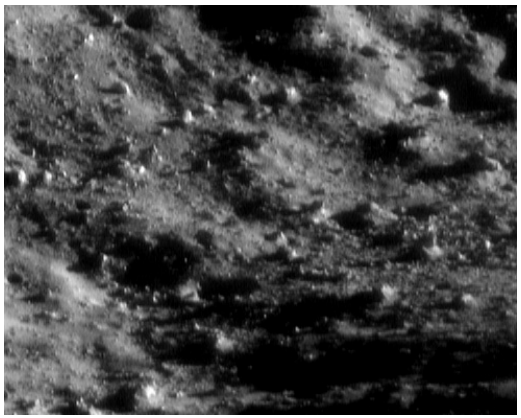
Boulder (0.1-5 m) of Itokawa



The boulder of Eros

Boulder (60-220 m)

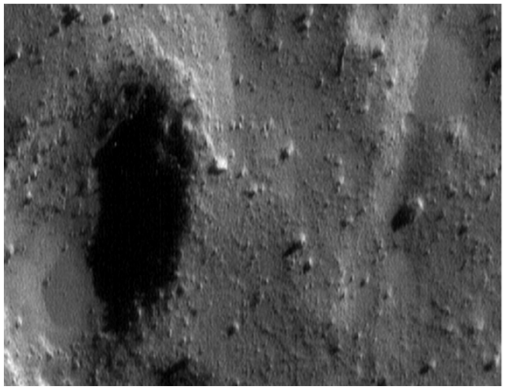
[Image ID 015313598] Rim of Saddle region



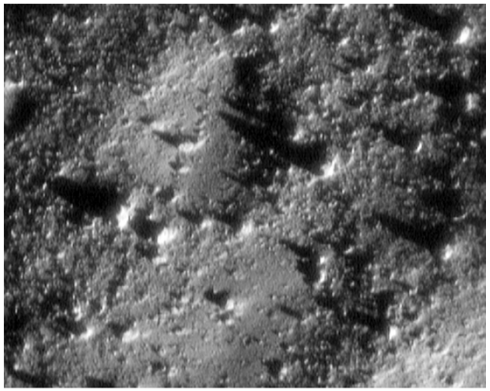
1.5km

Boulder (4-17 m)

[Image IDs 0156087736, 015588661]



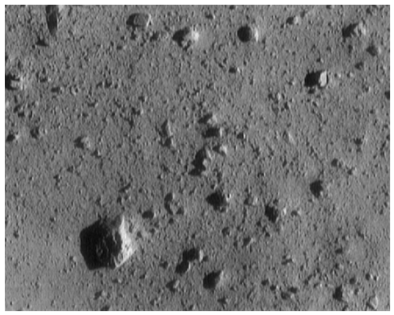
230m



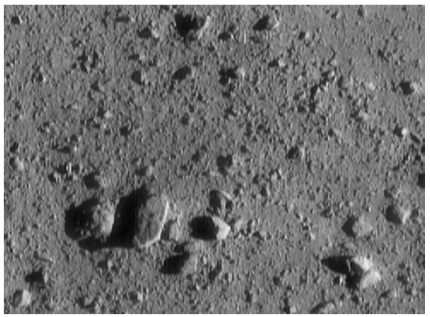
230m

Boulder (0.1-4 m)

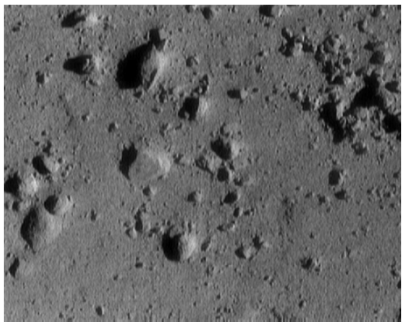
[Image IDs 0157417133, 0157417198, 0157417593] Four close-up Images



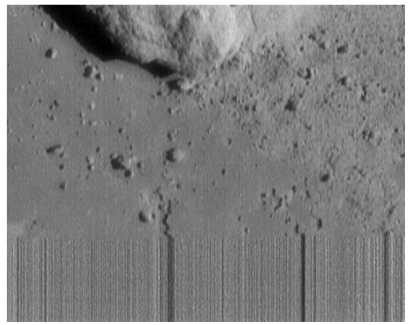
54m



33m



12m

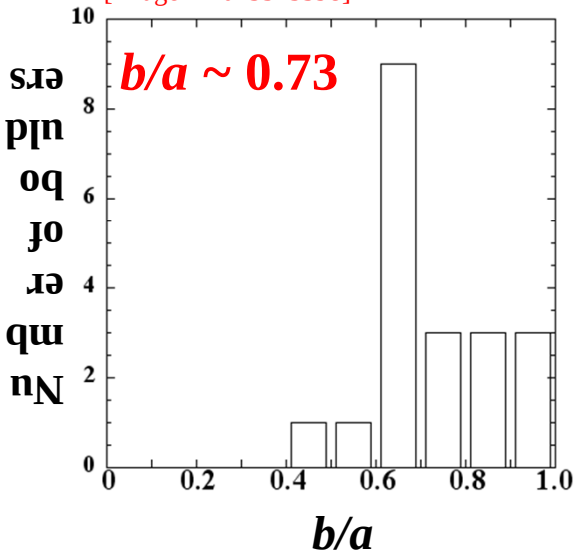


6m

◆The shape distribution of boulders (Eros)

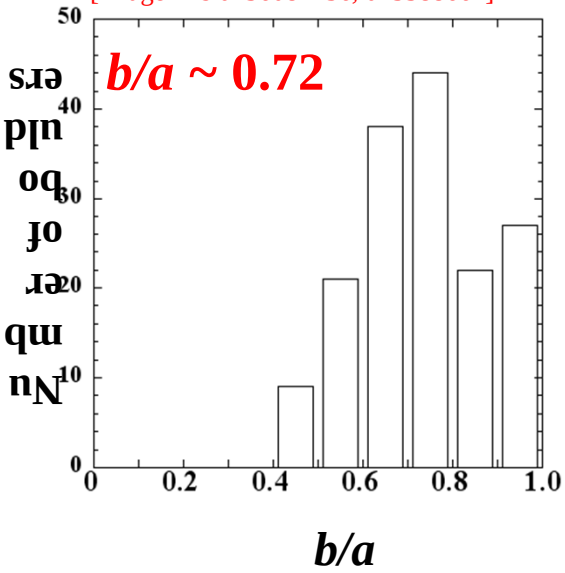
Boulder (60-220 m)

[Image ID 015313598]



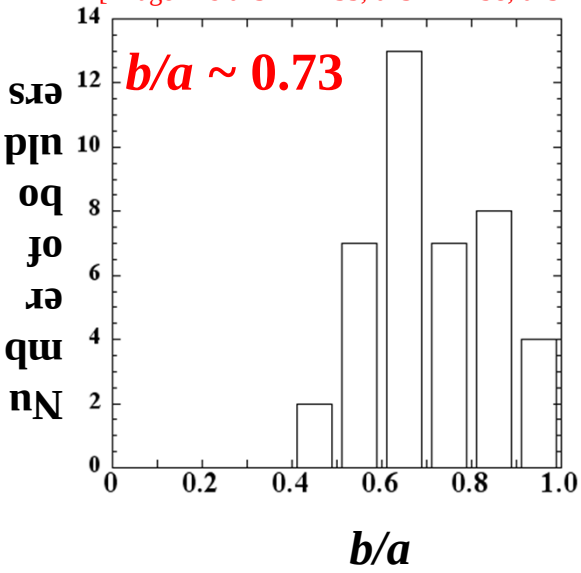
Boulder (4-17 m)

[Image IDs 0156087736, 015588661]



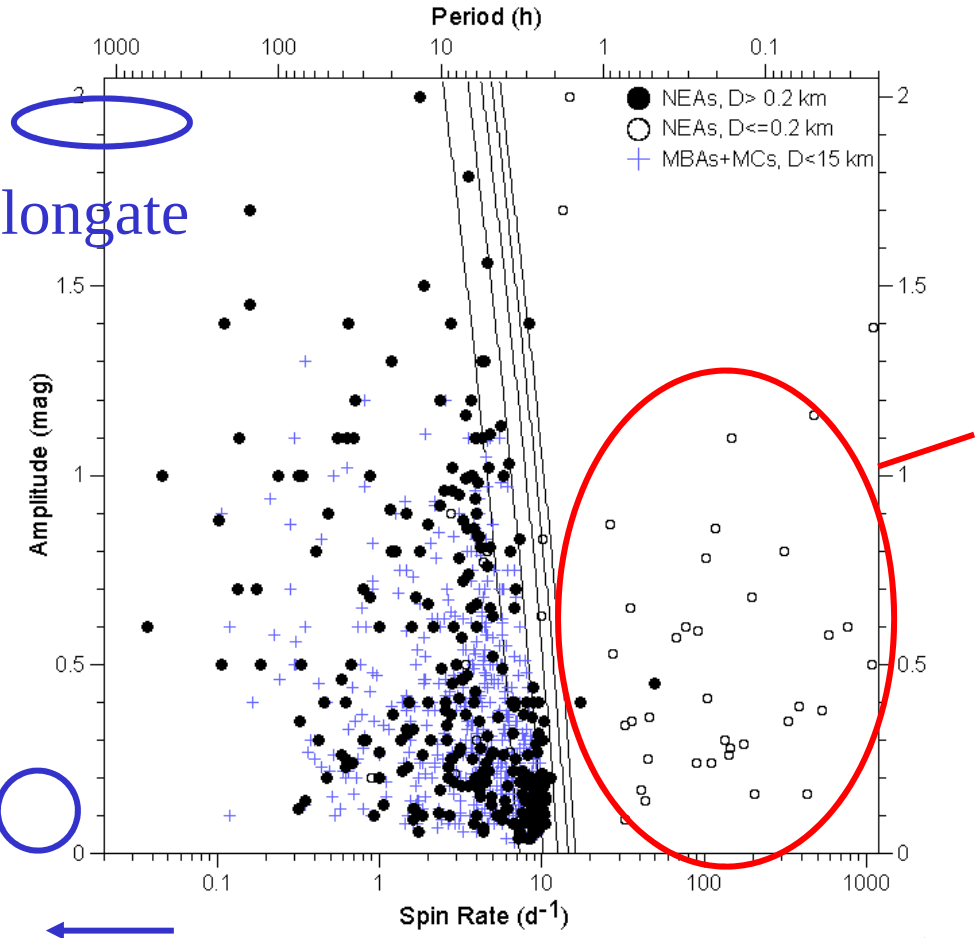
Boulder (0.1-4 m)

[Image IDs 0157417133, 0157417198, 0157417593]



The apparent mean axial ratios of Eros's boulders are similar to that of fragments in laboratory.

Shape distribution of small and fast-rotation asteroids
(diameter < 200m and rotation period <1hr)



more elongate

circle

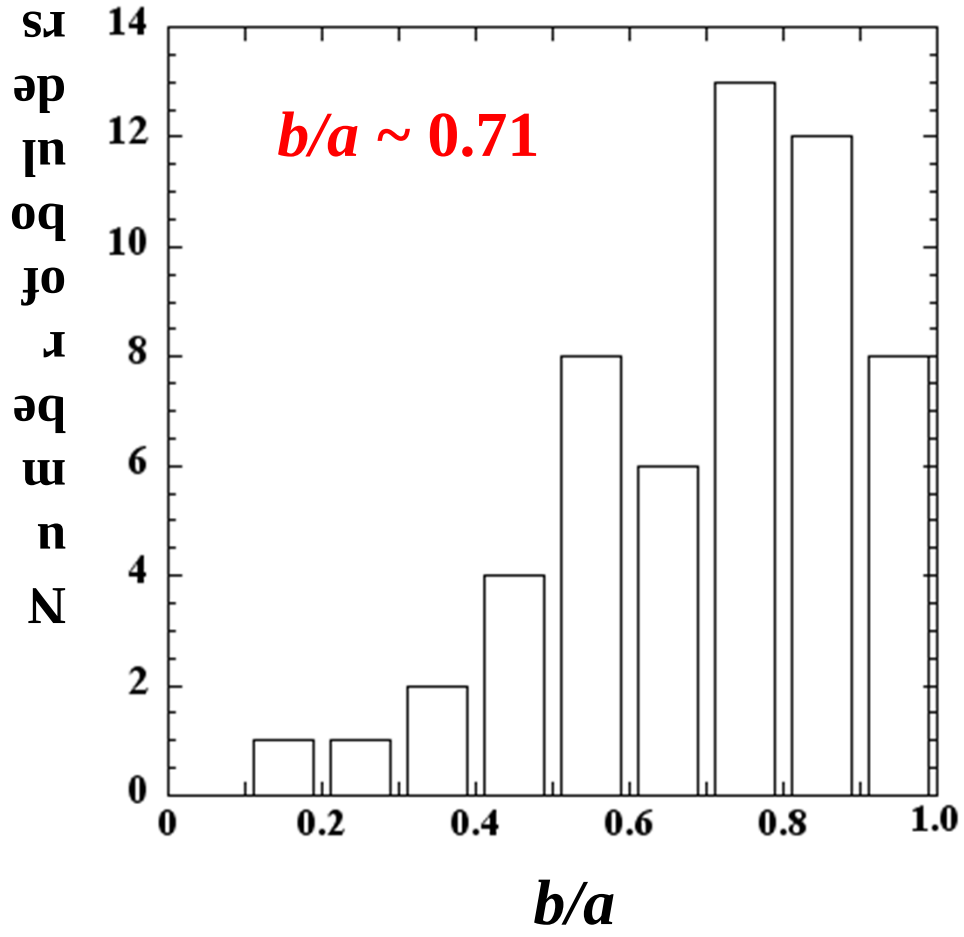
slow-rotation

fast-rotation

According to Holsapple 2007, these asteroids are monolithic bodies generated by impact cratering or catastrophic disruption of the parent asteroids.

Small and fast-rotation asteroids

(diameter < 200m and rotation period < 1hr)



The shape distribution of small and fast-rotation asteroids is similar to that of fragments in laboratory.

◆Summary

The apparent mean axial ratios (*b/a*) of boulders are

	Counted Number	Size Range	Axial ratio
Itokawa	(373)	5-30m	0.61 (±0.19)
Itokawa	(2033)	0.1-5m	0.68 (±0.16)
Eros	(20)	60-220m	0.73 (±0.17)
Eros	(41)	4-17m	0.72 (±0.14)
Eros	(163)	0.1-4m	0.73 (±0.15)
Small asteroids	(42)	< 200 m	0.71 (±0.19)
(Laboratory		< 0.1m	0.72 (±0.12))

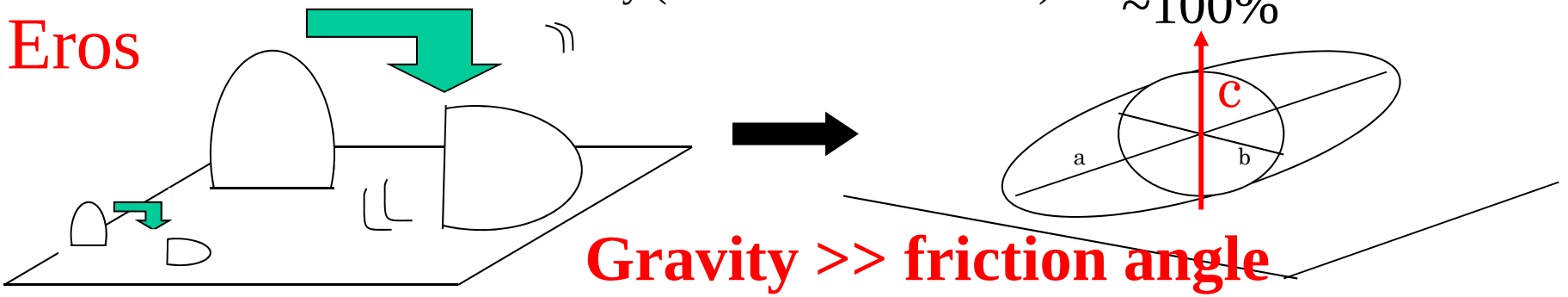
It looks like the typical boulders of Itokawa have more elongated shapes compared with that of fragments in laboratory. → Why???

◆Discussion

One possibility is that, the actual shape distribution of the boulders on Itokawa is similar to that of the fragments in laboratory.

Seismic activity (Richardson et al. 2005)

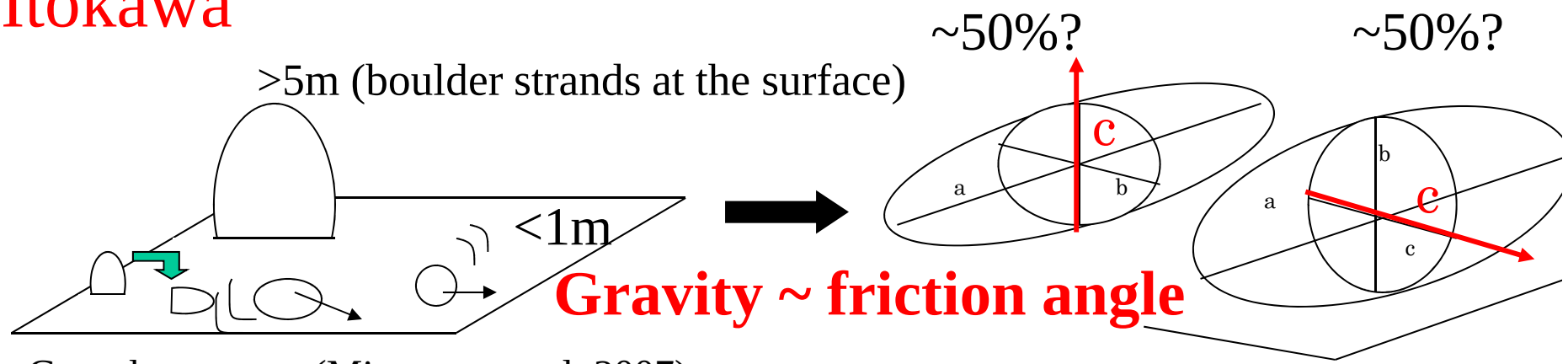
Eros



Gravity >> friction angle

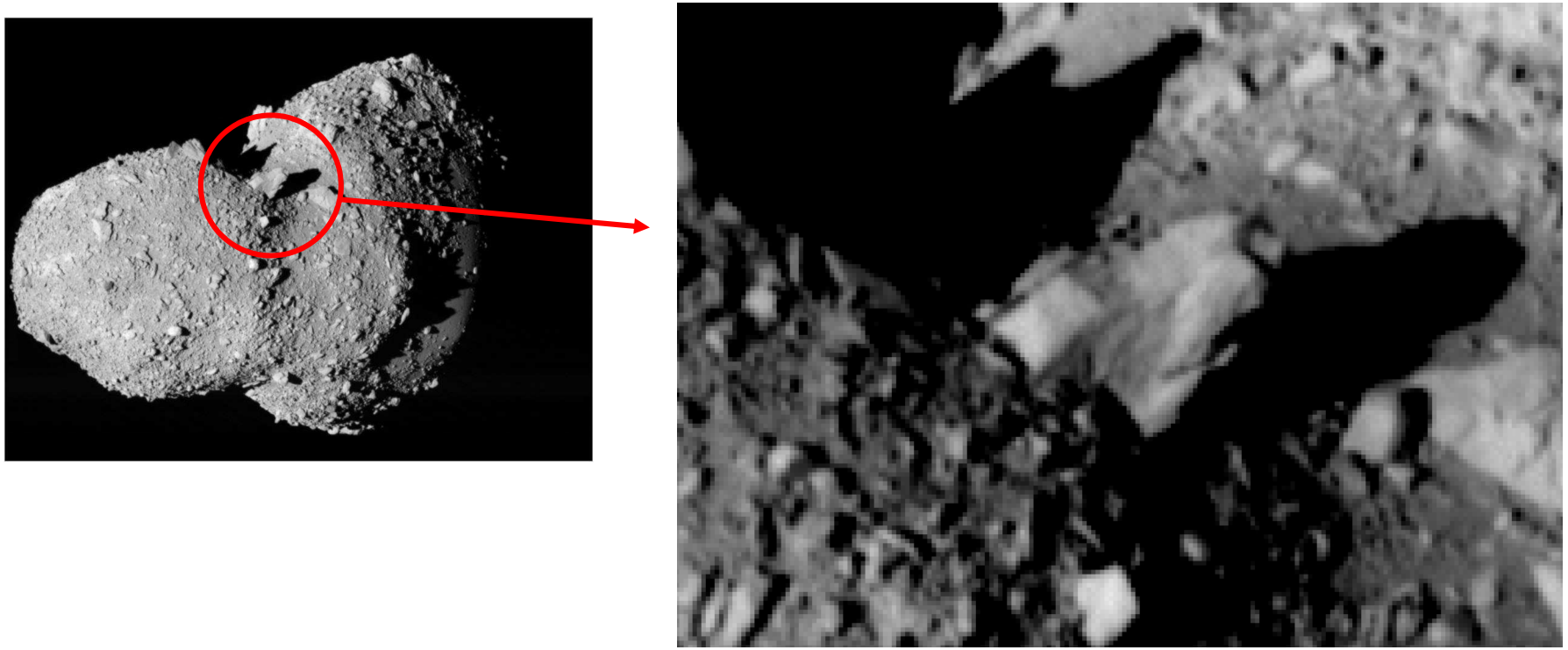
Itokawa

>5m (boulder strands at the surface)

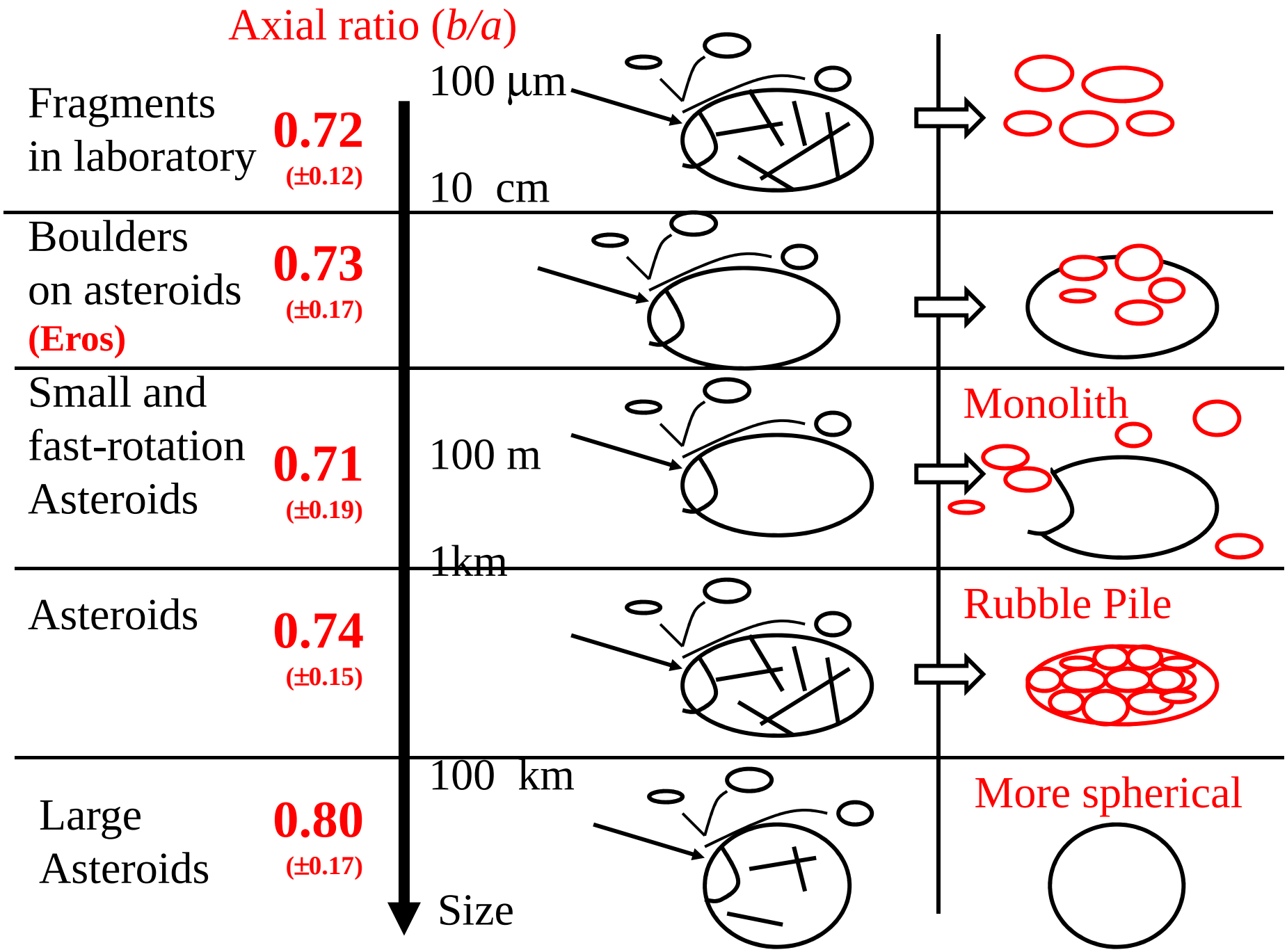


Gravity ~ friction angle

Granular process (Miyamoto et al. 2007)



This large boulder is even taller than they are wide, which is a rather unstable orientation.


Axial ratio (b/a)
Fragments in laboratory
0.72
(±0.12)
100 μm
10 cm
Boulders on asteroids
(Eros)
0.73
(±0.17)
Small and fast-rotation Asteroids
0.71
(±0.19)
100 m
1km
Monolith
Asteroids
0.74
(±0.15)
Rubble Pile
100 km
Large Asteroids
0.80
(±0.17)
More spherical
Size