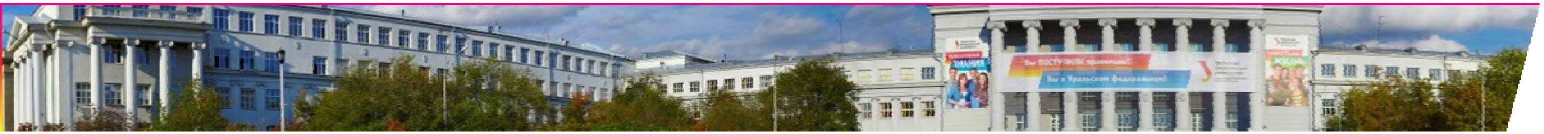
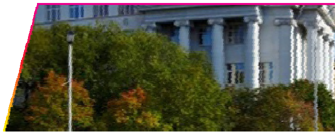
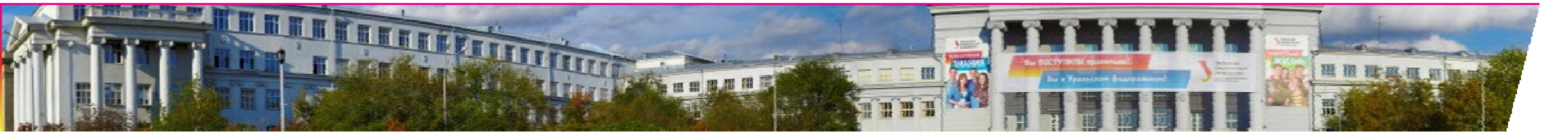


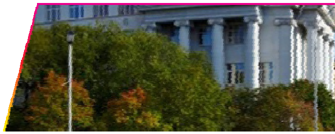


Состав, строение и физические свойства малых тел Солнечной системы, сближающихся с Землей

В.И.Гроховский

Уральский федеральный университет, г.Екатеринбург





Способы получения данных:

- ❑*Дистанционные наблюдения с Земли*
- ❑*Дистанционные наблюдения в космосе*
- ❑*Посадка на астероиды*
- ❑*Доставка внеземного вещества на Землю*
- ❑*Лабораторные исследования*

Имеется на Земле:

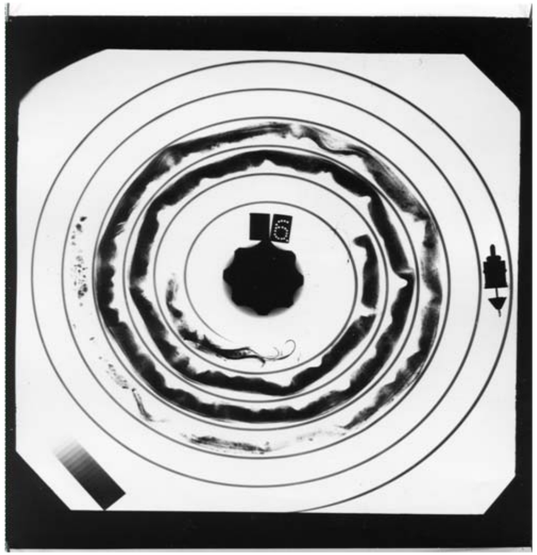
- ✓*Лунный грунт АМС Луна, КК Apollo*
- ✓*Миссии STARDUST, HAYABUSE*
- ✓*Космическая пыль*
- ✓***метеориты***

Миссия	Масса	Год
Аполлон-11	22 кг	1969
Аполлон-12	34 кг	1969
Аполлон-14	43 кг	1971
Аполлон-15	77 кг	1971
Аполлон-16	95 кг	1972
Аполлон-17	111 кг	1972
Итого	382 кг	

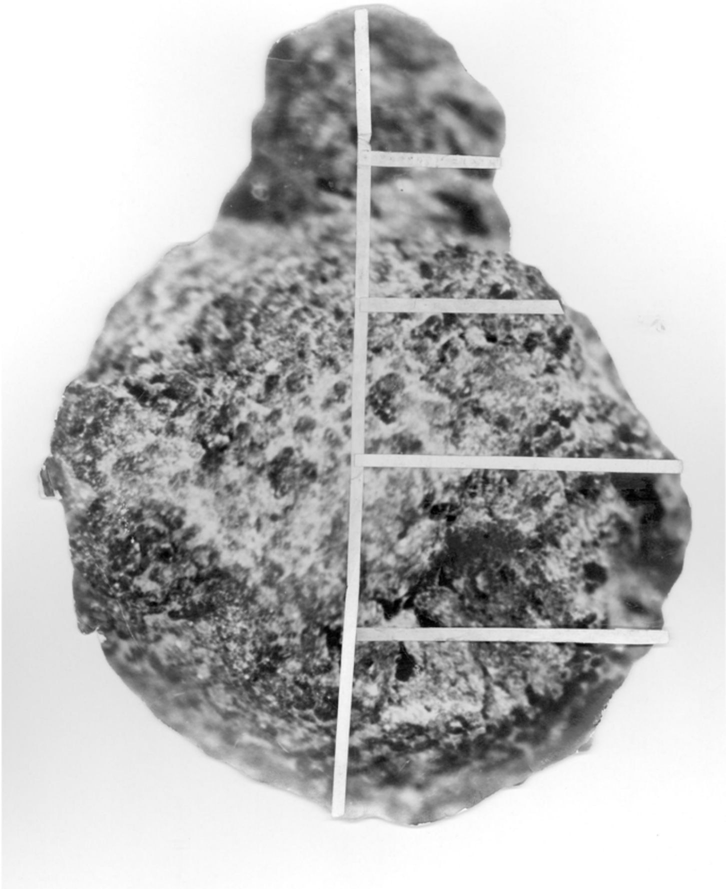
США → СССР 29,4 г

СССР→США 30,2

Миссия	Масса	Год
Луна 16	101 г	1970
Луна 20	55 г	1972
Луна 24	170 г	1976
Итого	326 г	

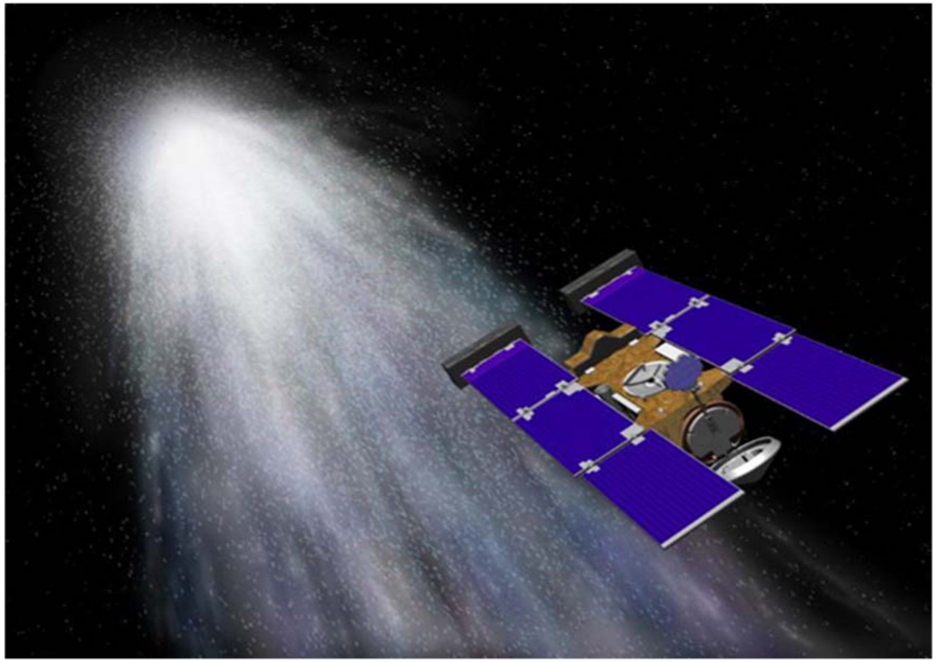


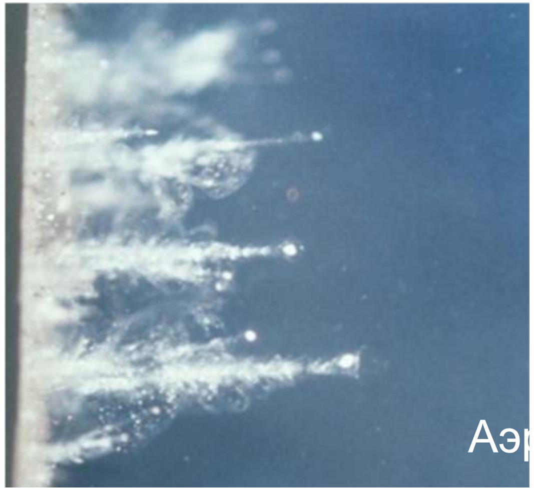
Металлические частицы, доставленные АМС
20

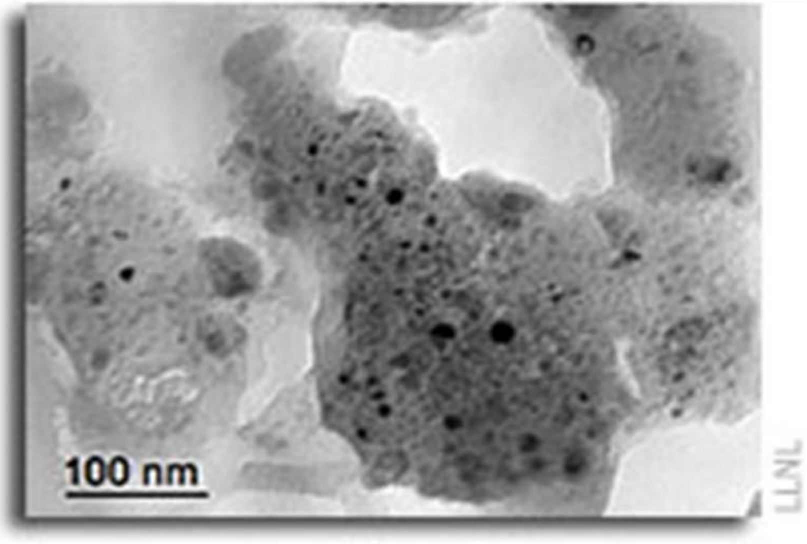


STARDUST Mission

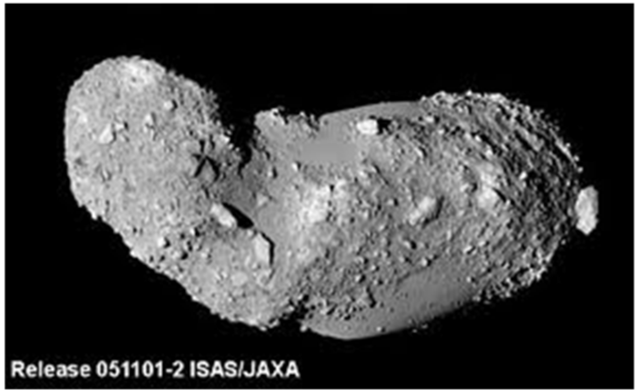
Комета Wild 2

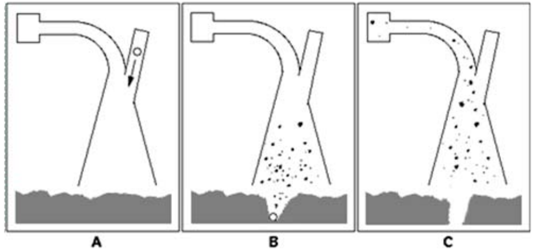




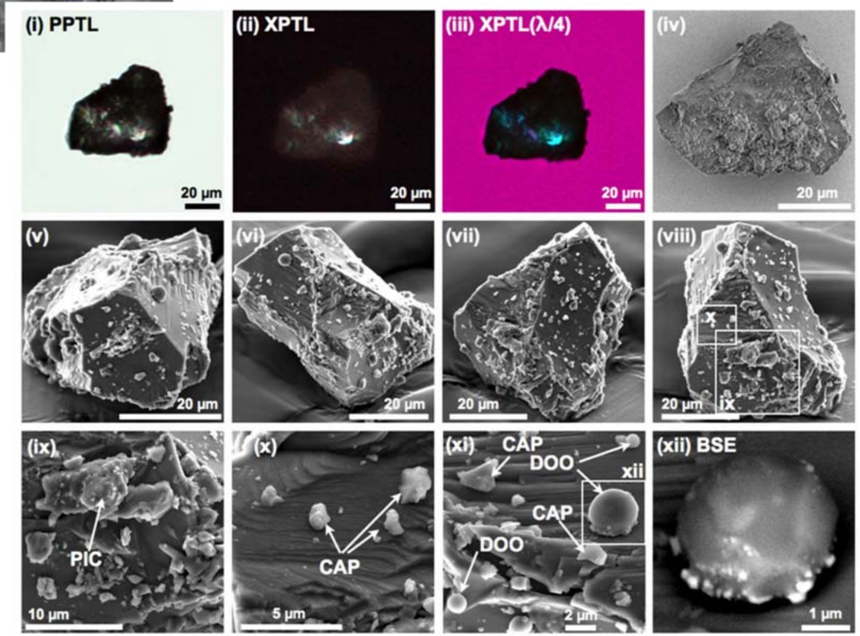


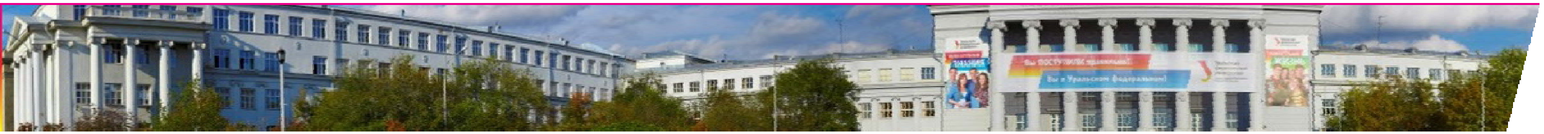
Оливин, пироксен,
Fe-Ni сульфид
CAI
Аморфные силикат

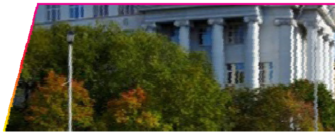




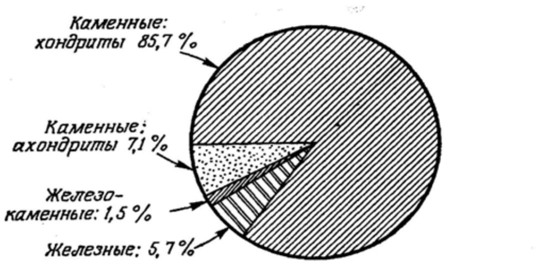
1500 микрозерен, 10 мкм ≤



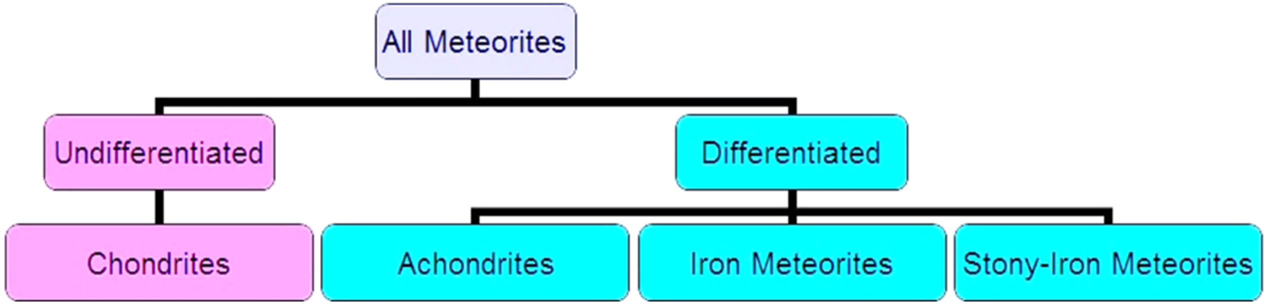


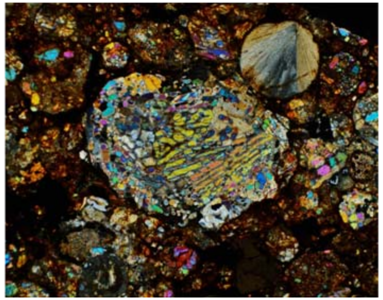


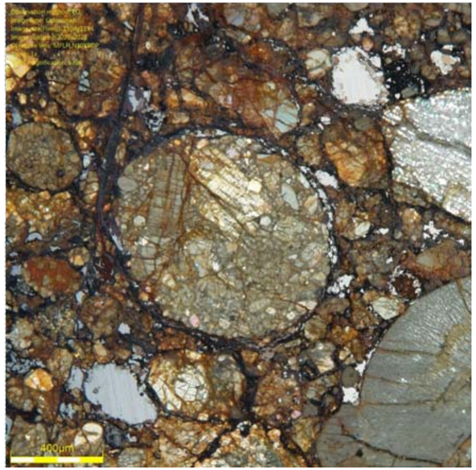
Классификация метеоритов

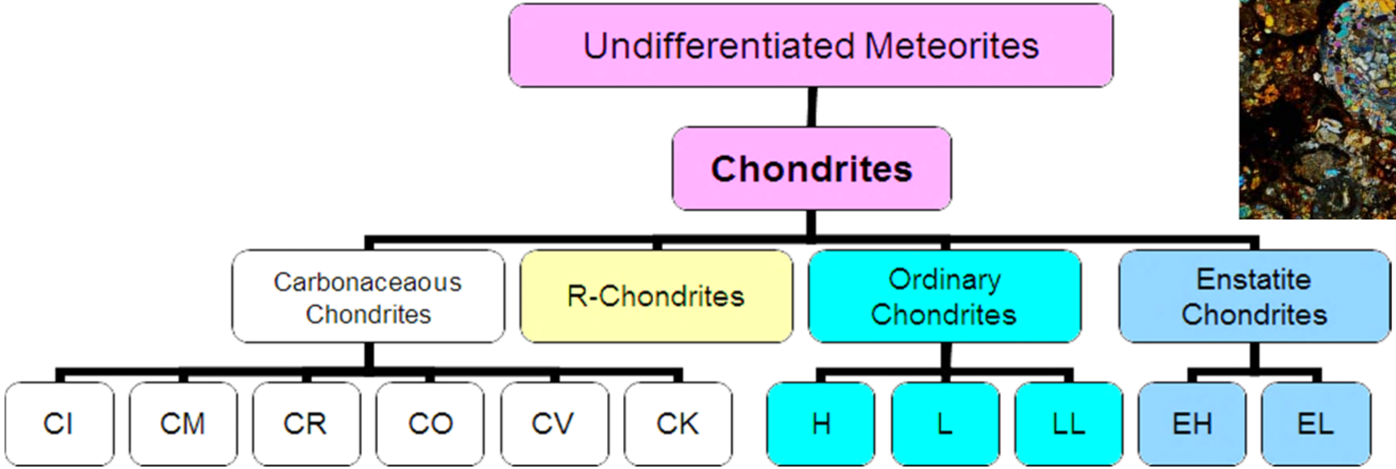


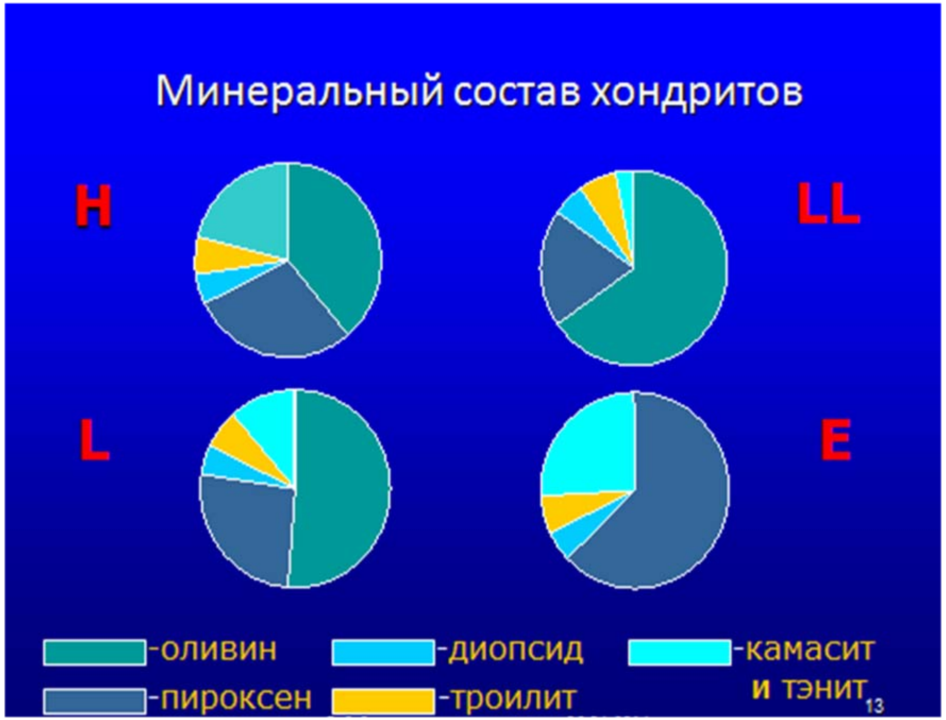
Соотношение хондритов, ахондритов, железо-каменных и железных метеоритов среди падений.

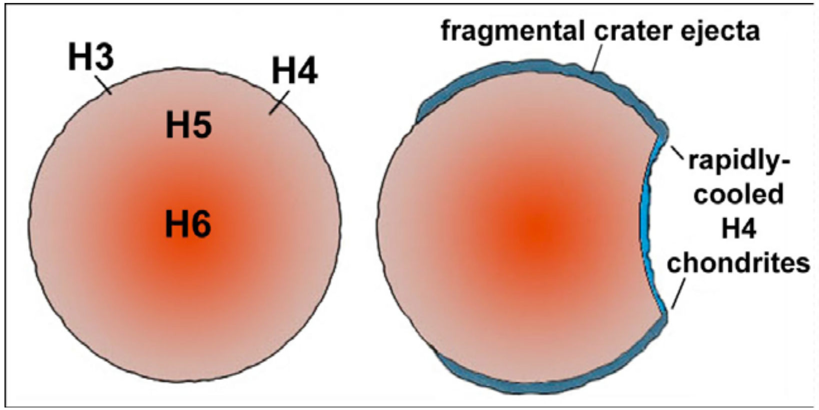


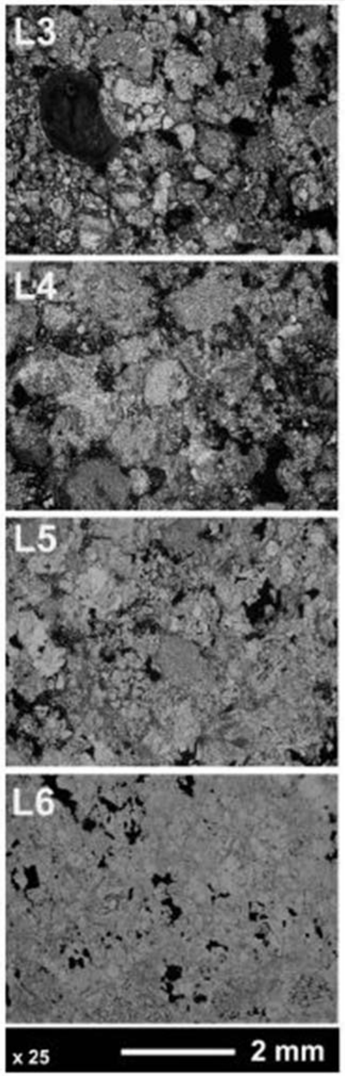


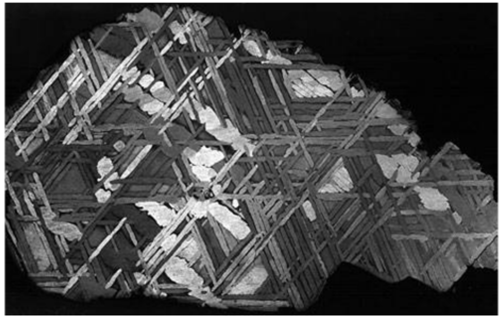


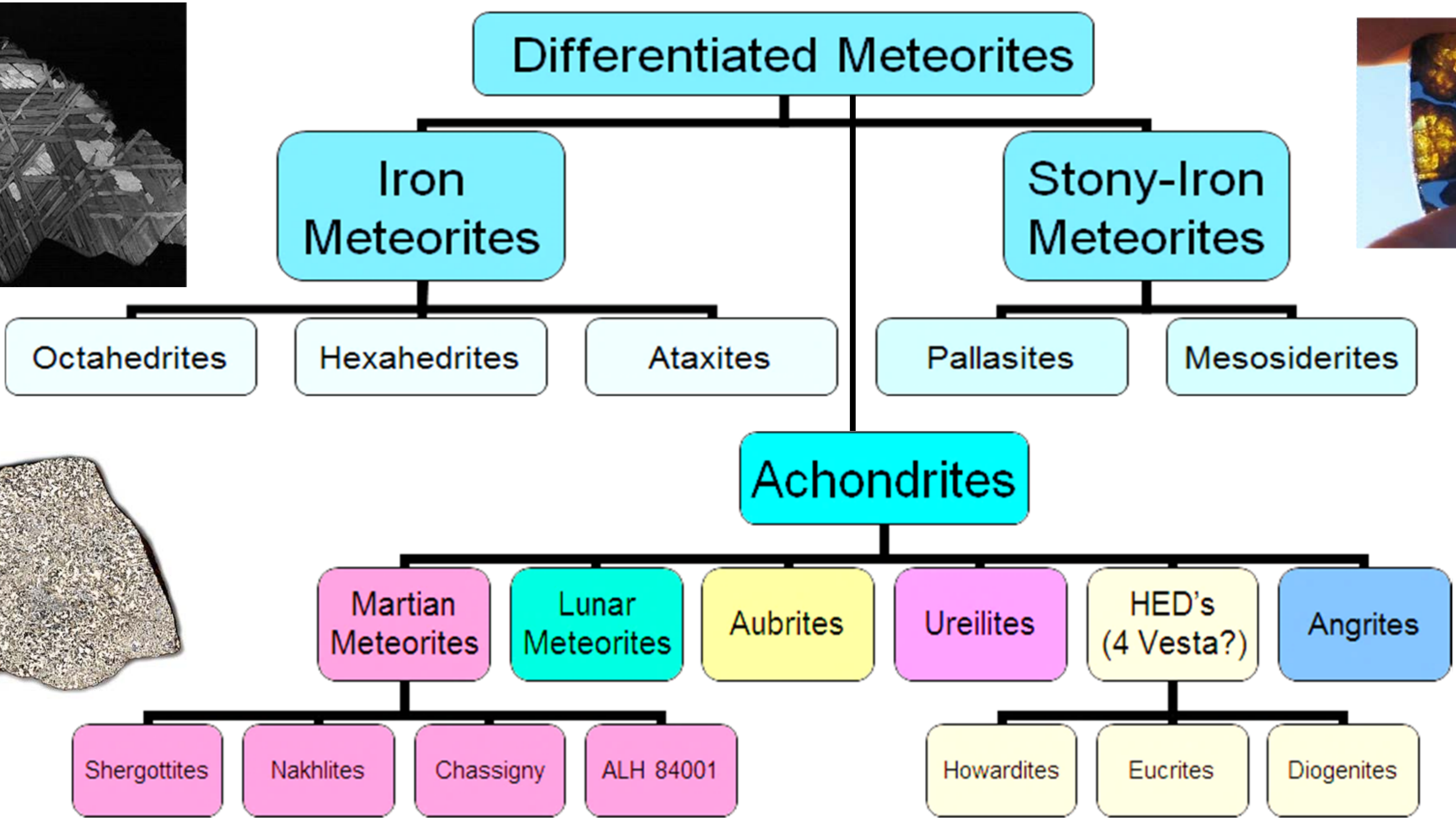


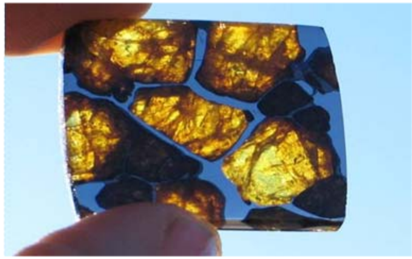

Минеральный состав хондритов
H
LL
L
E
-оливин
-пироксен
-диопсид
-троилит
-камасит
и тэнит
13

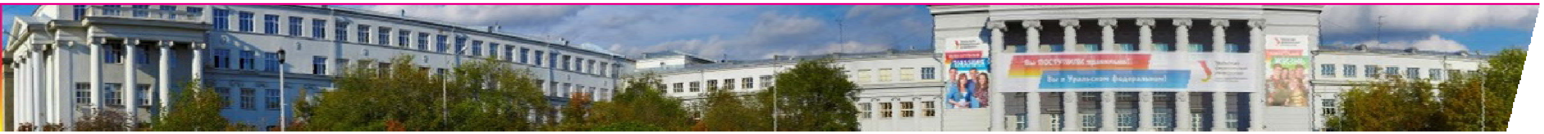

H3
H4
H5
H6
fragmental crater ejecta
rapidly-
cooled
H4
chondrites

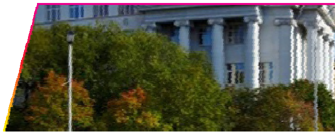

L3
L4
L5
L6
x 25
2 mm




Differentiated Meteorites
Iron Meteorites
Stony-Iron Meteorites
Octahedrites
Hexahedrites
Ataxites
Pallasites
Mesosiderites
Achondrites
Martian Meteorites
Lunar Meteorites
Aubrites
Ureilites
HED's (4 Vesta?)
Angrites
Shergottites
Nakhlites
Chassigny
ALH 84001
Howardites
Eucrites
Diogenites







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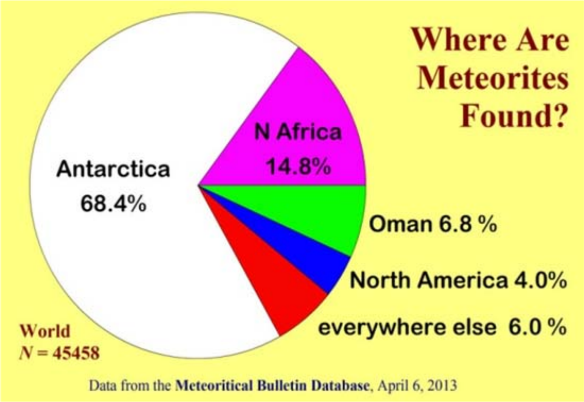
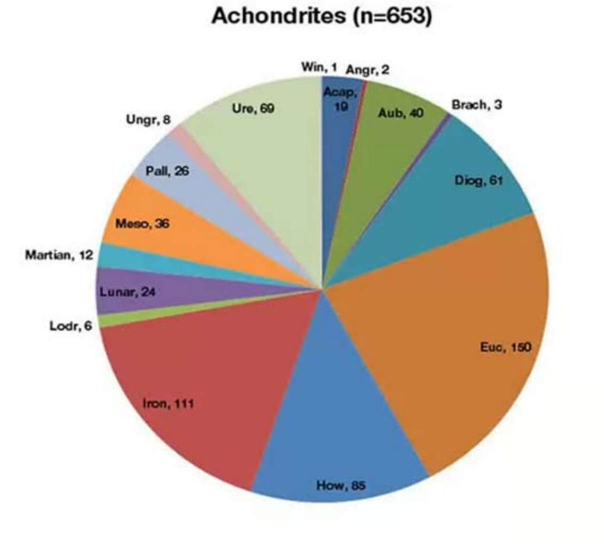
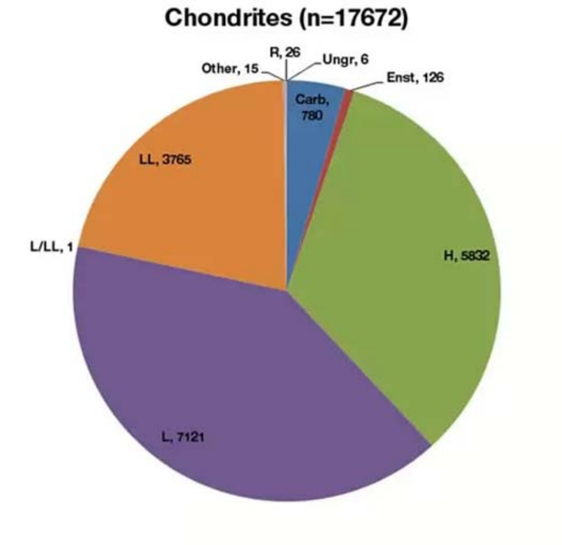
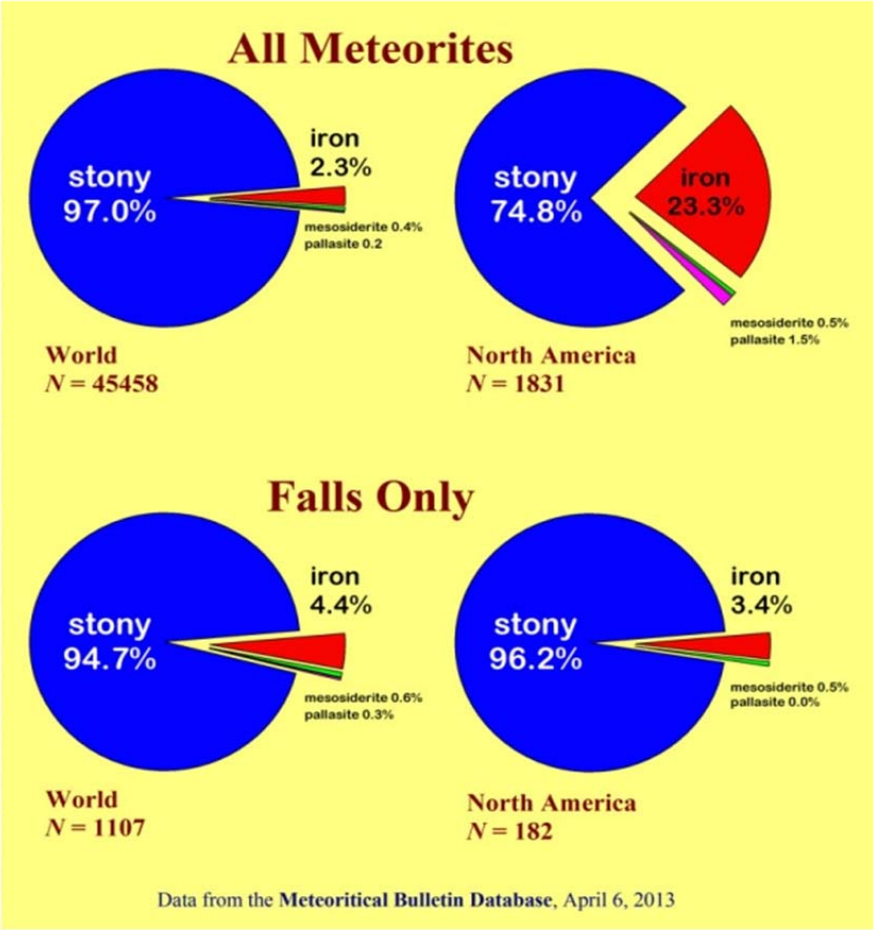
Статистические данные





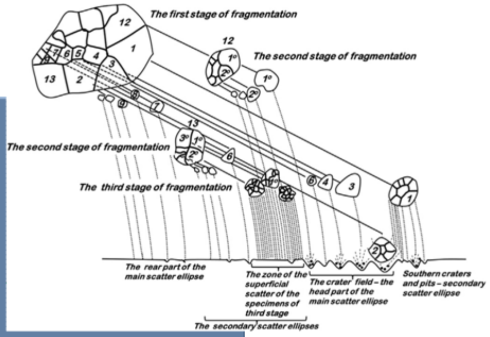




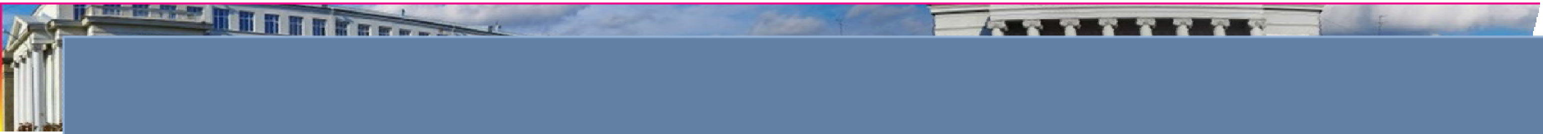
РАЗРУШЕНИЕ МЕТЕОРОИДОВ В АТМОСФЕРЕ ЗЕМЛИ

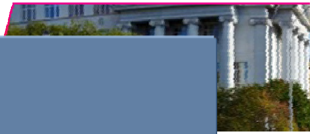
IIIAB IIAB H6 LL5

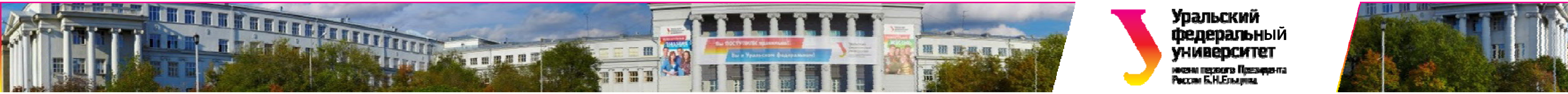
CI1



Derek W.G. Sears (2016)







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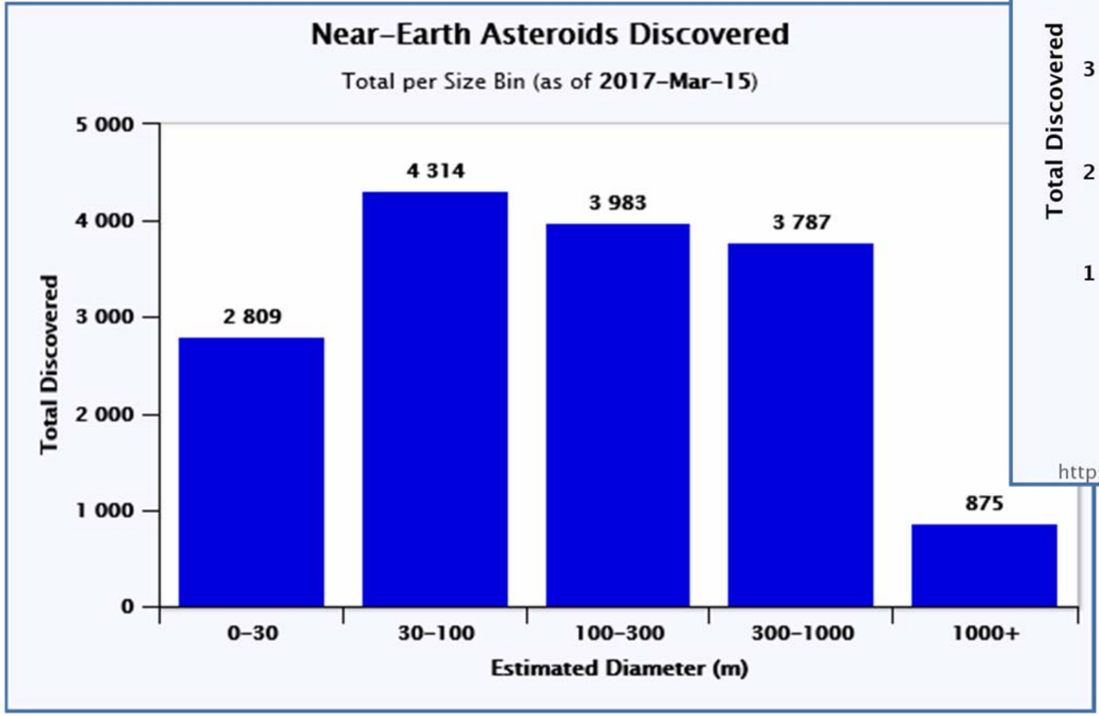
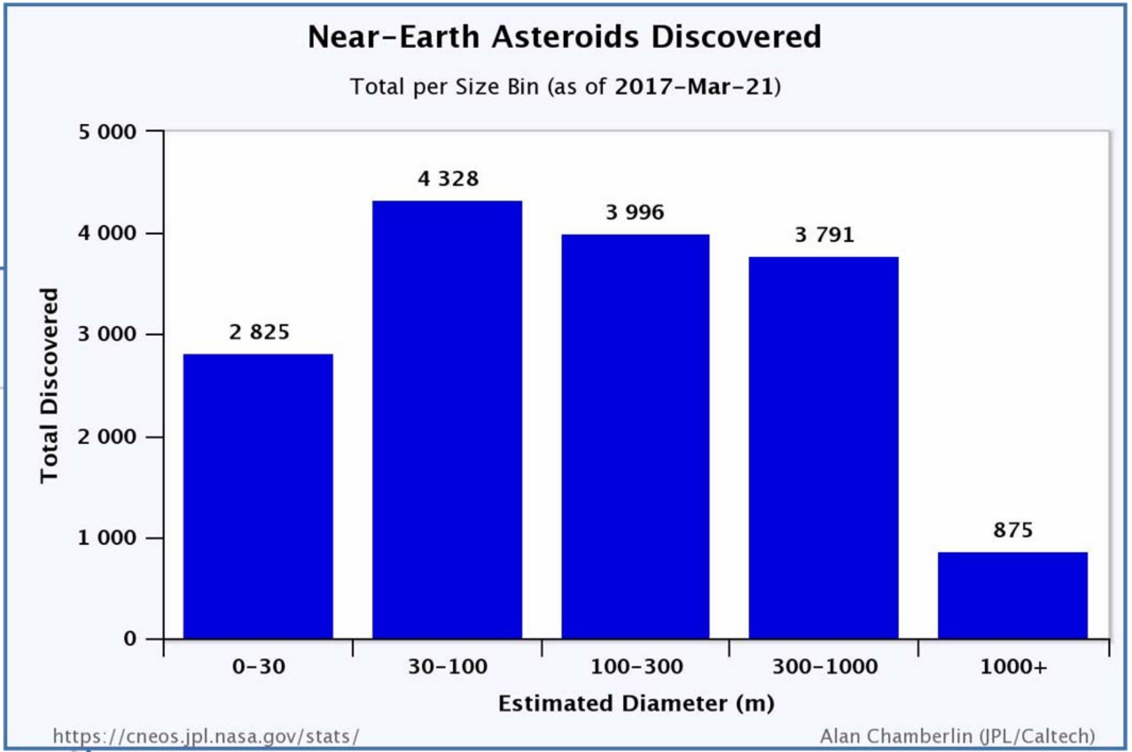
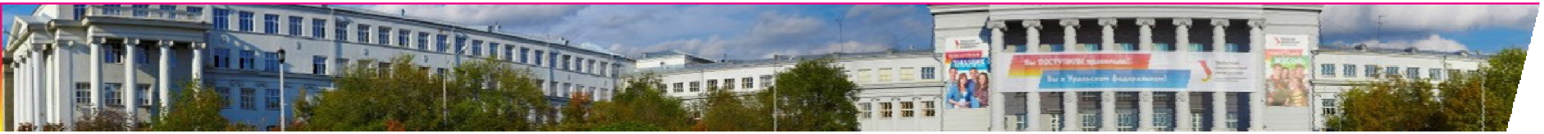
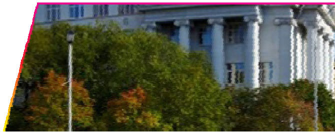
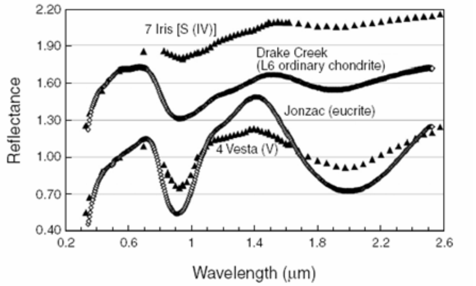
имени первого Президента России Б.Н.Ельцина









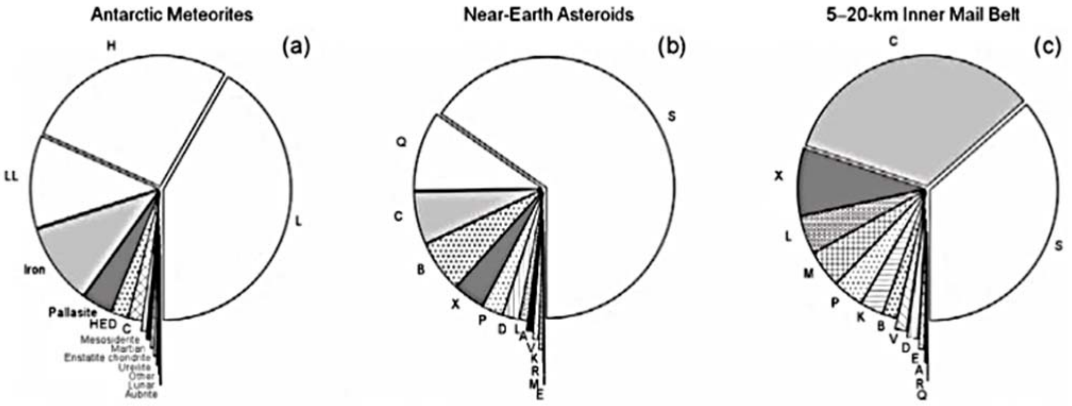


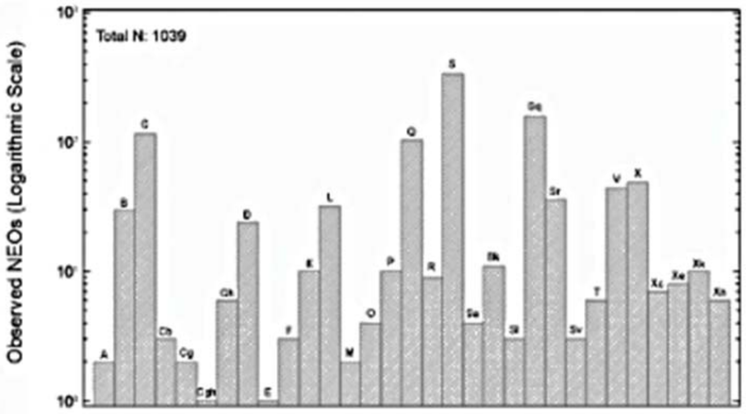
Подавляющее большинство объектов в Главном поясе составляют астероиды трёх основных классов:

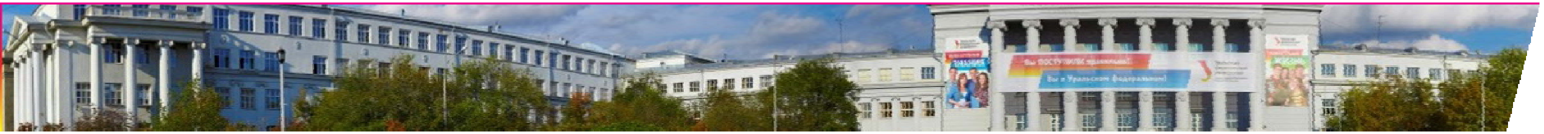
класс C — их ~75%; альбедо 3-9%; состав, близки к углистым хондритАМ; встречаются во внешней зоне ГП; пример - Гигея

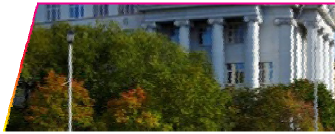
класс S — ~17%; альбедо 10-23%; состав - силикаты Fe, Mg, близок к хондритам ; во внутренней части пояса, до 2.5 а.е; Юнона.

класс M — ~10 %; альбедо 10-19%; богаты Ni и Fe; преимущественно в центральных областях ГП на расстоянии 2,7 а. е. от Солнца; Клеопатра.









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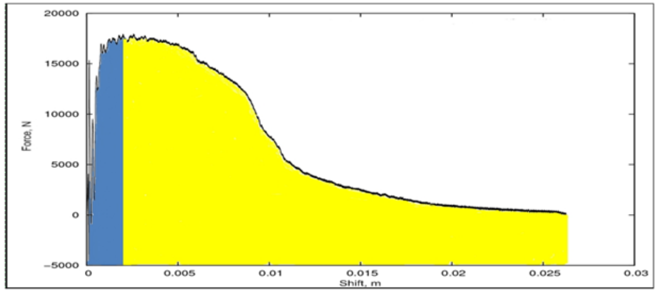
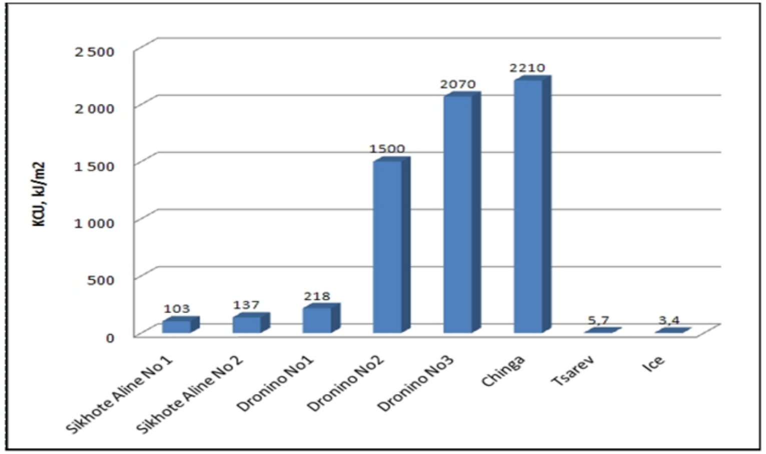
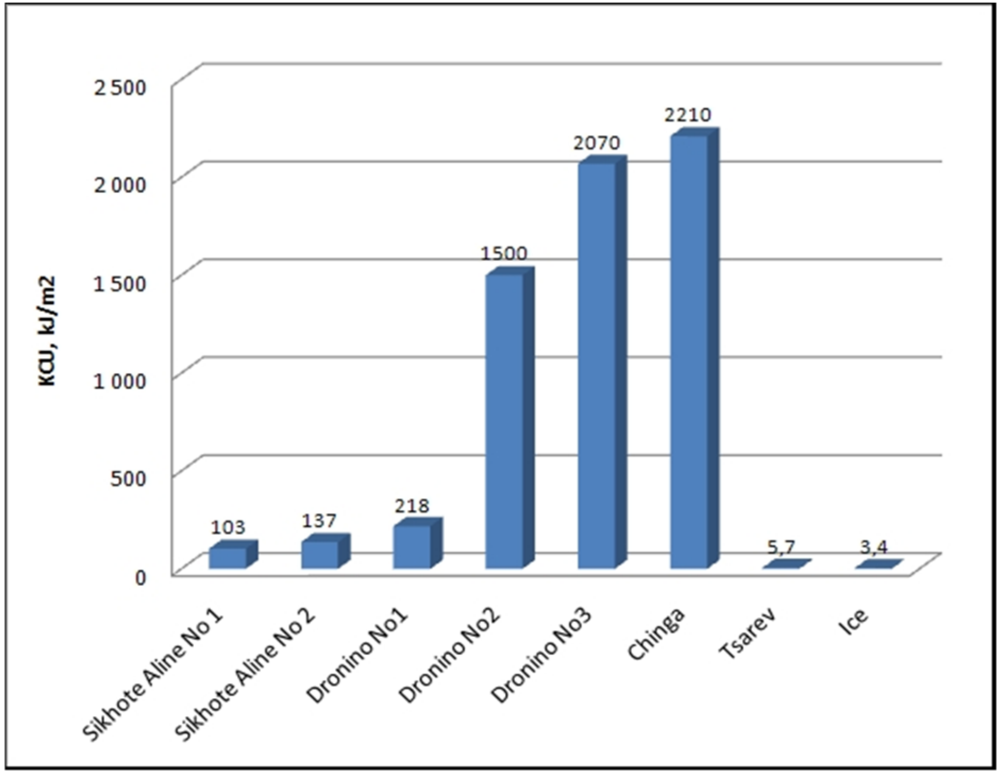
Ударная вязкость метеоритов с различной структурой

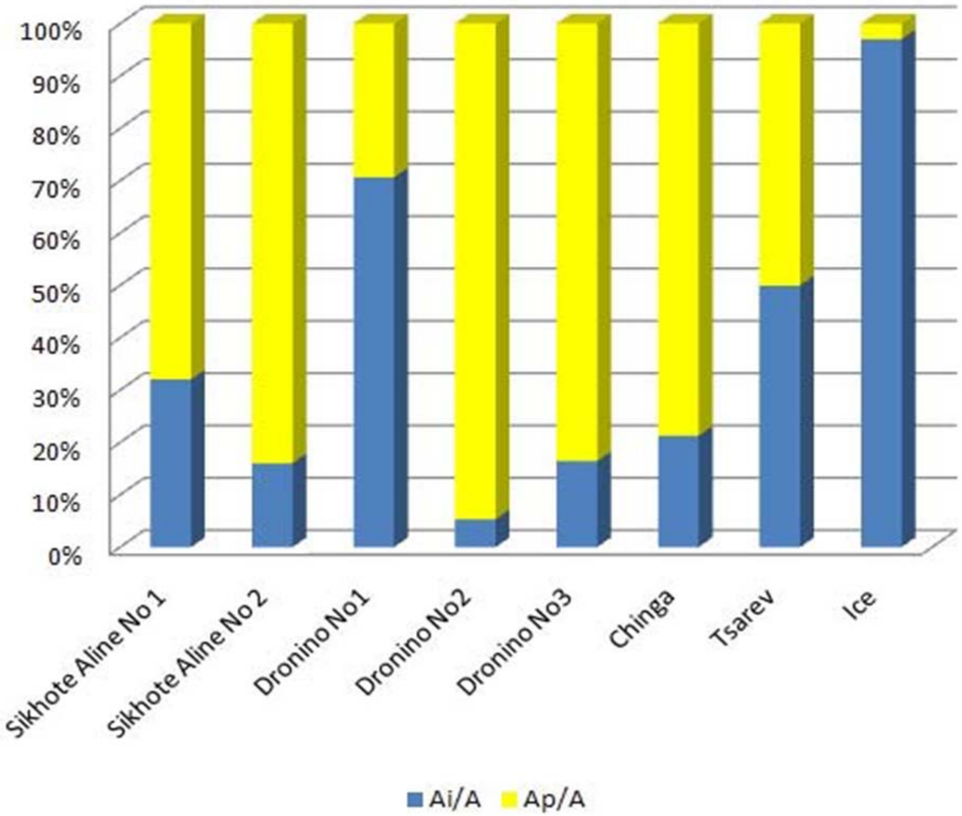
N	Meteorite fragment	300 K		77 K		3-point bending, P, H
		KCU, kJ/m²	Ap/Ai	KCU, kJ/m²	Ap/Ai	
1	Sikhote-Alin IIAB, poly					54
2	Sikhote-Alin IIAB, mono No 1	103	0.67			
3	Sikhote-Alin IIAB, mono No 2	137	0.84			
4	Dronino Iron-ung			47.2	0.59	
5	Dronino Iron-ung poly	218	0.29			
6	Dronino Iron-ung	1500	0.95			
7	Dronino Iron-ung	2070	0.84			
8	Chinga IVB-an	2210	0.79			
9	Chinga IVB-an			1170	0.50	
10	Tsarev L5	5.7	0.50			
11	Tsarev L5					344
12	Ice	3.4	0.05			

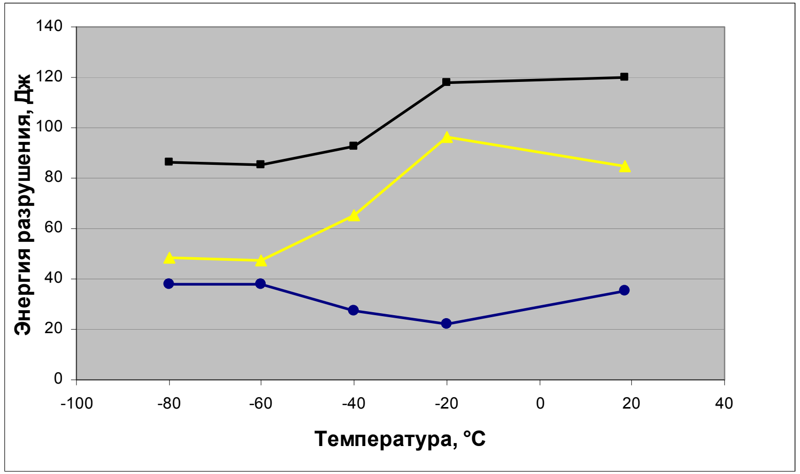




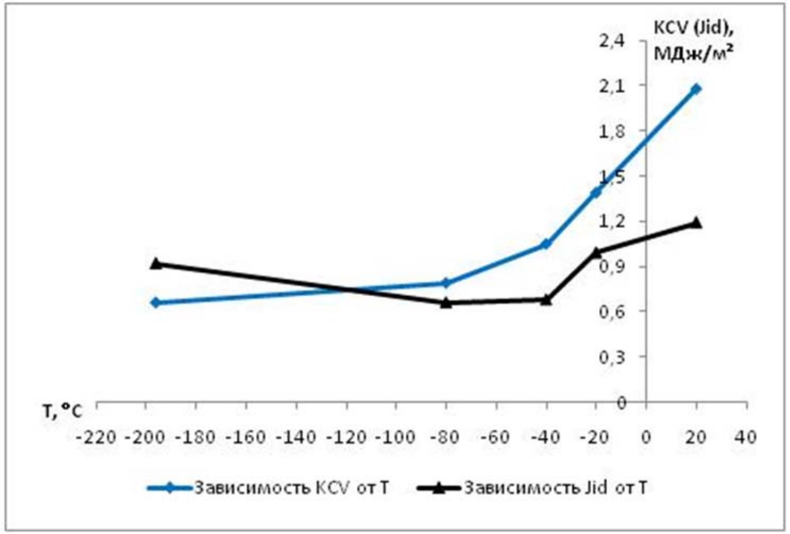
Ударная вязкость метеоритов с различной структурой

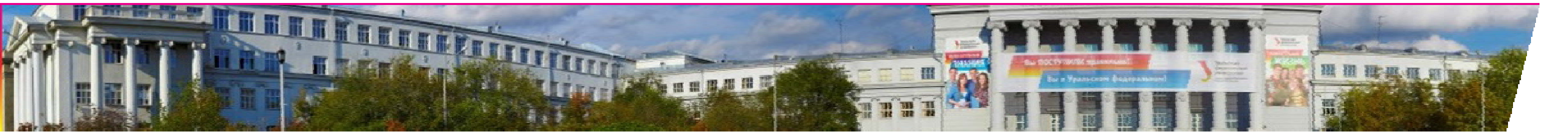


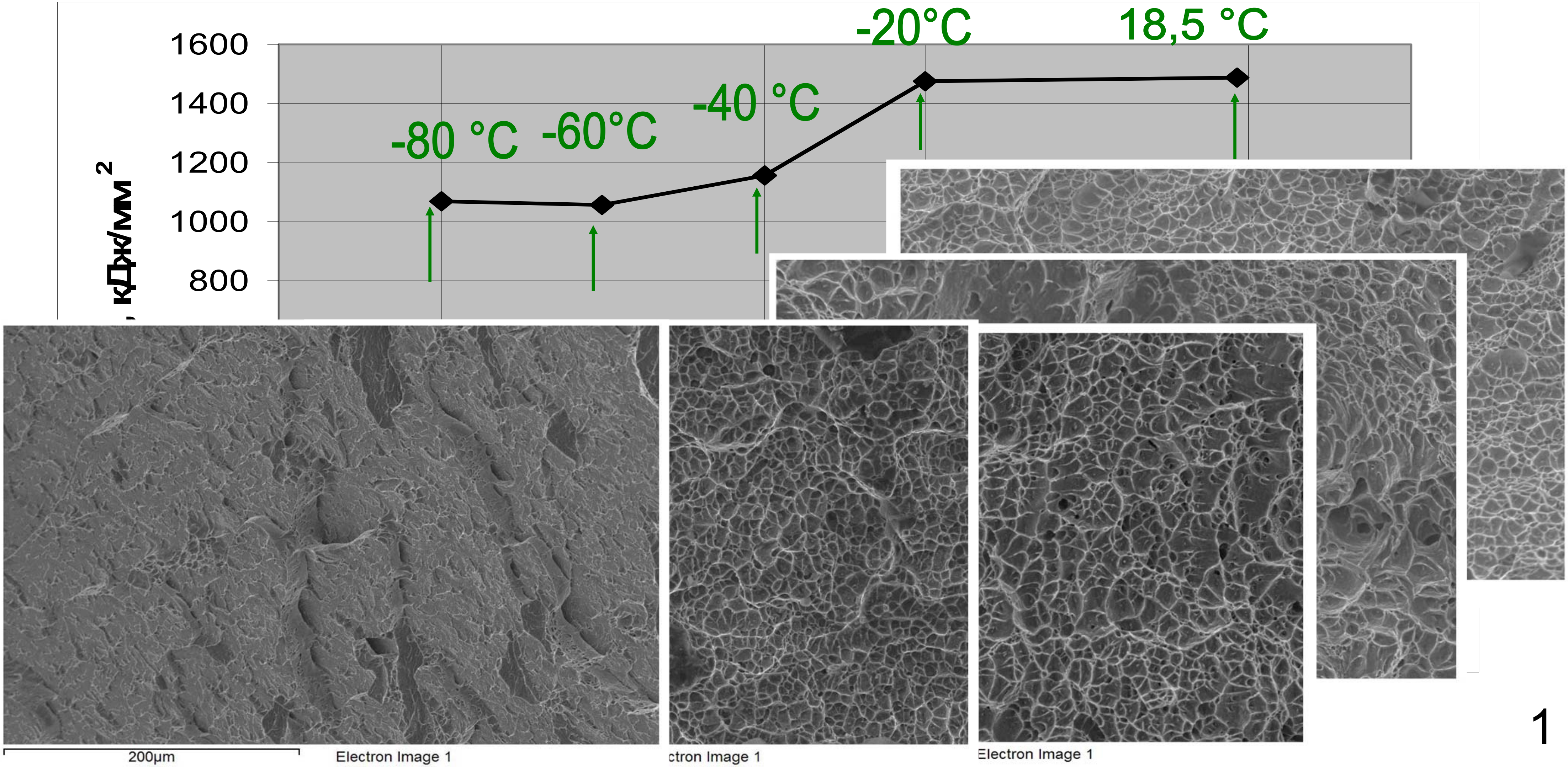



140
120
100
80
60
40
20
0
Энергия разрушения, Дж
-100
-80
-60
-40
-20
0
20
40
Температура, °С


2500
2000
1500
1000
500
0
кДж/м²
2070
47,2
40
2210
1,9
1170
Дронино 3
Дронино 4
Чинге 1
Чинге 2


KCV (Jid), МДж/м²
2,4
2,1
1,8
1,5
1,2
0,9
0,6
0,3
0
T, °C
-220 -200 -180 -160 -140 -120 -100 -80 -60 -40 -20 0 20 40
Зависимость KCV от T
Зависимость Jid от T




1600
1400
1200
1000
800
кДж/мм 2
-80 °C
-60°C
-40 °C
-20°C
18,5 °C
200µm
Electron Image 1
ctron Image 1
Electron Image 1

Physical and Mechanical Properties of Stony Meteorites

E. N. Slyuta
V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Russ
Academy of Sciences, Moscow, 119334 Russia

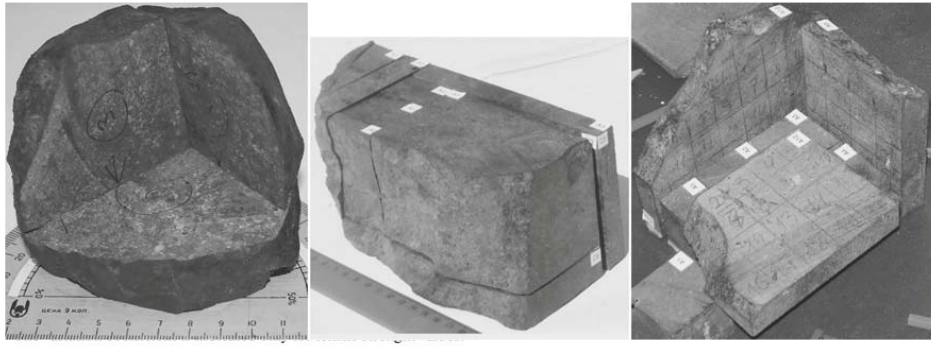


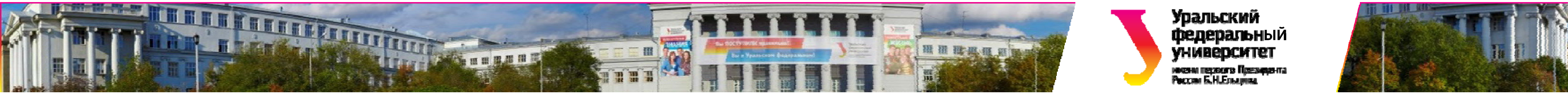
Table 6. Average density, specific density, and porosity of the meteorites* (Britt et al., 2002)

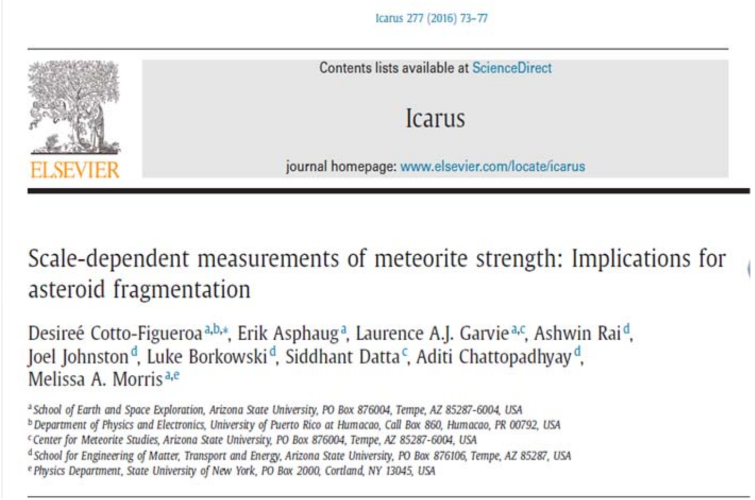
Meteorite type	Specific density, g/cm^3	Density, g/cm^3	Average porosity, %
H ordinary chondrite	3.84	3.40	11.5
L ordinary chondrite	3.75	3.34	10.8
LL ordinary chondrite	3.56	3.19	10.4
Achondrite	3.20	2.97	7.0
CI carbonaceous chondrite	2.27	2.12	11.0
CM carbonaceous chondrite	2.71	2.21	12.0
CR carbonaceous chondrite	3.11	2.92	6.0
CV carbonaceous chondrite	3.51	3.10	11.0
CO carbonaceous chondrite	3.69	3.11	16.0

* Properties of some samples of different meteorites can be drastically different from average values.

Table 4. Three-dimensional distribution of physical and mechanical properties in ordinary chondrites

Name	Anisotropy ellipsoid axes			Average for sample
	a_c	b_c	c_c	
SAUH 001 Meteorite (a_c/c_c = 1.6)				
Compression strength, MPa	**143**	**94**	**91**	**105**
Number of measurements	6	7	10	23
Variation coefficient, %	20	29	23	31
Tensile strength, MPa	**18**	**17**	**18**	**18**
Number of measurements	13	13	14	40
Variation coefficient, %	28	26	27	27
Tsarev Meteorite, sample no. 15390.9 (a_c/c_c = 1.6)				
Compression strength, MPa	**262**	**168**	**160**	**203**
Number of measurements	25	27	13	65
Variation coefficient, %	19	37	29	35
Tensile strength, MPa	**28**	**34**	**27**	**29**
Number of measurements	23	20	33	76
Variation coefficient, %	32	35	31	34
Tsarev Meteorite, sample no. 15384.1 (a_c/c_c = 1.3)				
Compression strength, MPa	**223**	**182**	**174**	**194**
Number of measurements	22	17	20	59
Variation coefficient, %	29	25	29	30
Tensile strength, MPa	**31**	**34**	**29**	**31**
Number of measurements	12	24	25	61
Variation coefficient, %	33	30	42	35

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Scale-dependent measurements of meteorite strength: Implications for asteroid fragmentation

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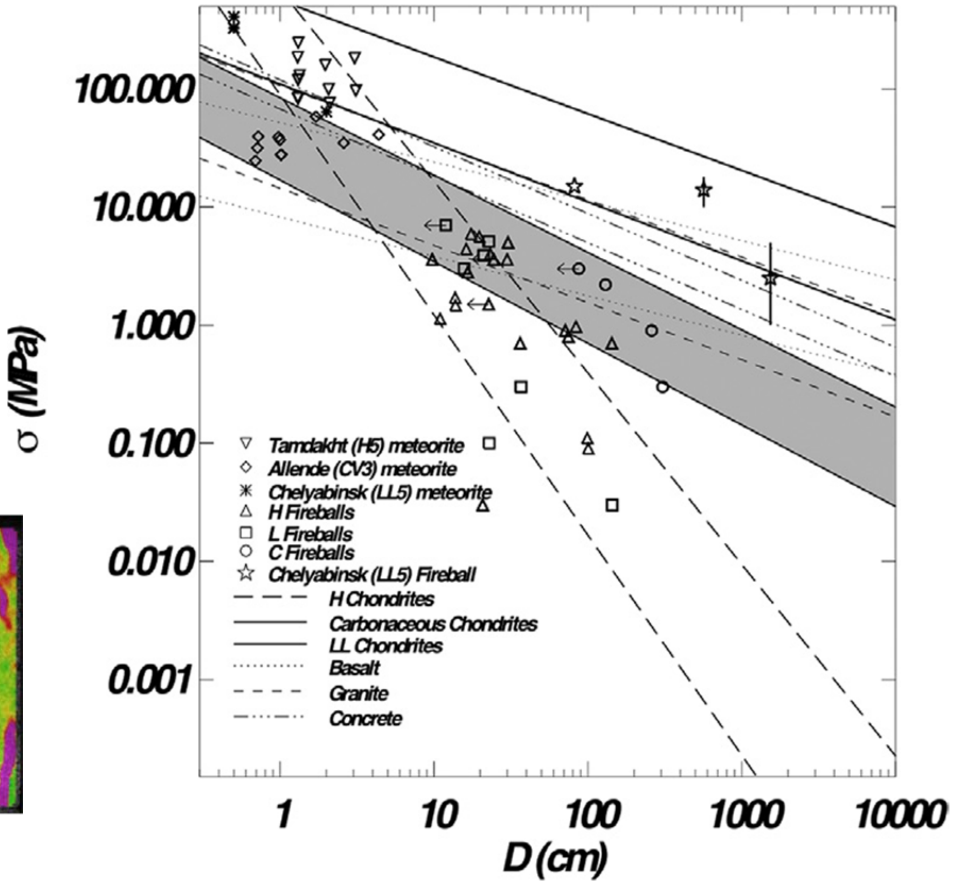
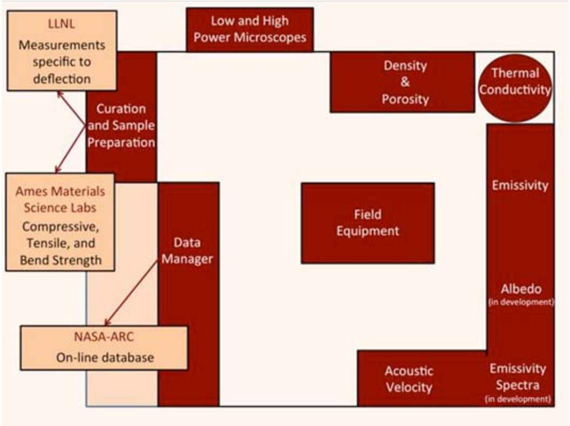
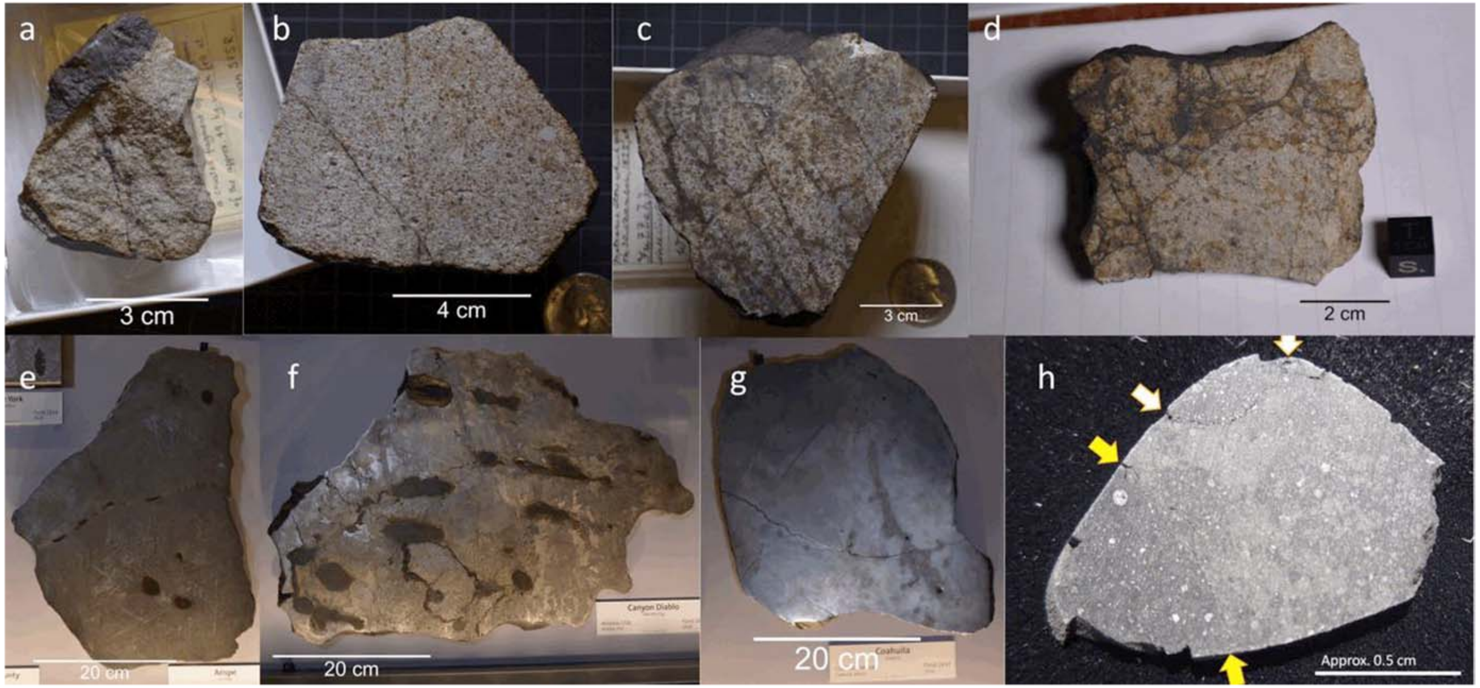




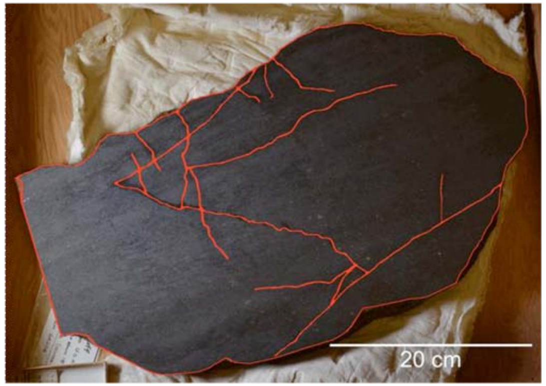
Пуст
хонд

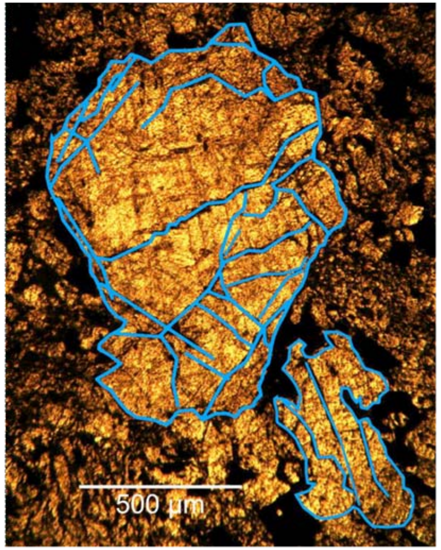
The Meteorite Laboratory is part of the NASA Ames Asteroid Threat Assessement Project (ATAP).

K. L. Bryson and D. R. Ostrowski (2016)



Fracture Patterns: a. Pervomaisky, b. Chandpur, c. Futtehpur d. Pacula, e. Arispe, f. Canyon Diablo, g.Coahuila, h. Sutter's Mill

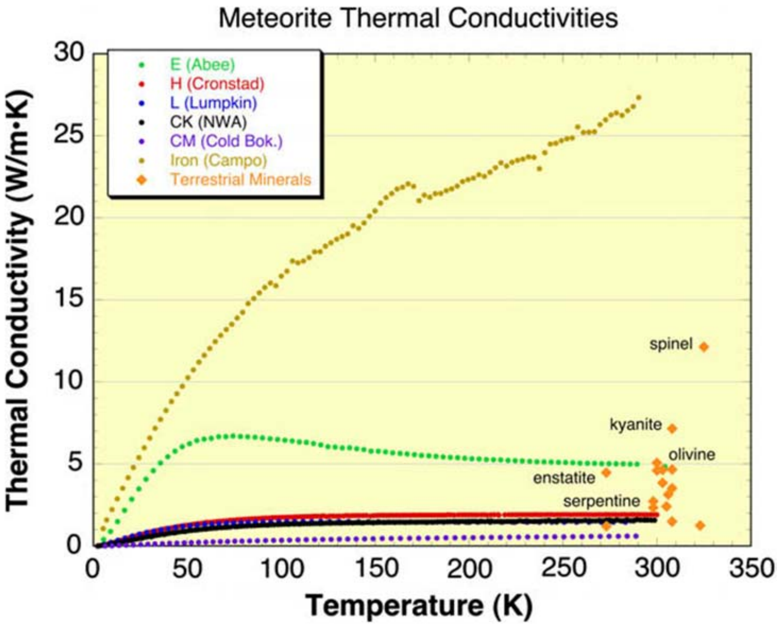




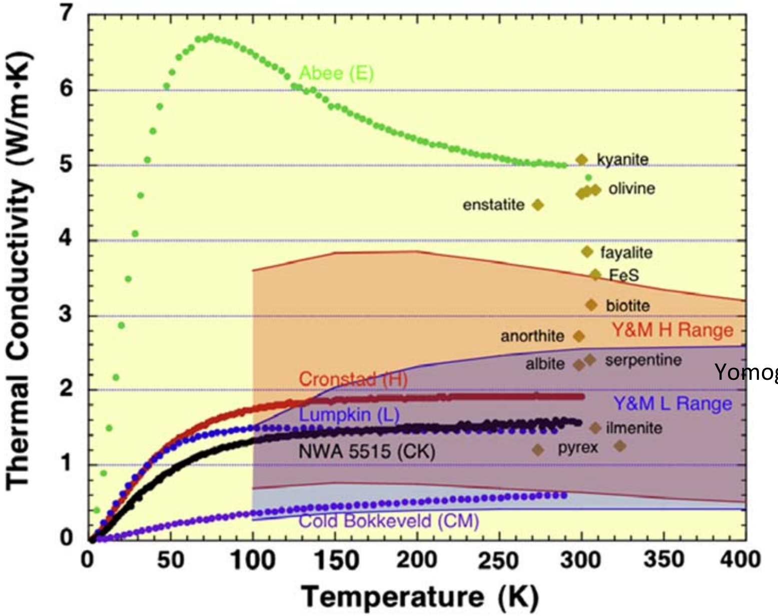
Bluff

Теплопроводность метеоритов

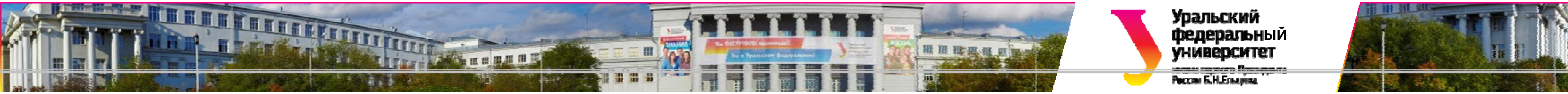
C.P. Opeil , G.J. Consolmagno , D.T. Britt (2010)



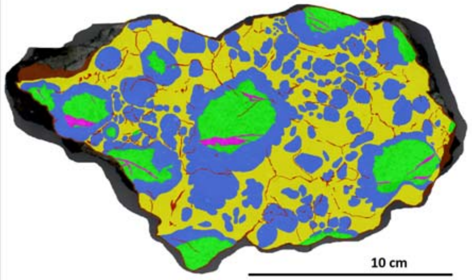
Summary of meteorite thermal conductivity measurements, with assorted conductivities for terrestrial minerals taken from Clauser and Huenges (1995).

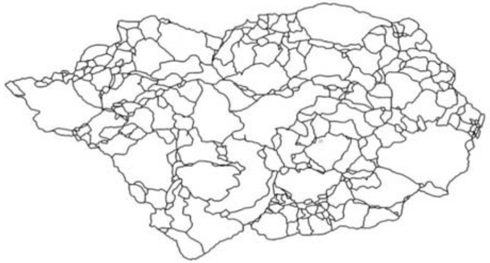


Yomogida and Matsui (1983).

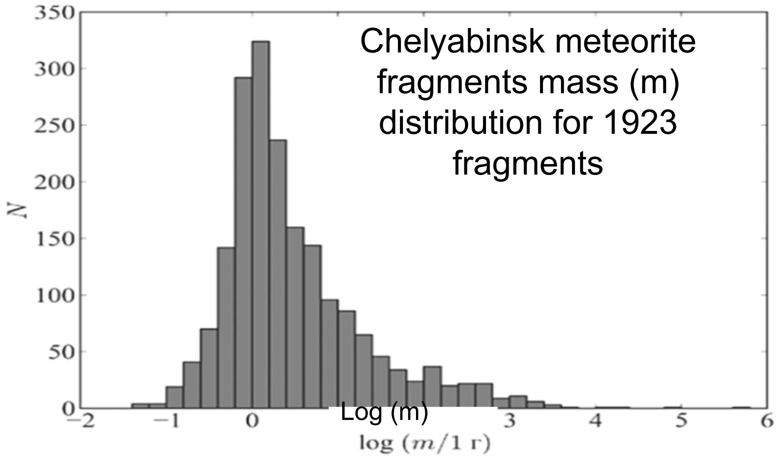


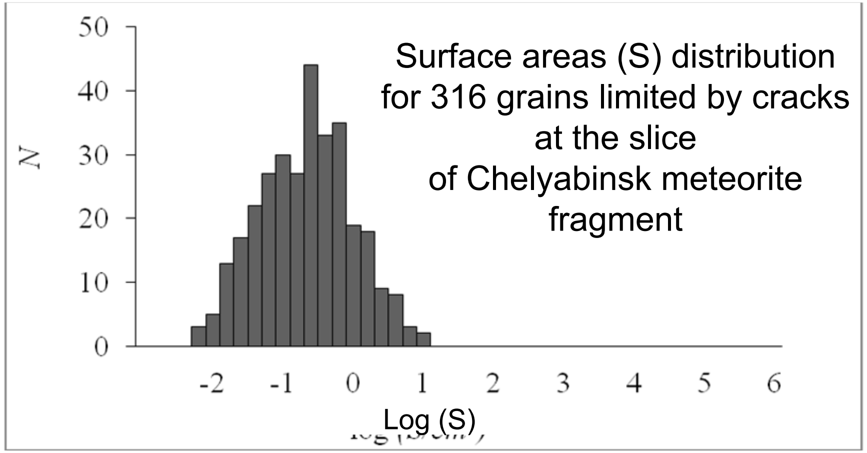
FRACTURE STRUCTURE OF CHELYABINSK METEORITE BODY WITH DIFFERENT LITHOLIGY





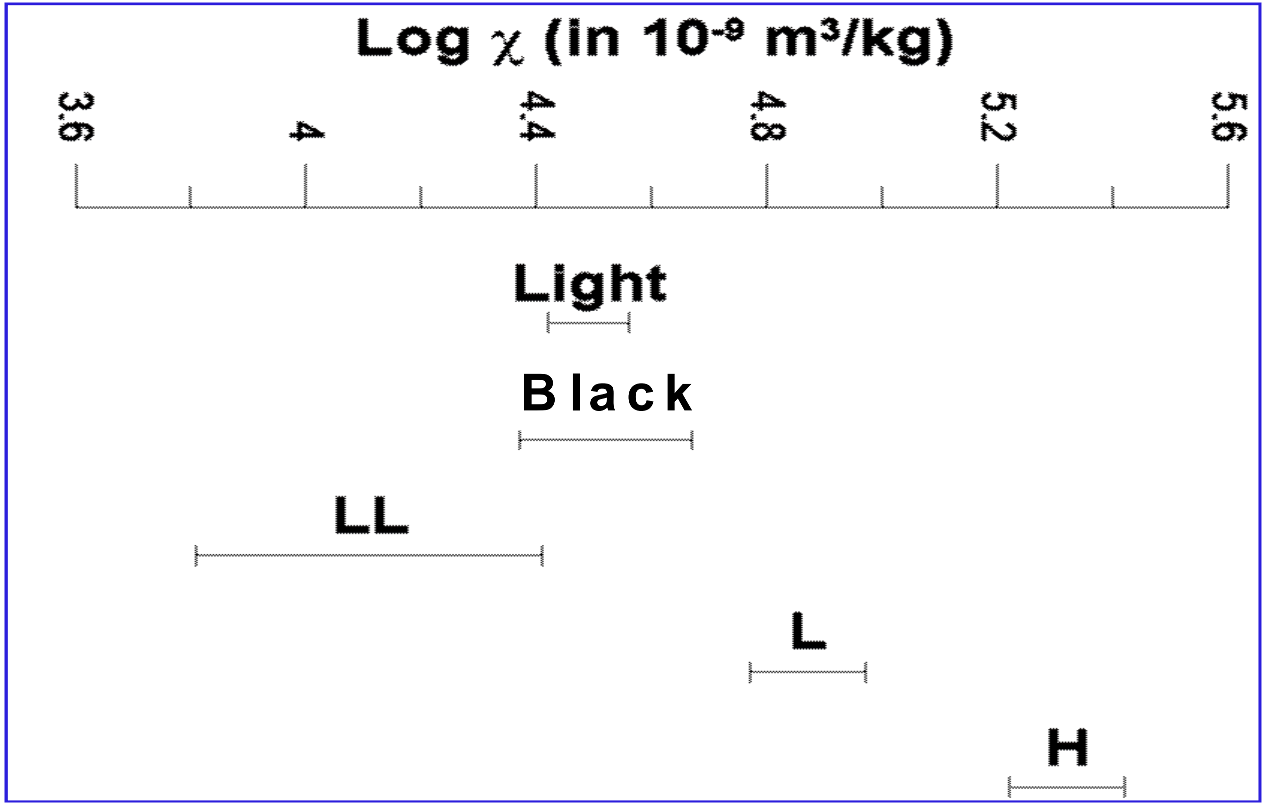
Crack analysis at the surface of the slice of Chelyabinsk meteorite fragment.





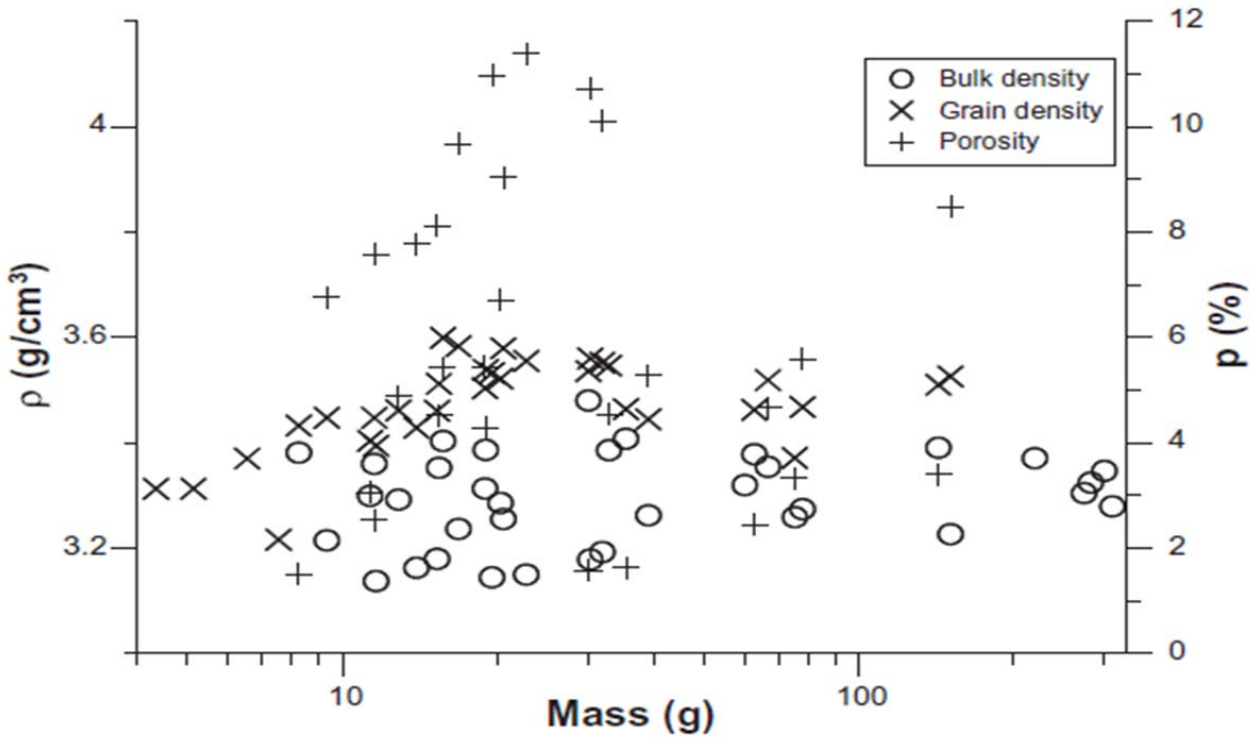
Mass distribution of Chelyabinsk fragments Badyukov et al. (2014) and distribution of surface areas of the grains limited by cracks at the slice modeling one fragment fracture.

CHELYABINSK LL5: MAGNETIC MEASUREMENTS



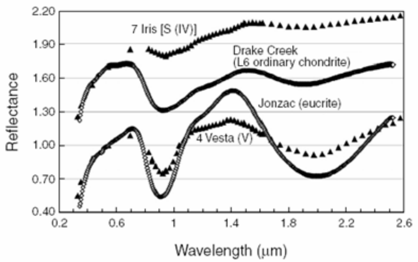
Magnetic study demonstrated that magnetic susceptibility for investigated fragments appeared to be between magnetic susceptibility data for ordinary chondrites from LL and L groups (*Kohout et al. 2014*).

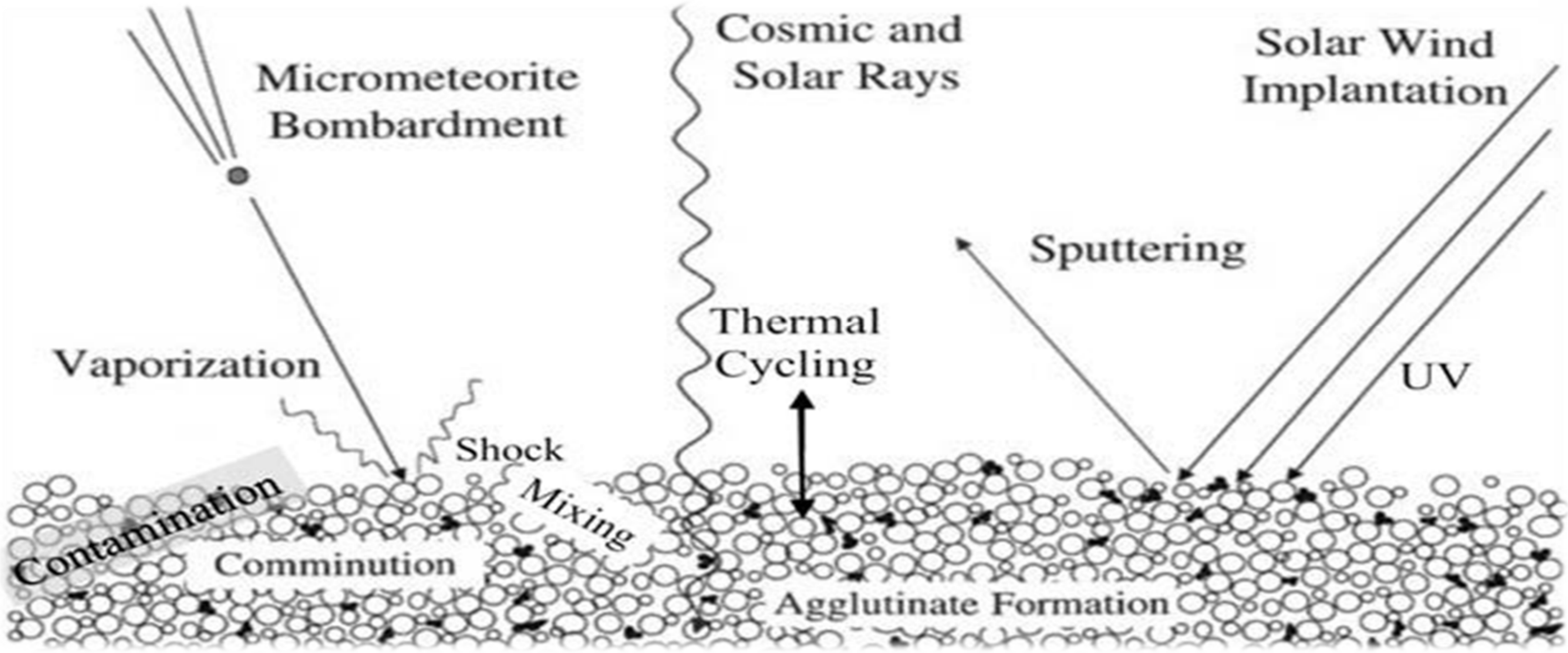
CHELYABINSK LL5: BULK AND GRAIN DENSITY AND POROSITY



Bulk and grain density (ρ) and porosity (P) of the Chelyabinsk meteorites as a function of their mass. No correlation with lithology is observed, but closely
resemble other LL chondrites.

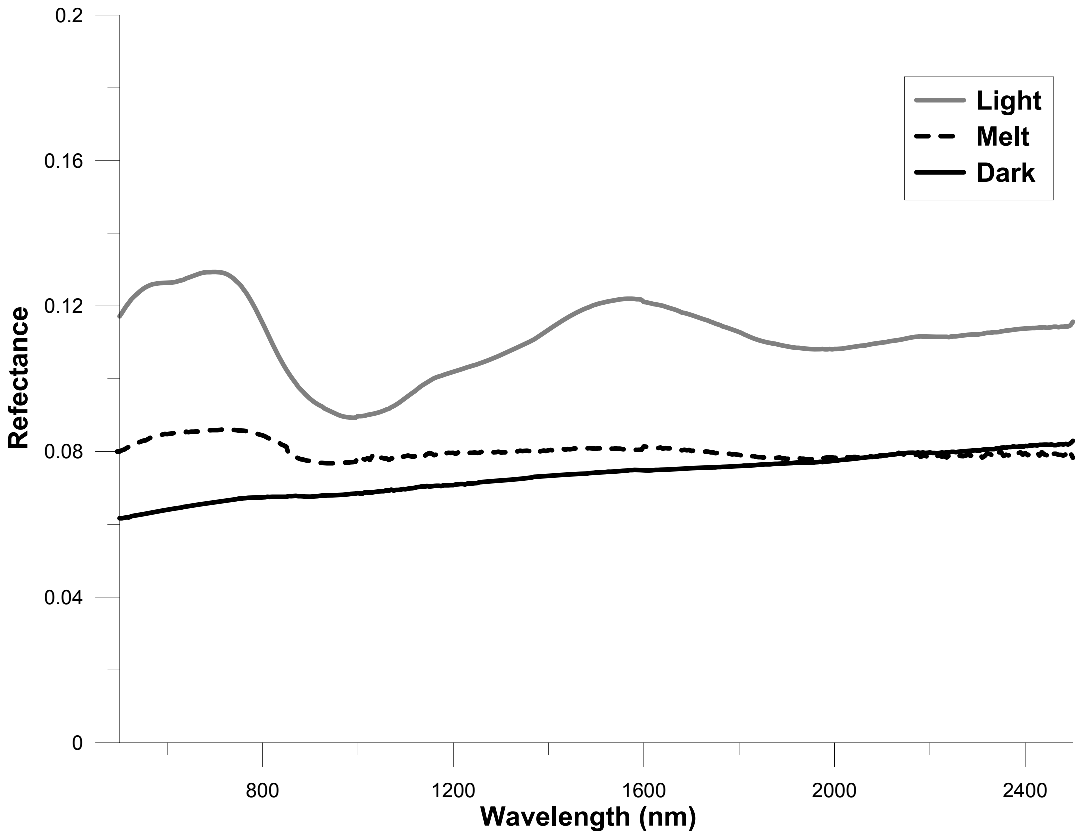
Космическое выветривание (Space weathering)

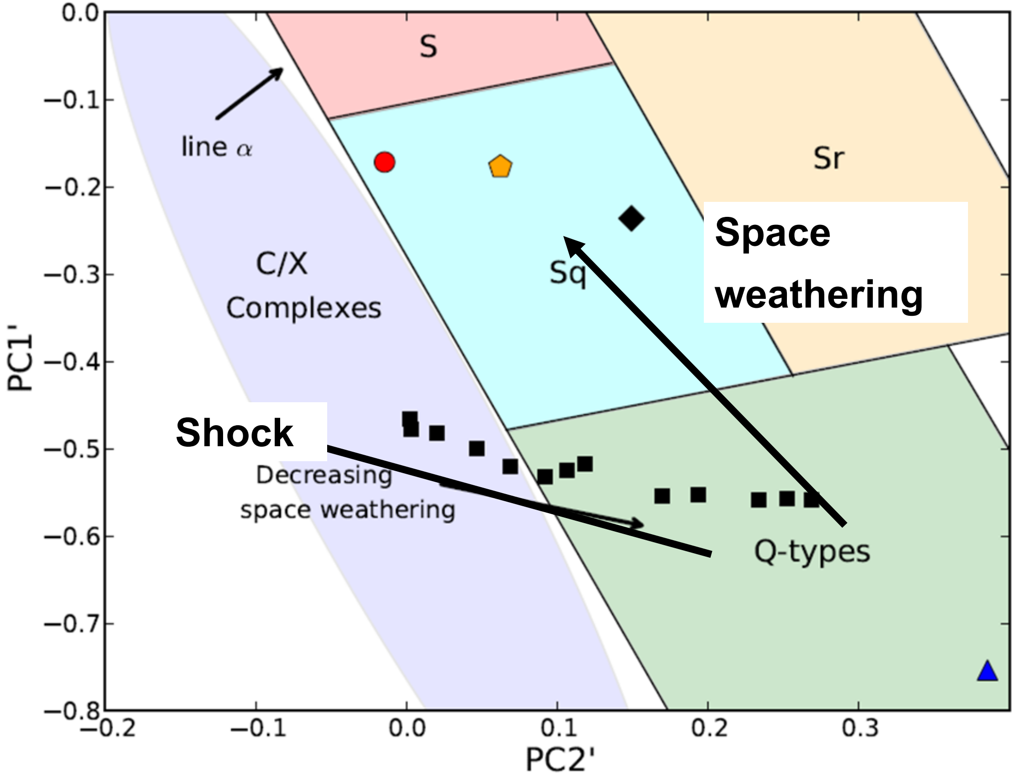


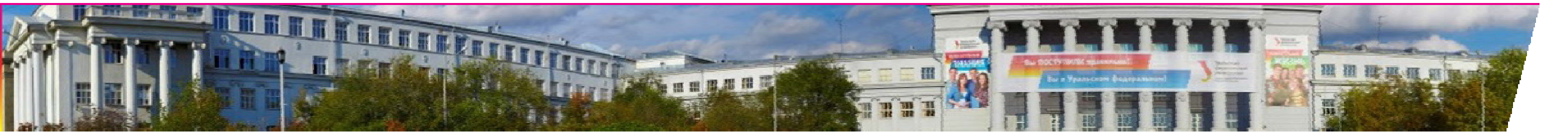


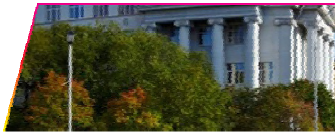
(Carle M. Pieters, 2016)

Челябинск LL5, различные литологии









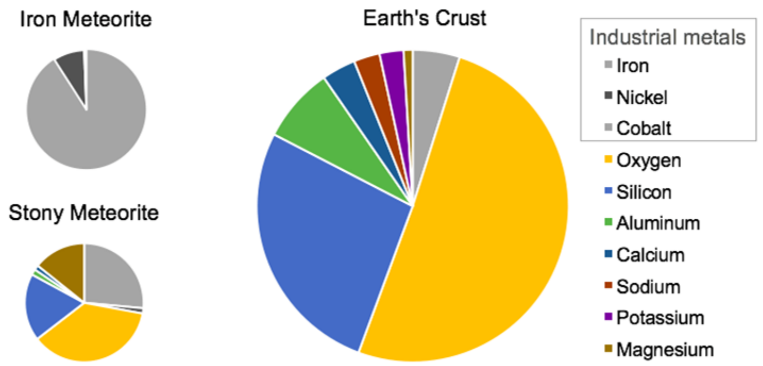
Вопросы от трех частных горнодобывающих компаний участникам ASIME 2016 по освоению астероидов

1. **Grain properties :**
Size distribution; Mean particle size; Broadness of size distribution;
Coefficient of curvature (a geotechnical parameter); Coefficient of uniformity (a geotechnical parameter);
Internal erodibility (a geotechnical parameter); Particle Shapes distribution (Morphology);
Specific surface area; Intra-grain porosity

2. **Electrostatic properties** (depends critically on the environment and is hard to replica

3. **Magnetic Properties**

4. **Geomechanical Properties:** Fatigue; Tensile Strength; Compressive Strength; She
Grain Hardness (hardness indexes); Surface friction; Abrasivity (tool development)
Flexural Strength-bending resistance;Fracture properties, friability; Impact resistance; Rheology
Angle of Repose; Internal Friction; Cohesion; Adhesion (depends on tool material, too)
Compressibility of regolith; Compactibility of regolith (index test, like Proctor Compaction)



5. Physical
Thermal properties (derived properties from mineralogy, texture, and volatile content);
heat capacity; conductance; thermal cracking behavior; emissivity;Bulk density of rocks;
Particle density; Porosity of rocks; Surface area of rocks; Permeability of rocks
Permeability of regolith as a function of porosity/compaction;Bulk density of regolith as a function of porosity/compaction

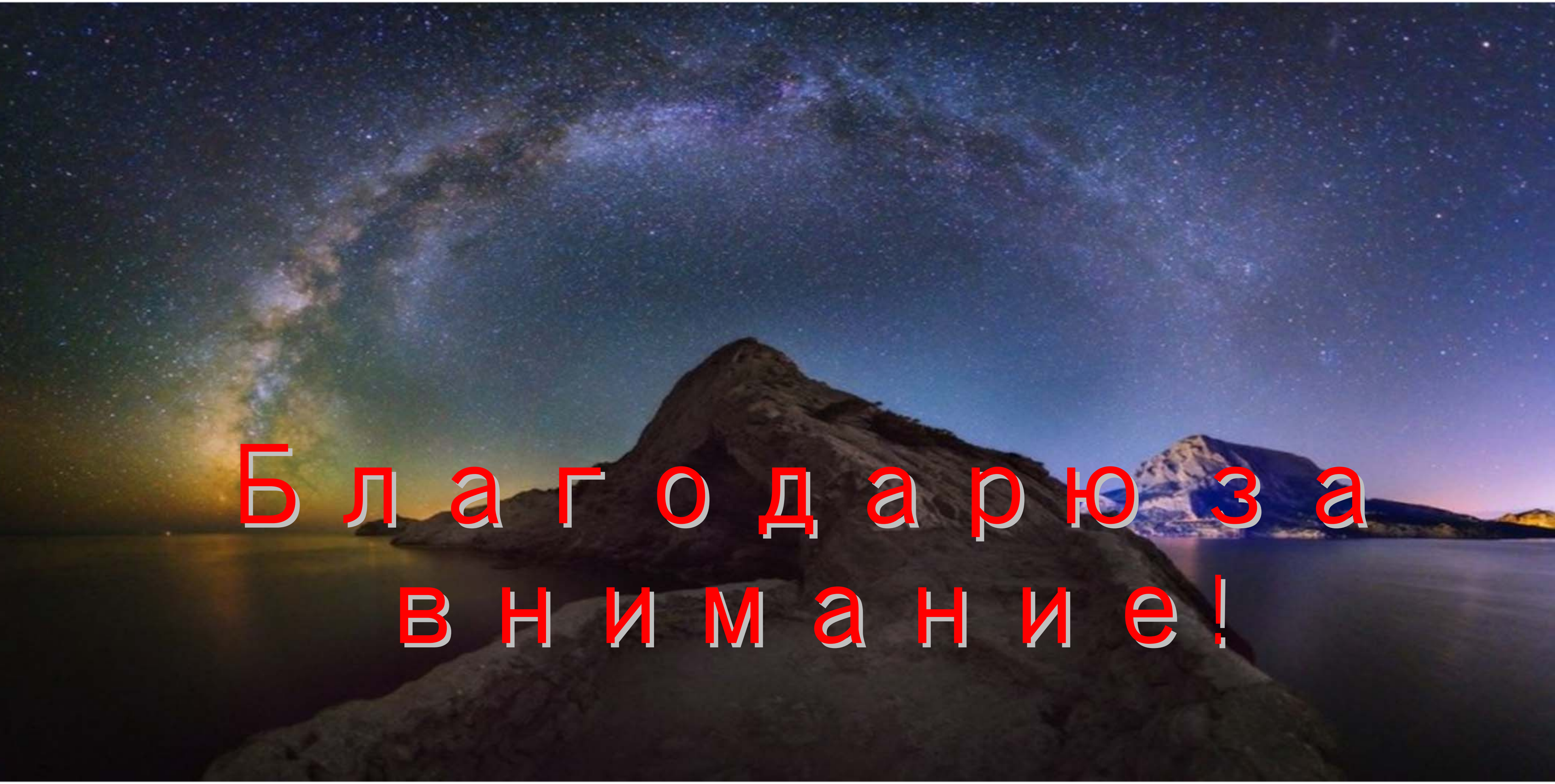
6. **Geochemical properties:**
Mineralogy; Organic content; C-to-H ratio (aliphatic vs aromatic); Toxicity; Sulphur and Nitrogen content of the organic matter;
Bulk chemistry (derived property of the composition); Chemical reactivity; From surface damage; As volatile /soluble minerals;
Absorptive capacity for volatiles; Isotopic ratios; Modal Composition; Siderophile elements in Iron simulants

7. Texture:
Homogeneity and isotropy of texture; Chondrules

8. Volatiles:
Volatiles content; Water; Organics; Sulphur compounds; Release pattern; thermal and/or vacuum release
chemisorbed, physisorbed patterns; Implanted solar wind particles (users may dope simulant if desired)

9. Optical properties:
Albedo; Reflectance spectrum; Absorption; Thermal emissivity;

10. Aerodynamic properties:
Gas erodibility (rocket exhaust); Particles’ coefficient of drag



ЗНЧ 2017, г Снежинск 23 марта 2017 г.