









VNIR reflectance of brachinites & implication for their parental body

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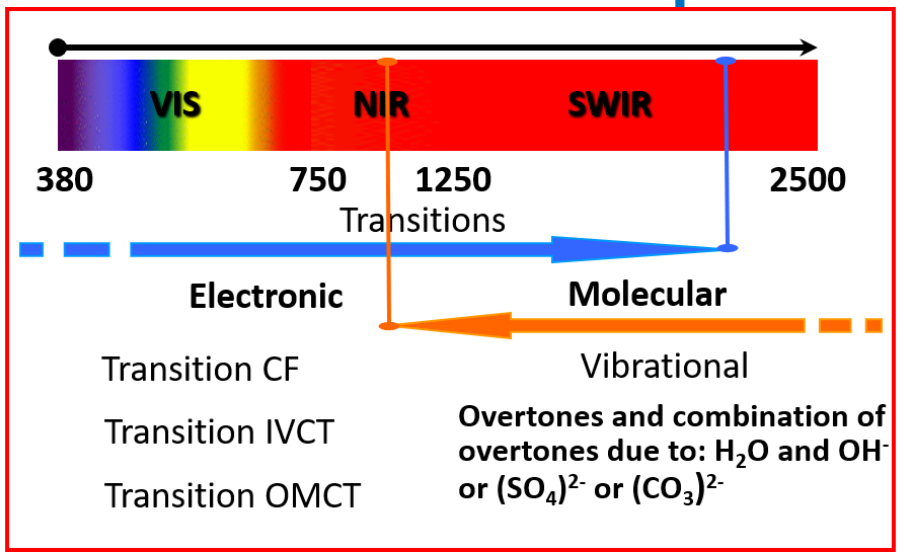
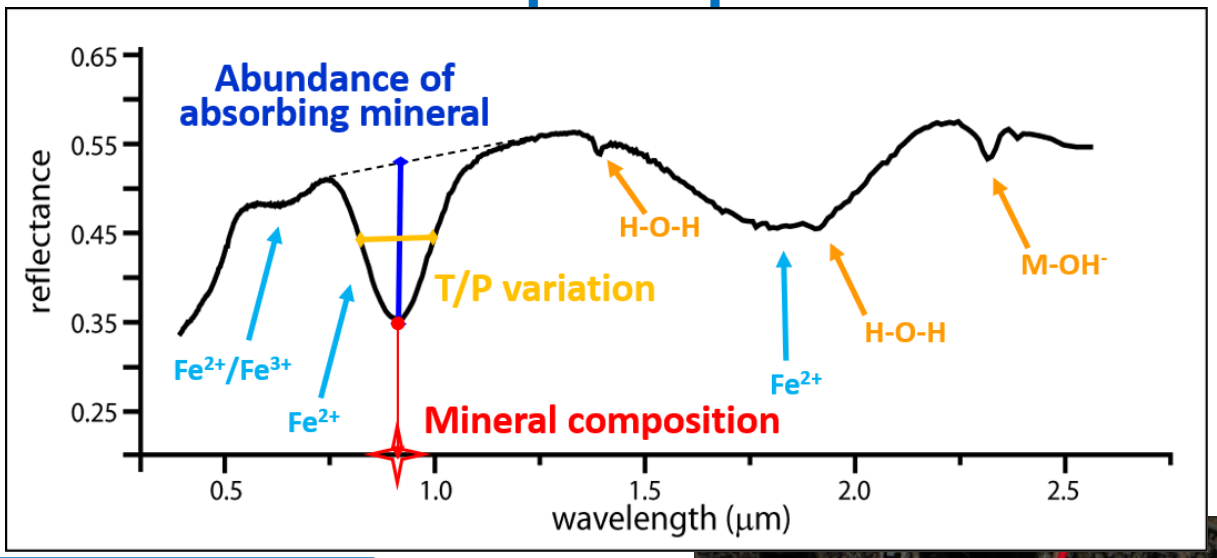
Summary of context

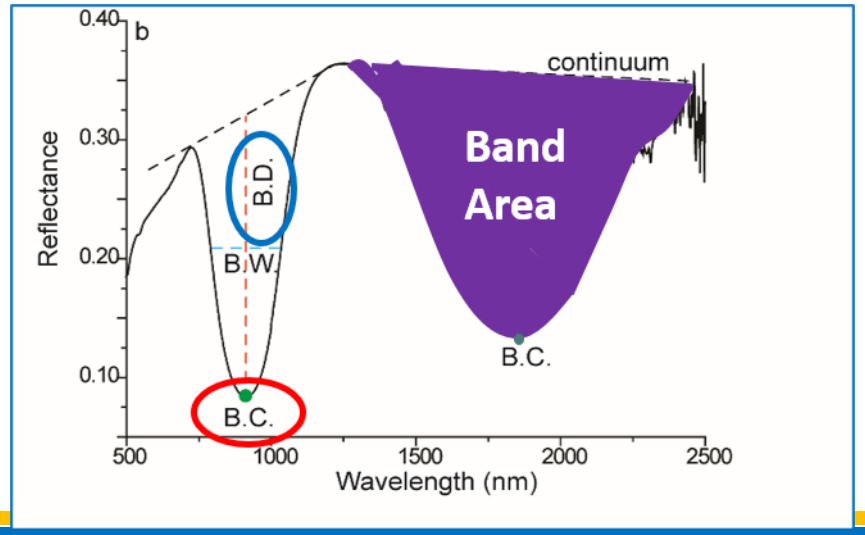
- Introducing VNIR spectroscopy and taxonomy of small bodies
- Introducing brachinites spectral implications
- Studied brachinites (… and UBA)
- Reflectance properties of the studied brachinites
- Defining a brachinite field in reflectance properties
- Implications for spectral properties of the parental body

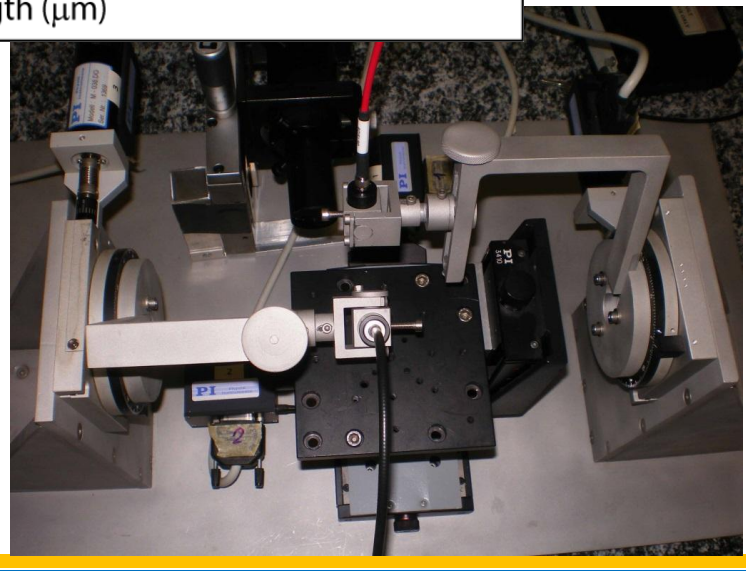
VNIR spectroscopy

Reflectance spectra in the VNIR - Absorption parameters



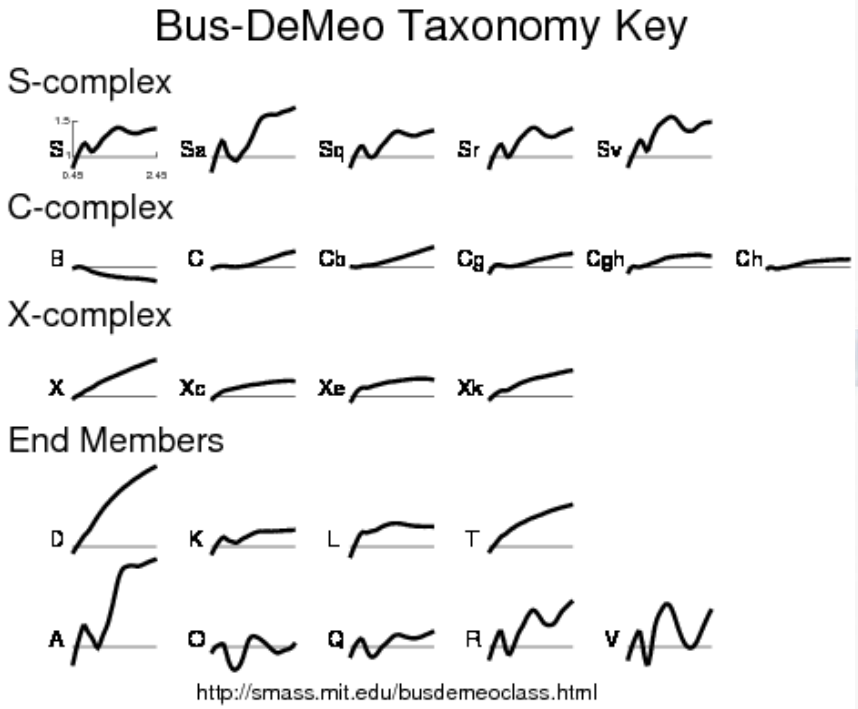




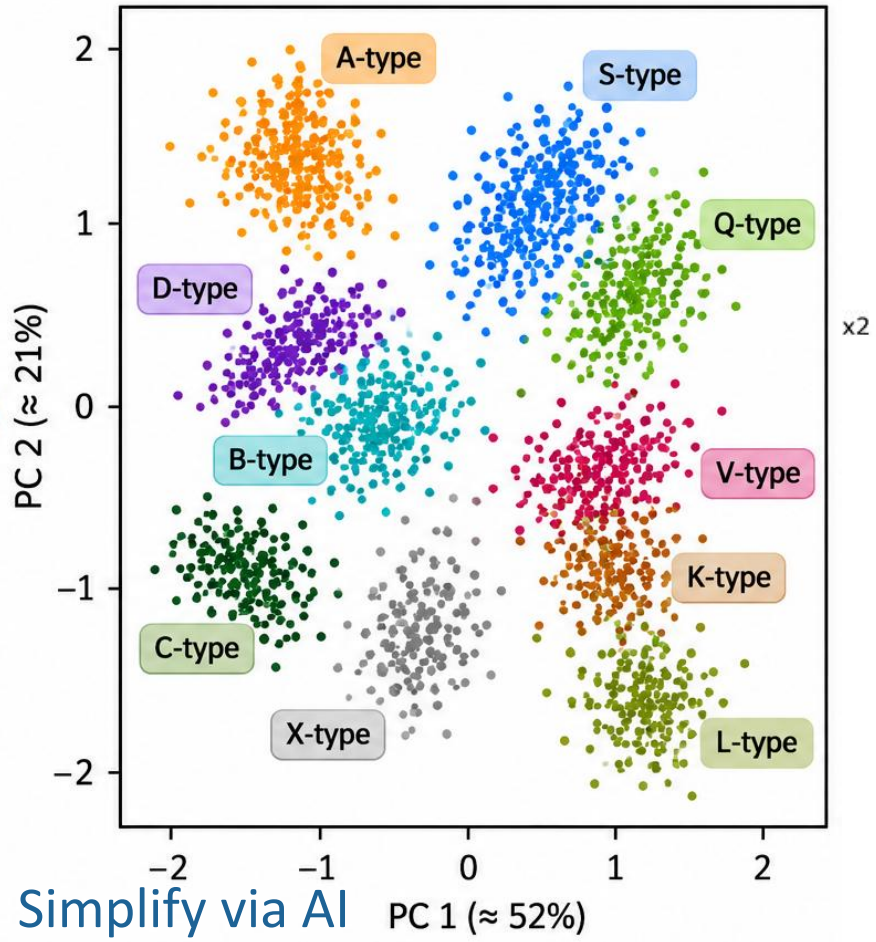


Small Bodies Taxonomy

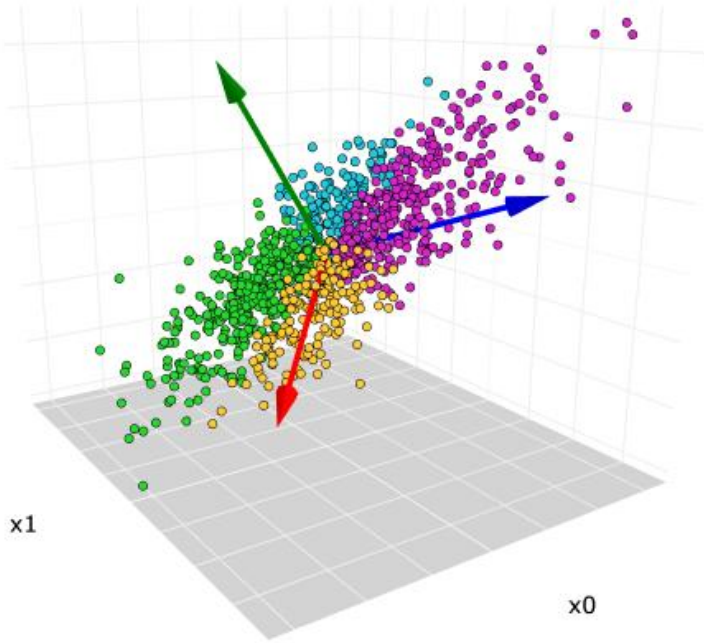
Bus–DeMeo Taxonomic Classes: Representative Spectra



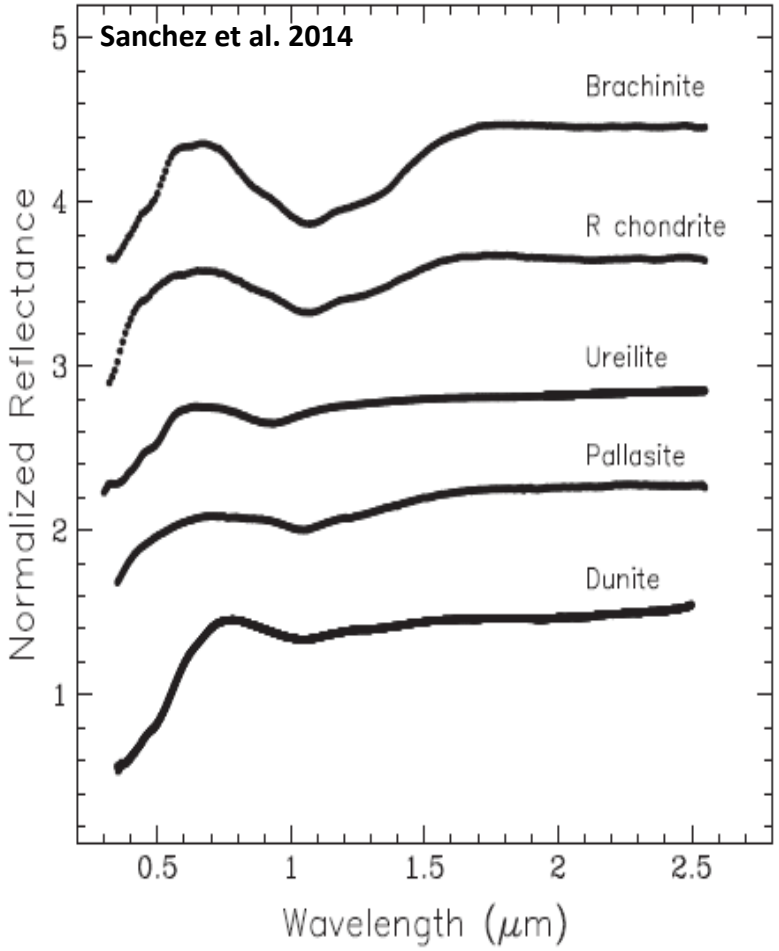
PCA: Spectral Families in PC1–PC2 Space



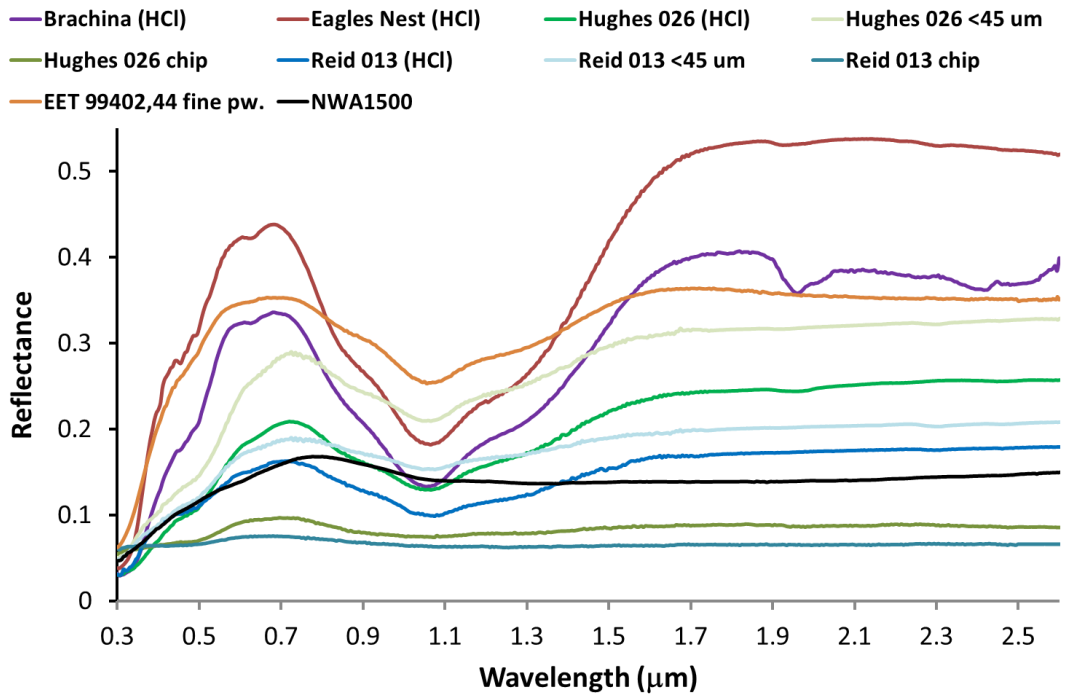
Simplify via AI



Reflectance of Brachinites so far

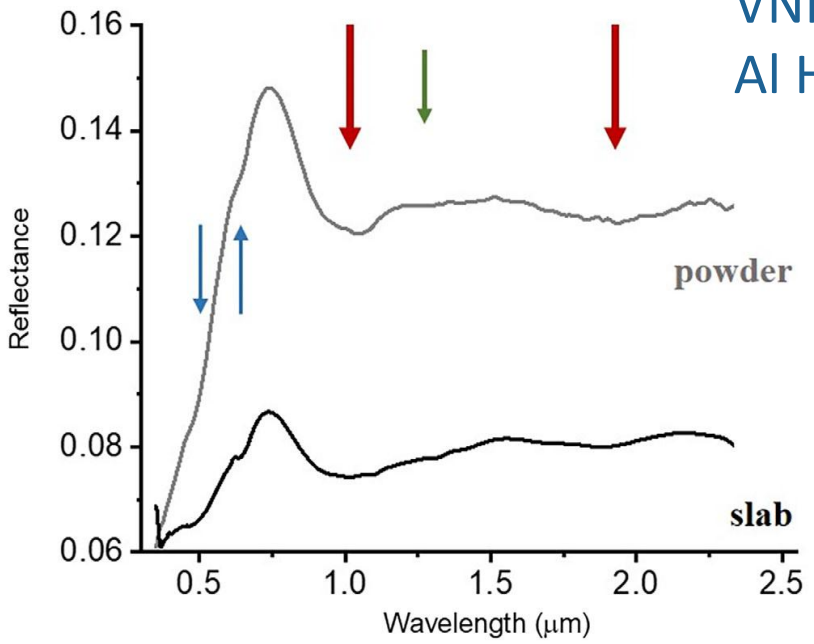


VNIR Spectra of other meteorites from Relab:



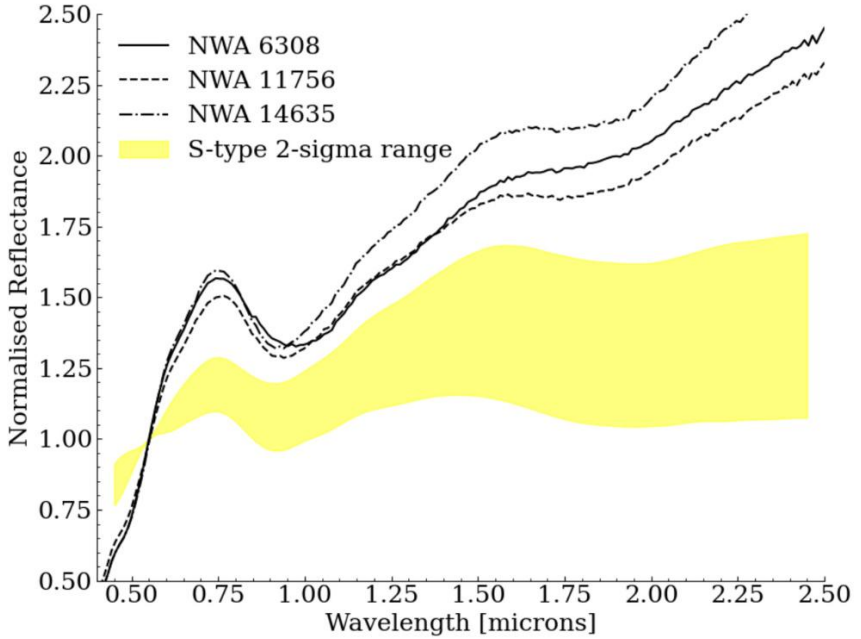
Reflectance of Brachinites so far

Carli et al. 2023

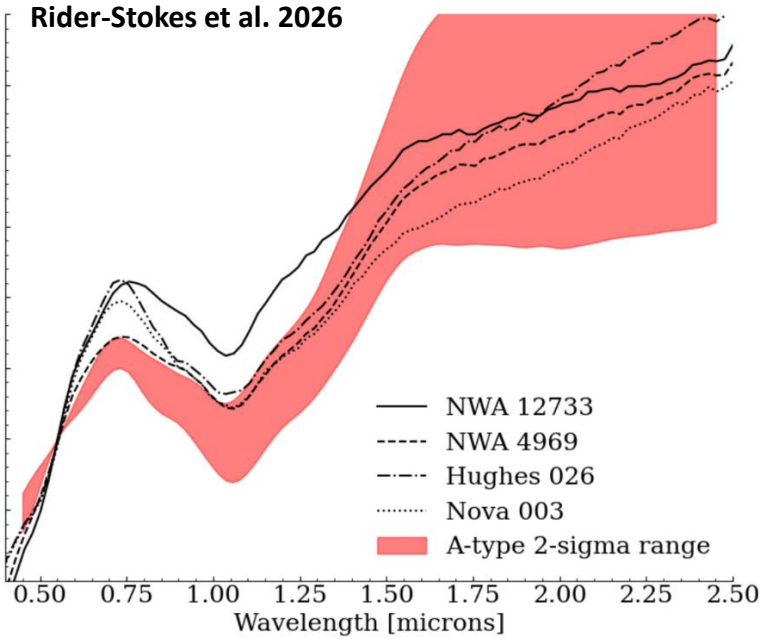


VNIR Spectra of
Al Huwaysah 010

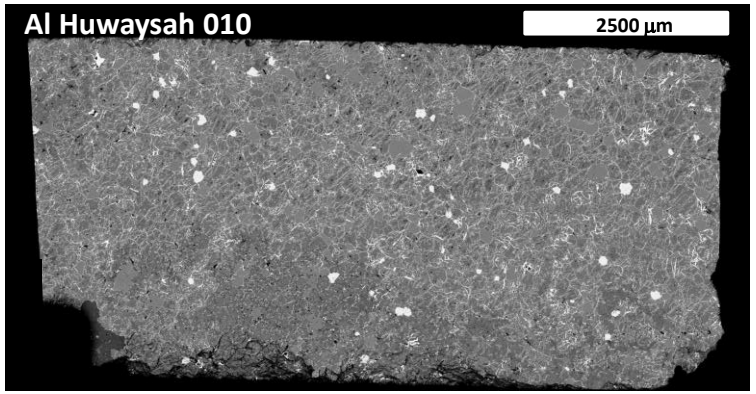
Spectra of UBA
+ brachinites

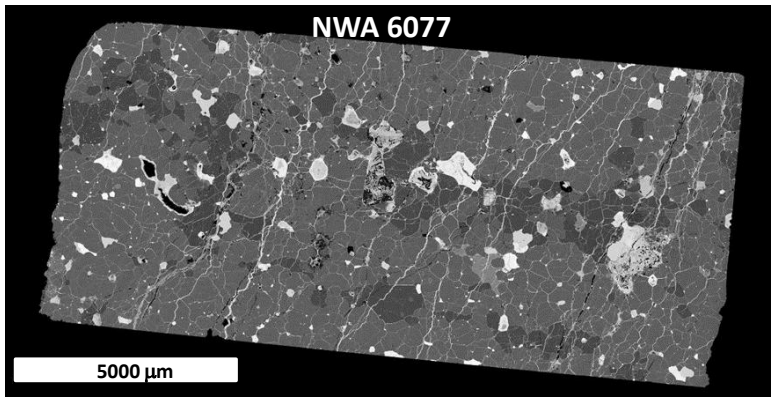


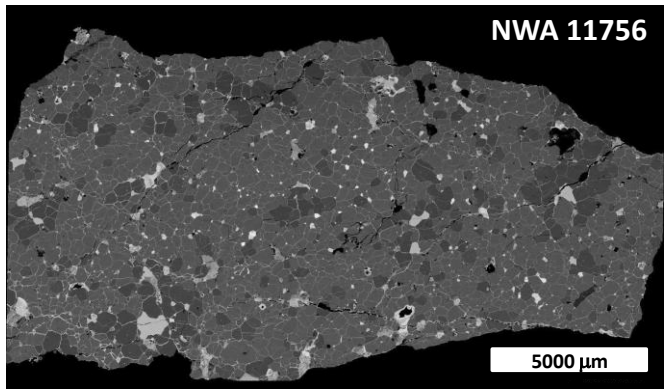
Rider-Stokes et al. 2026



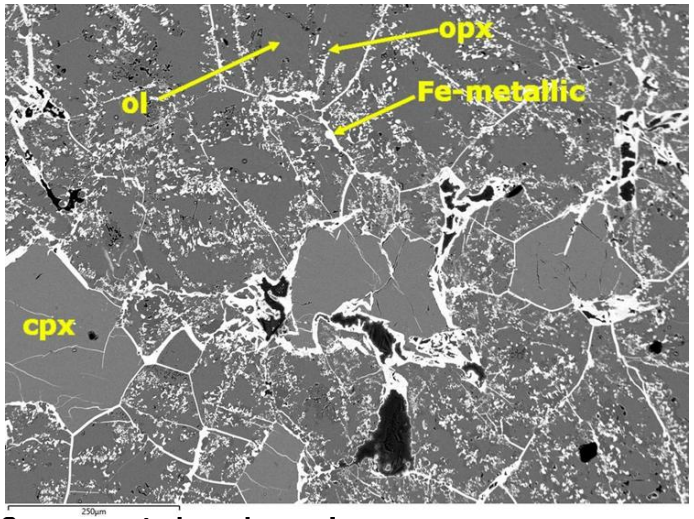
Brachinites : a "red-oxidized" word

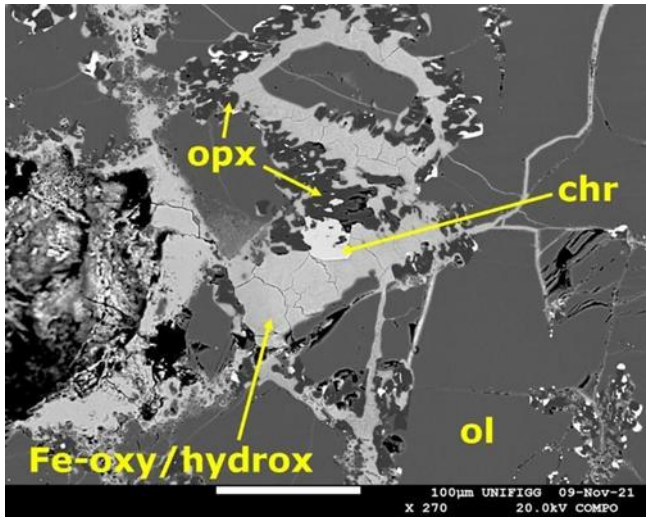


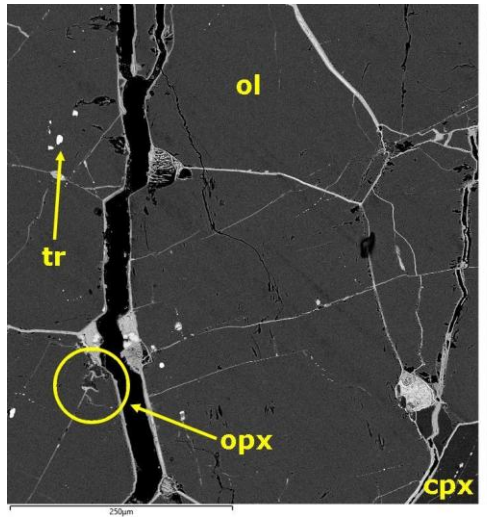


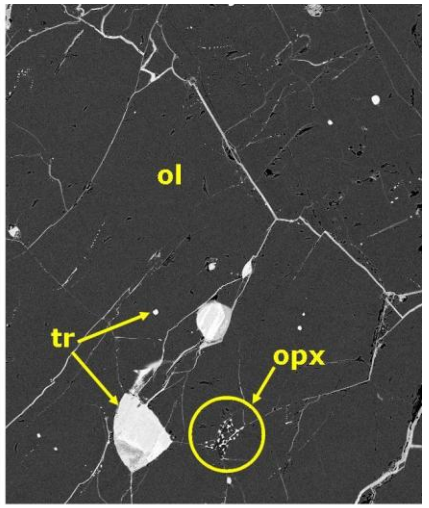


RED → **OX**



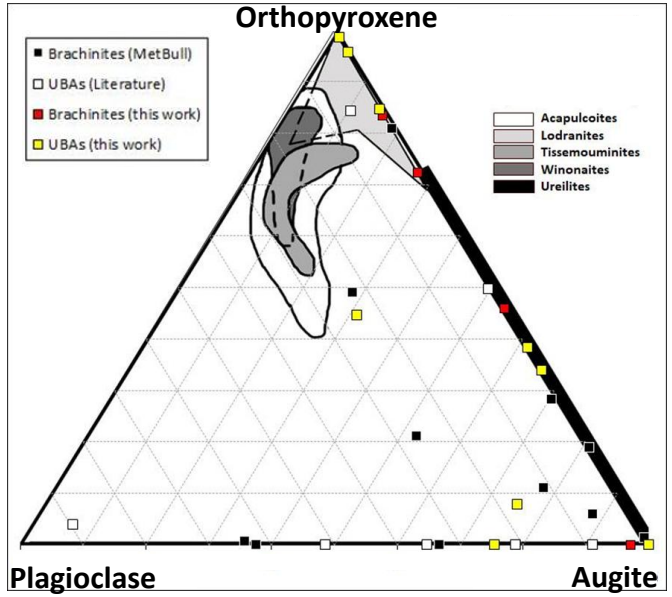


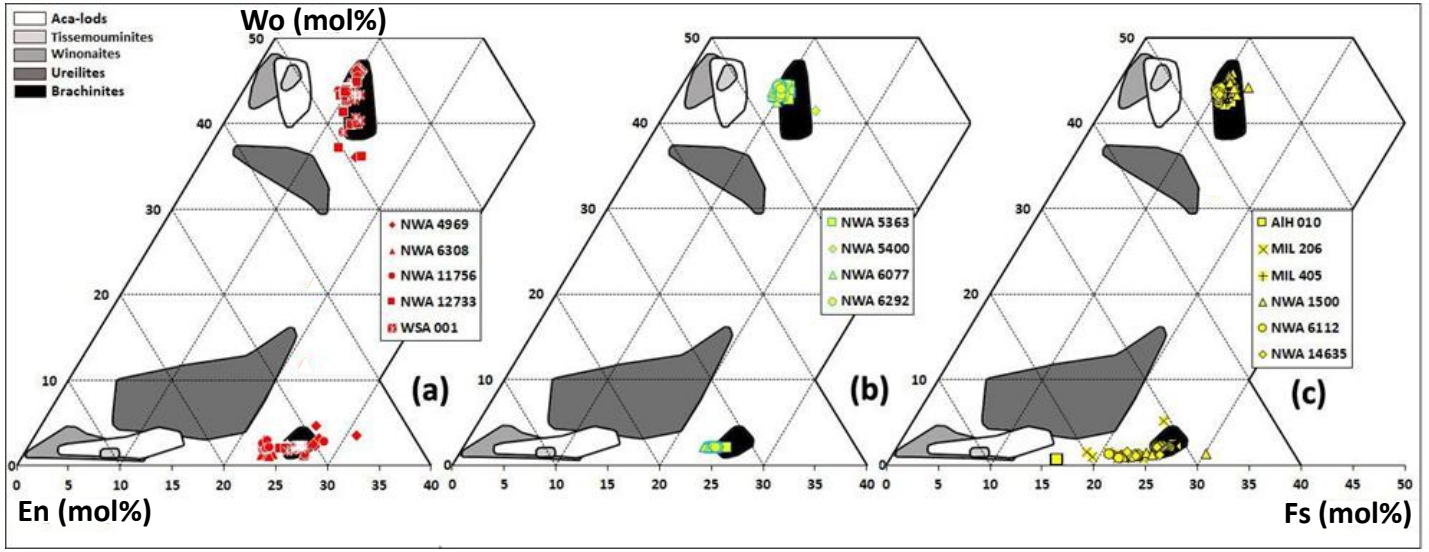


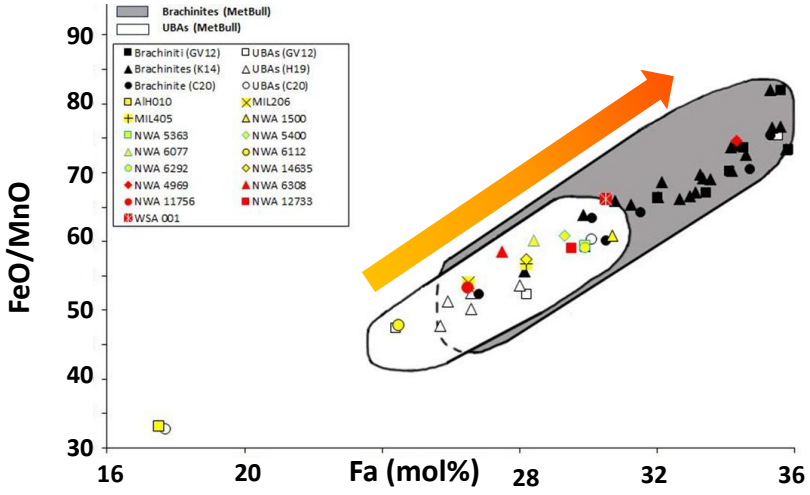


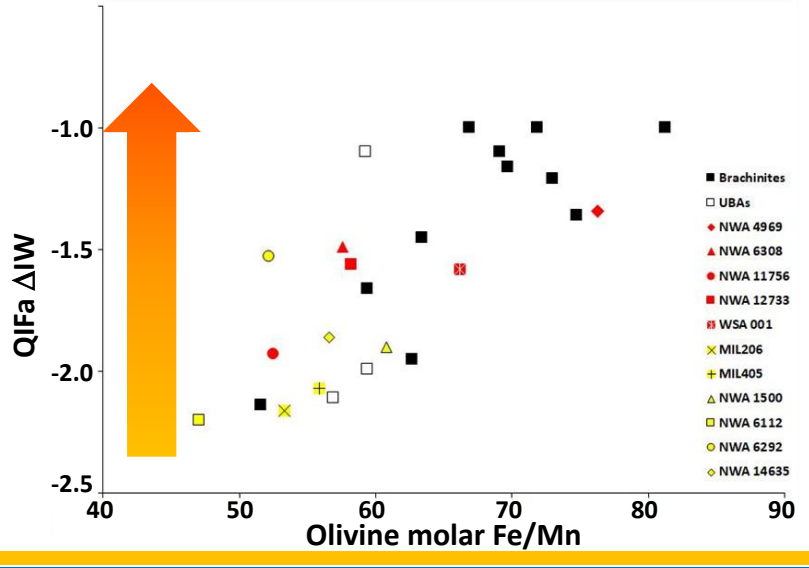
Cuppone et al. under review

Brachinites : a "red-oxidized" word





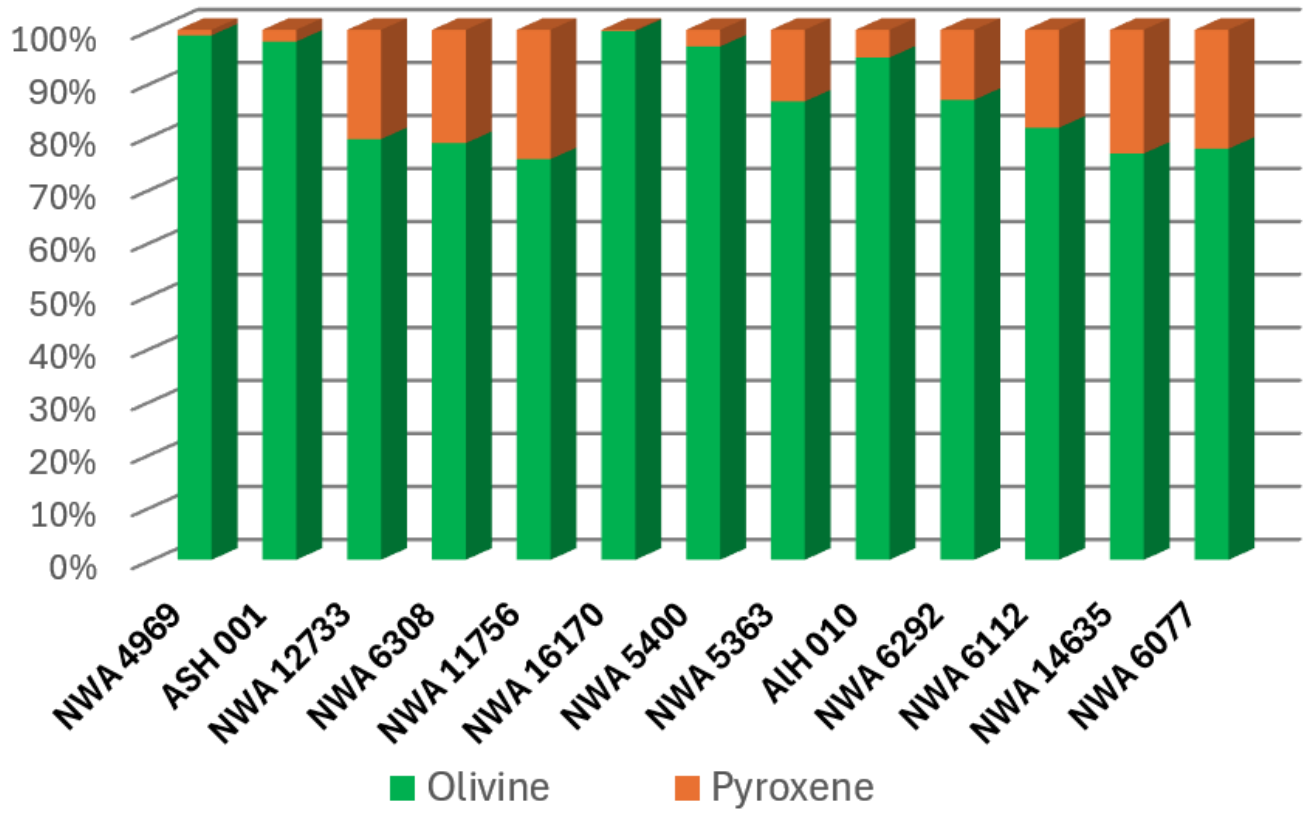




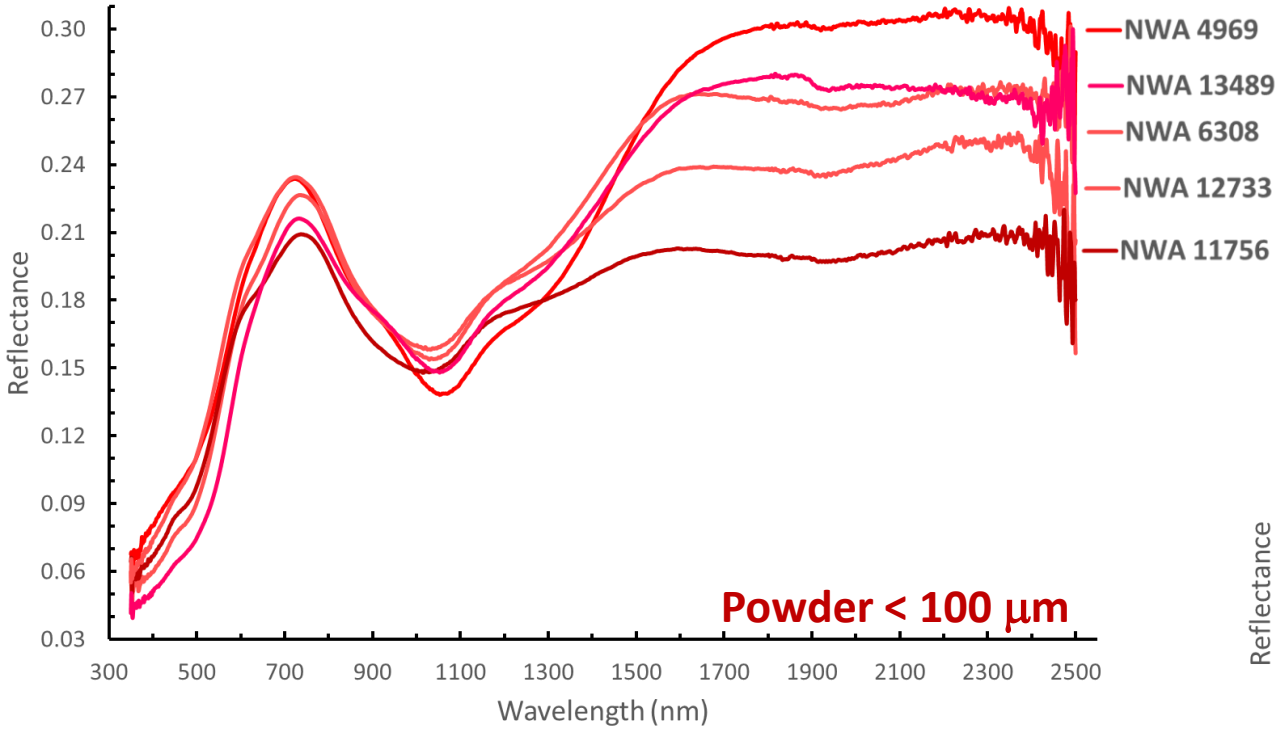
Cuppone et al. under review

Brachinites mafic phases

Meteorite	Olivine %	Reference
NWA 6077	60.2	This work
NWA 14635	77 63.2	Rider Stokes et al. 2026; this work
NWA 6112	64.0	This work
MIL 090206	65.2	This work
NWA 11756	76 67.3	Crossley et al. 2020; This work
NWA 6308	70.2	This work
NWA 6292	70.3	This work
Al. H. 010	72.5	Carli et al. 2023
NWA 12733	74.5	This work
NWA 5363	81.3	This work
MIL 09405	83.2	This work
Ash Shaqqah 010	83.9	This work
NWA 1500	89.9	This work
NWA 5400	92.0	This work
NWA 4969	93.6	This work

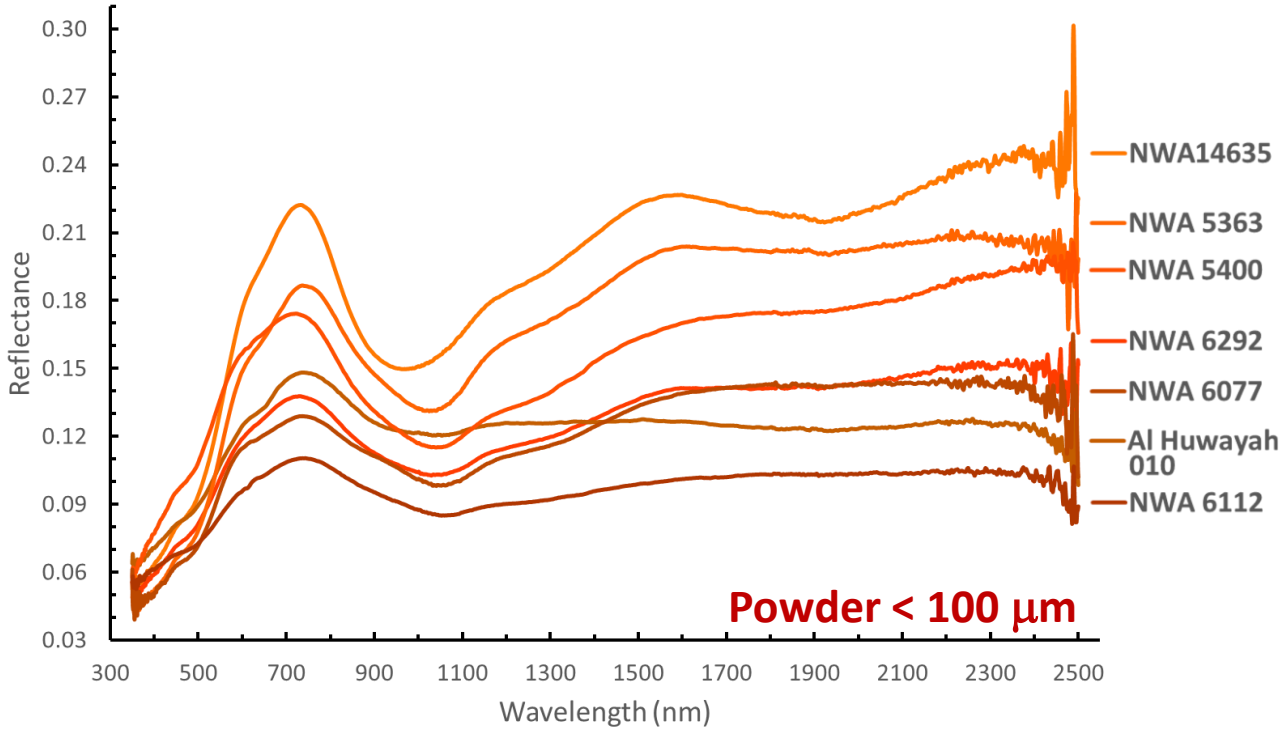


Reflectance of Brachinites this work



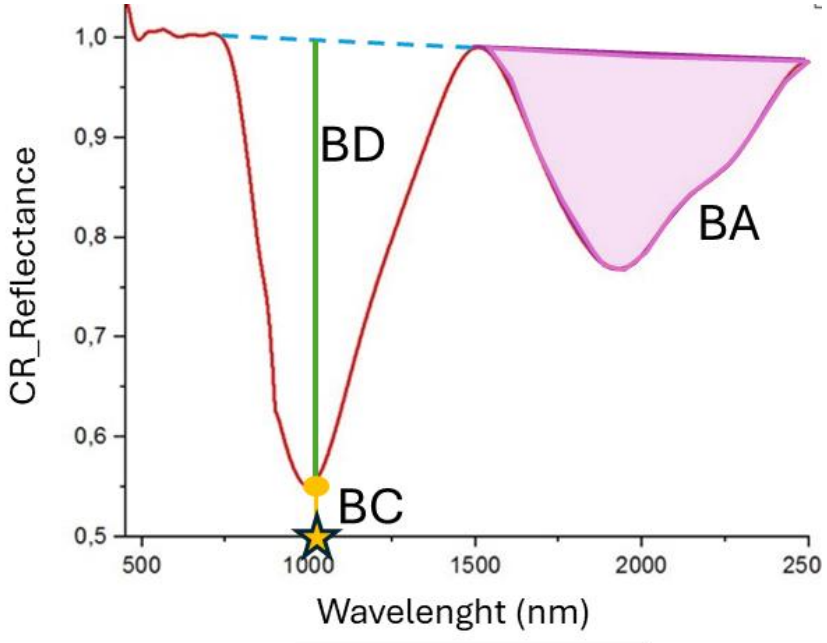
- Brachinites in S.S. looks like olivine dominated

- Brachinites, before UBA, looks like an olivine - pyroxene mixture



Carli et al. 2024 @ Met.Soc. conference

Reflectance properties

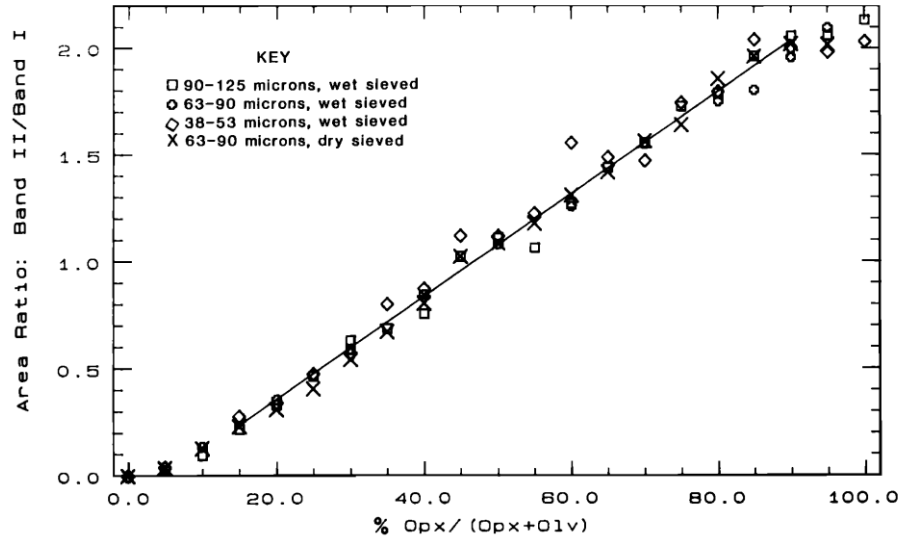


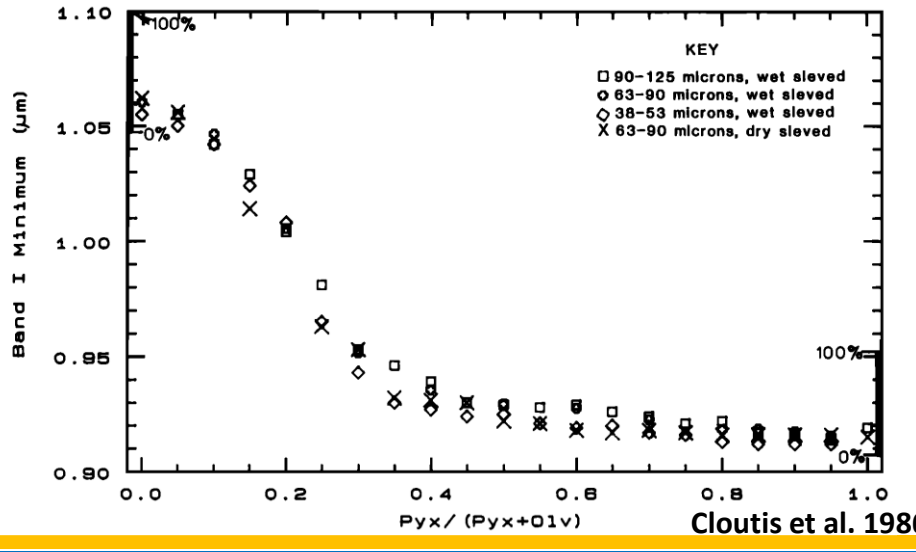
- Band Depth (BD)
- Band Center (BC)
- Band Area (BA)

Relationship between olivine and pyroxenes

e.g. Clark and Roush 1984; Cloutis et al. 1986

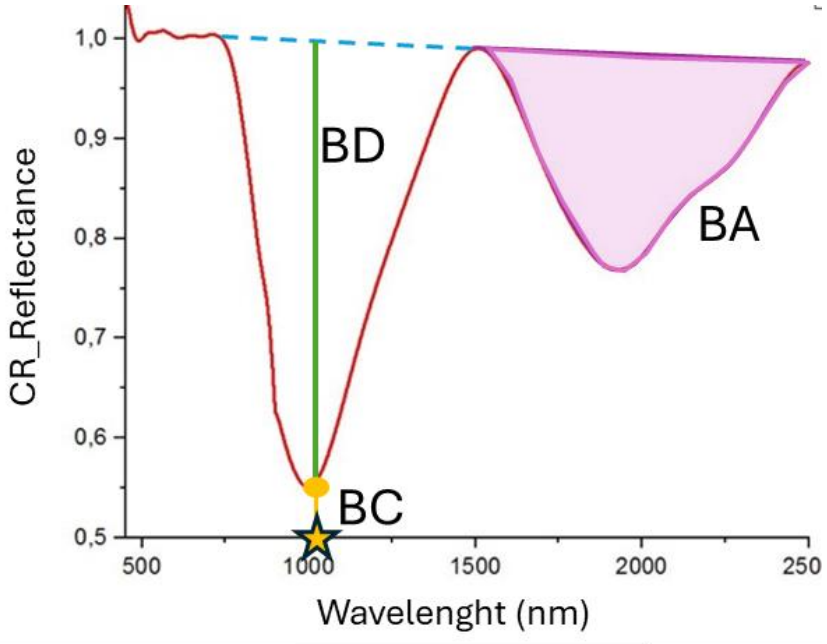
Mixtures olivine and Low-Ca pyroxenes





Cloutis et al. 1986

Reflectance properties



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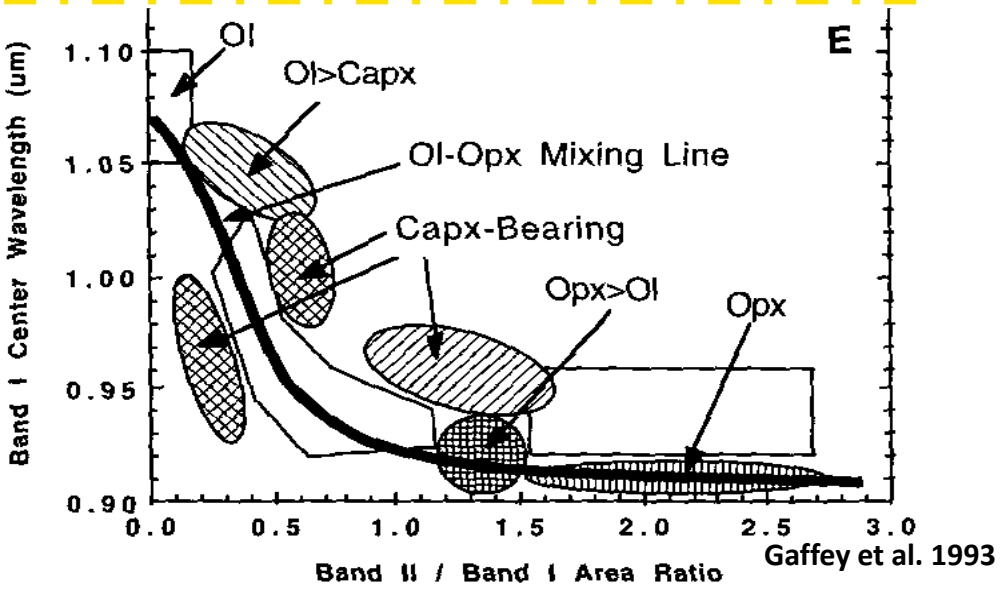
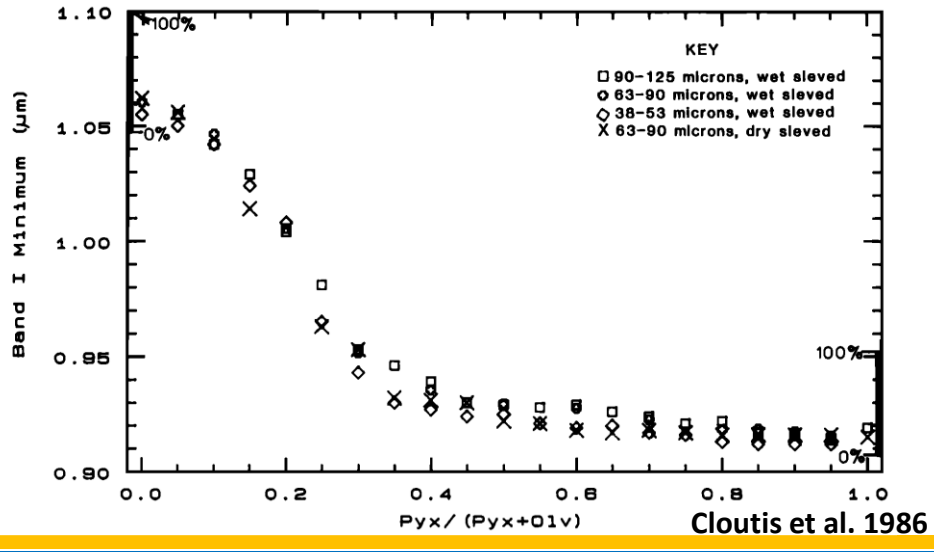
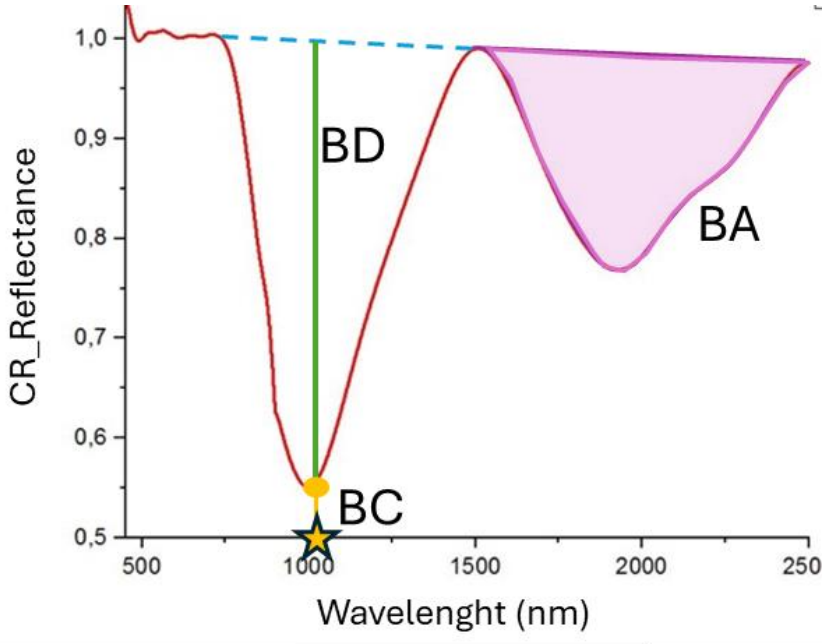


Gaffey et al. 1993



Cloutis et al. 1986

Reflectance properties



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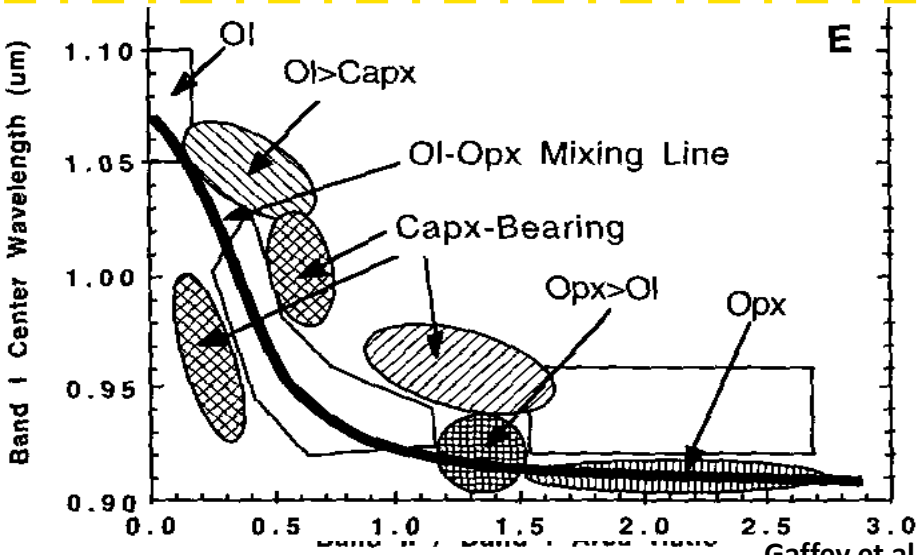
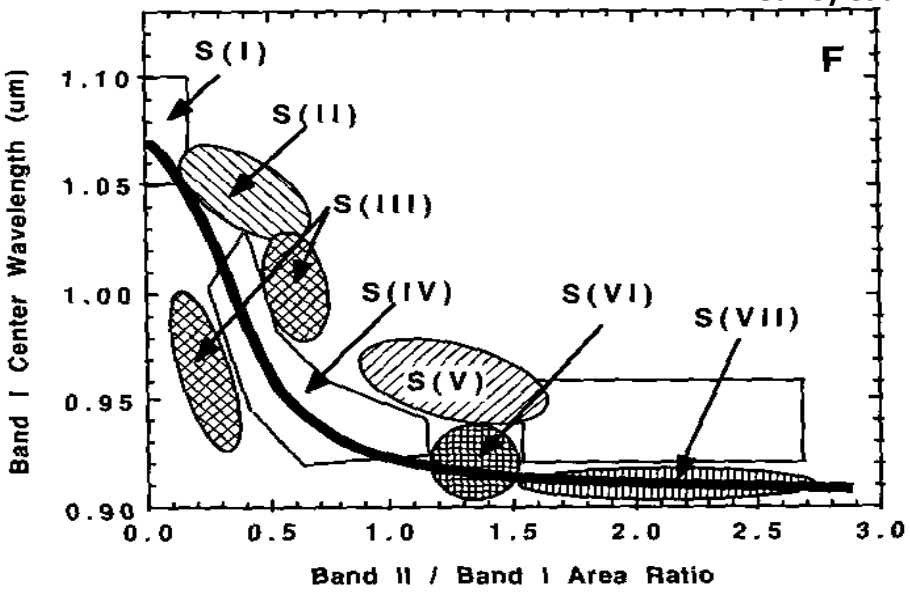
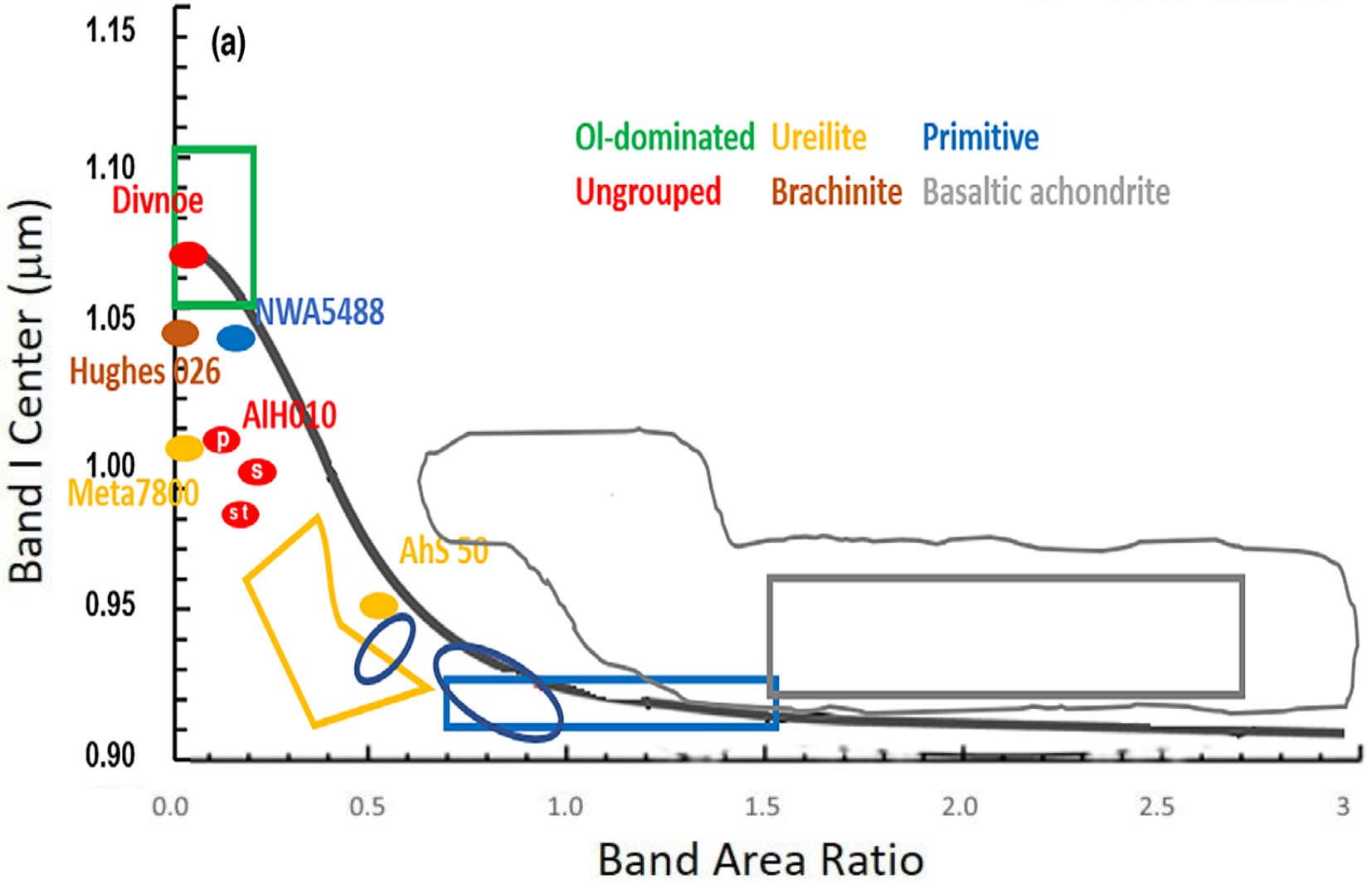


Gaffey et al. 1993



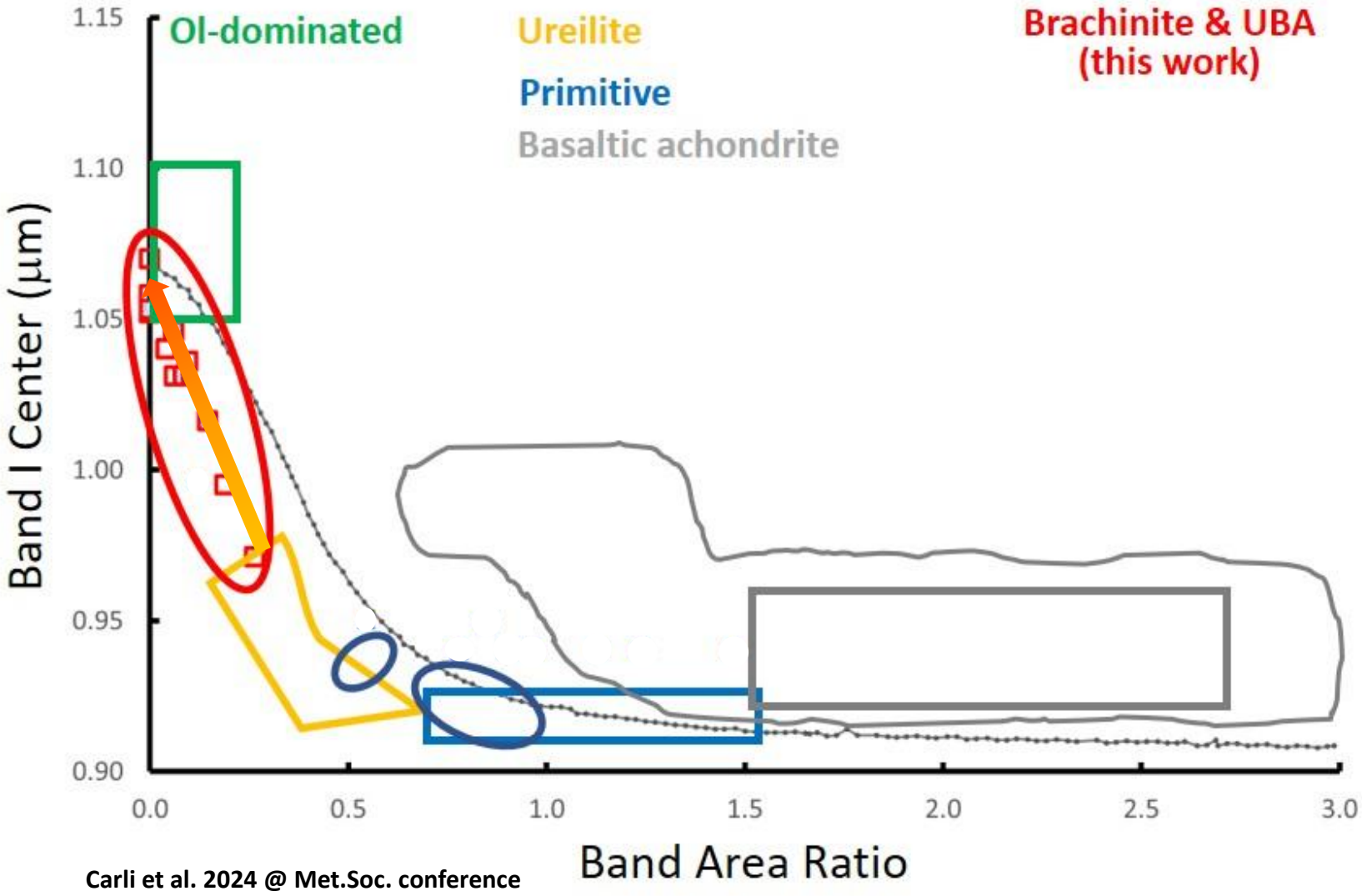
Reflectance properties



Carli et al. 2023 (references therein)

- Main achondrites group show a clustered variation of BIC vs BAR
- Peculiar samples shift outside the main cluster
- Brachinites are indicated as ol-dominated but no sistematic field as been identified yet, as well as no UBA are reported in the literature

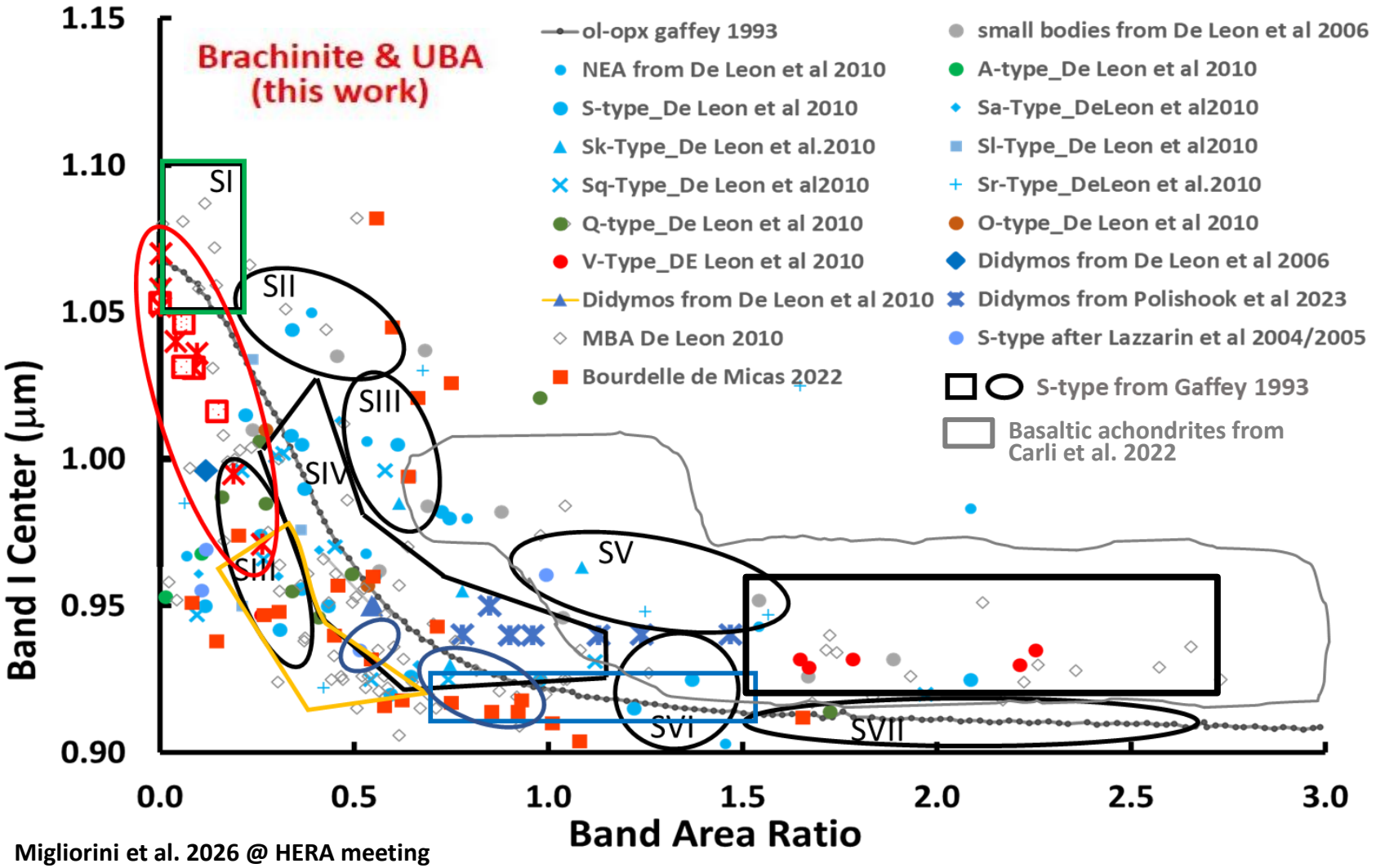
Brachinites VNIR field



Carli et al. 2024 @ Met.Soc. conference

- We identified a specific field for Brachinite as defined in Cuppone et al.
- The field characterized a region from urelite (defined in Cloutis et al. 2014) up to olivine dominated
- The trend is compatible with a variable olivine composition with respect the variation of clinopyroxene/orthopyroxene → following the trand of oxidation

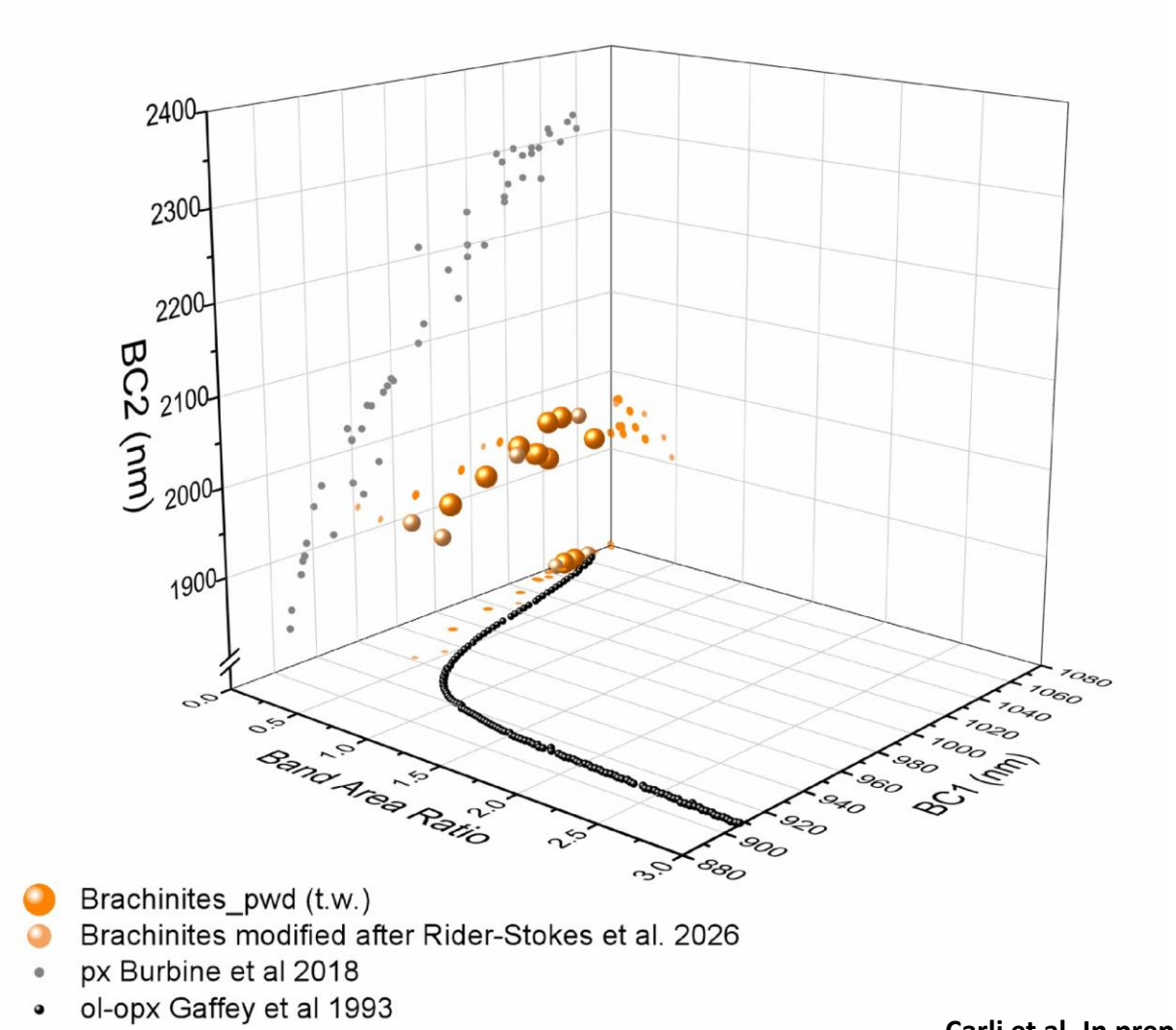
Meteorites vs Asteroids

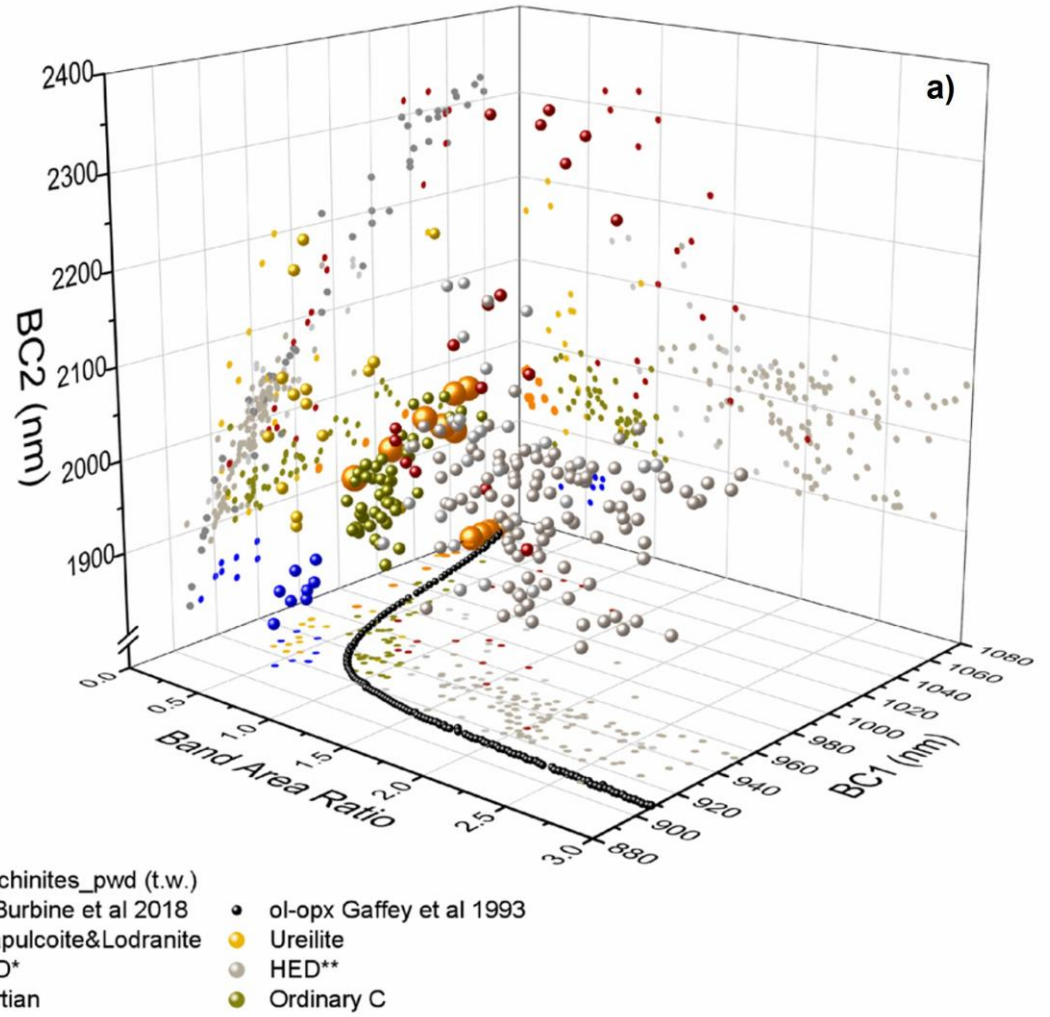


Migliorini et al. 2026 @ HERA meeting

- BIC vs BAR can be used to differentiated the spectral properties of parental bodies
- Comparison with meteorites can give indication of potential associations
- Brachinites identify potential correlation with objects that goes from S-type (SIII of Cloutis et al. 1986) up to A-type (SI of Cloutis et al. 1986)

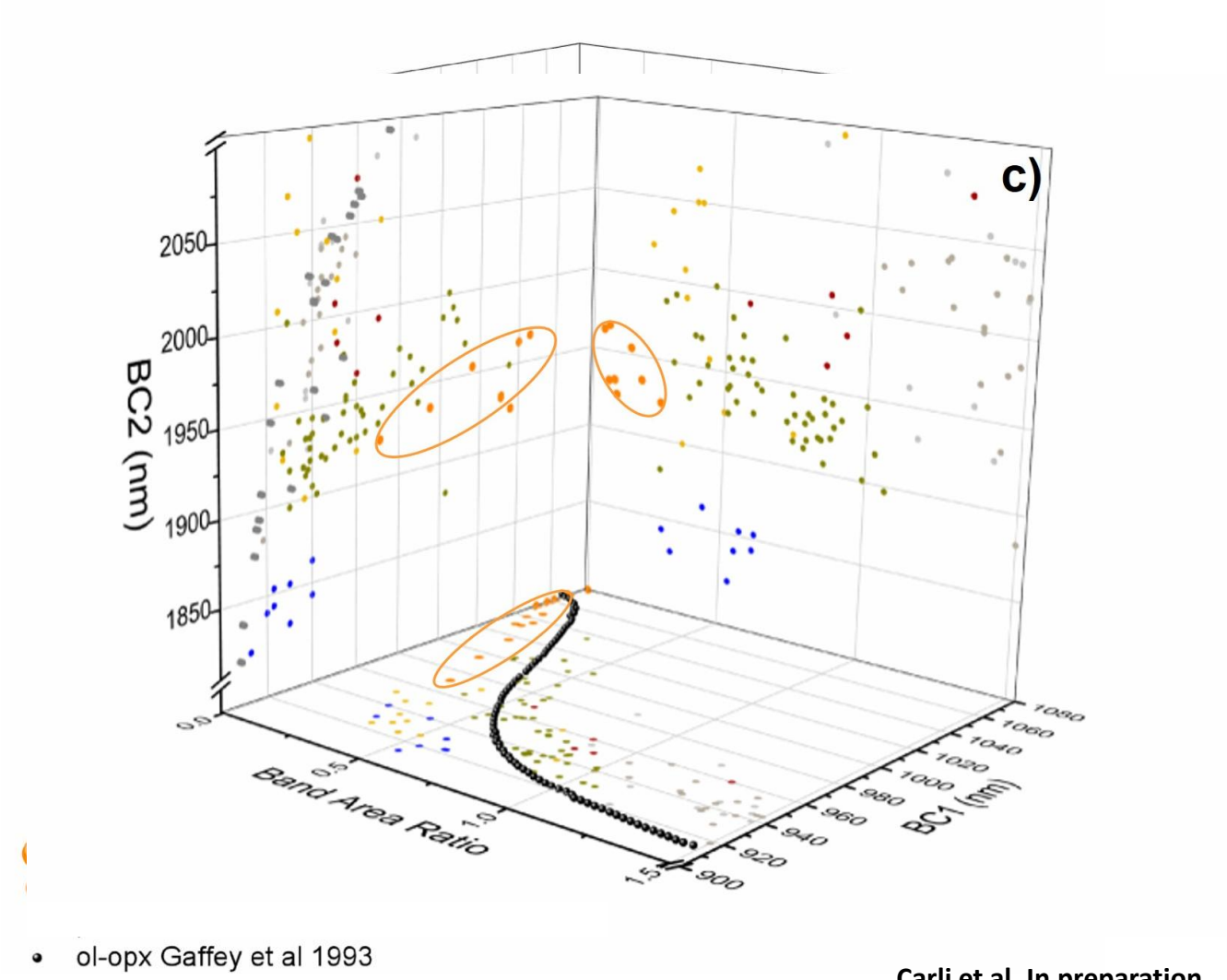
Brachinites vs Asteroids

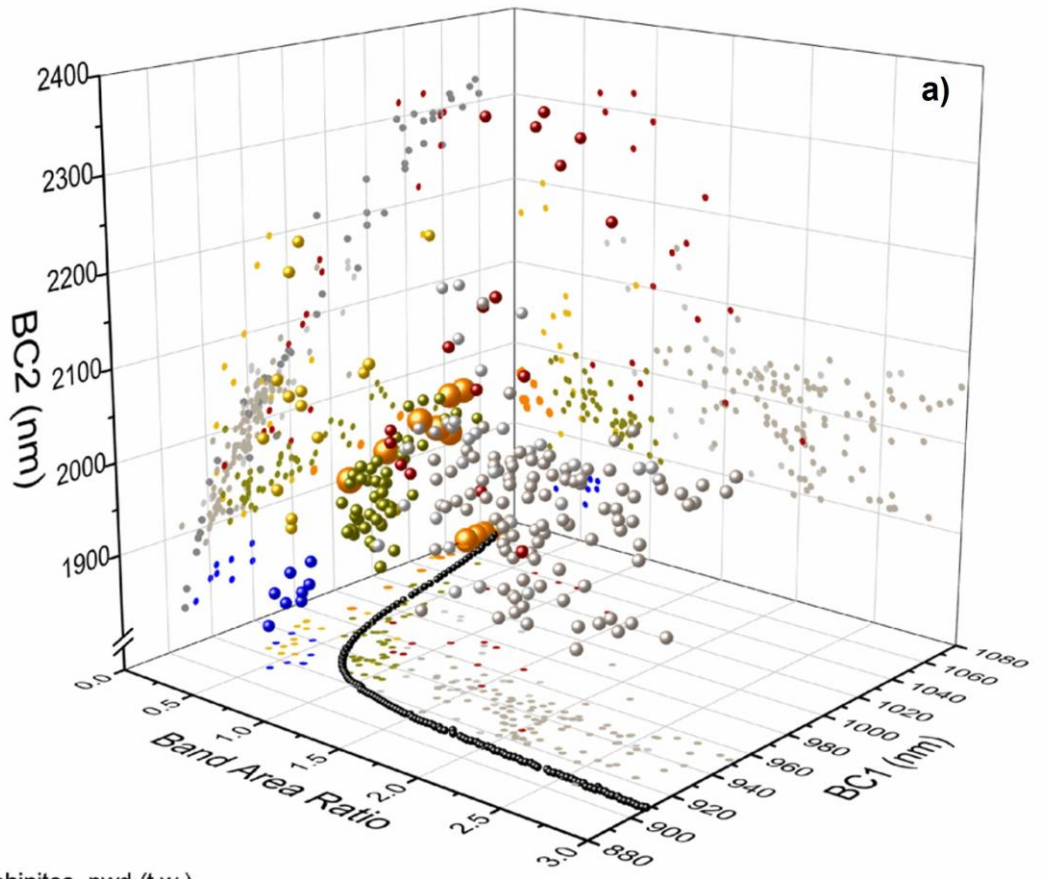




Carli et al. In preparation

Brachinites vs Asteroids

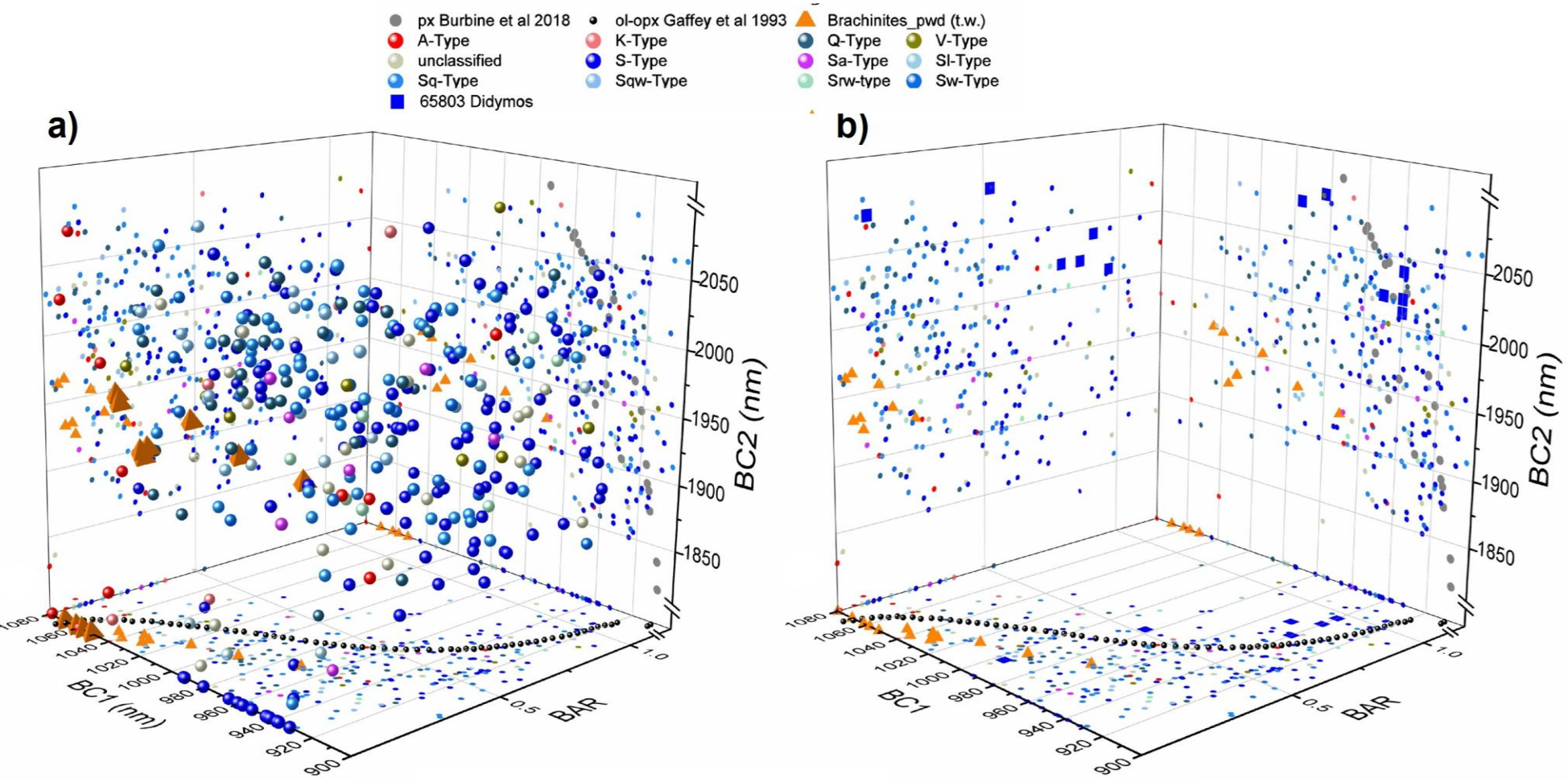




- ol-opx Gaffey et al 1993

Carli et al. In preparation

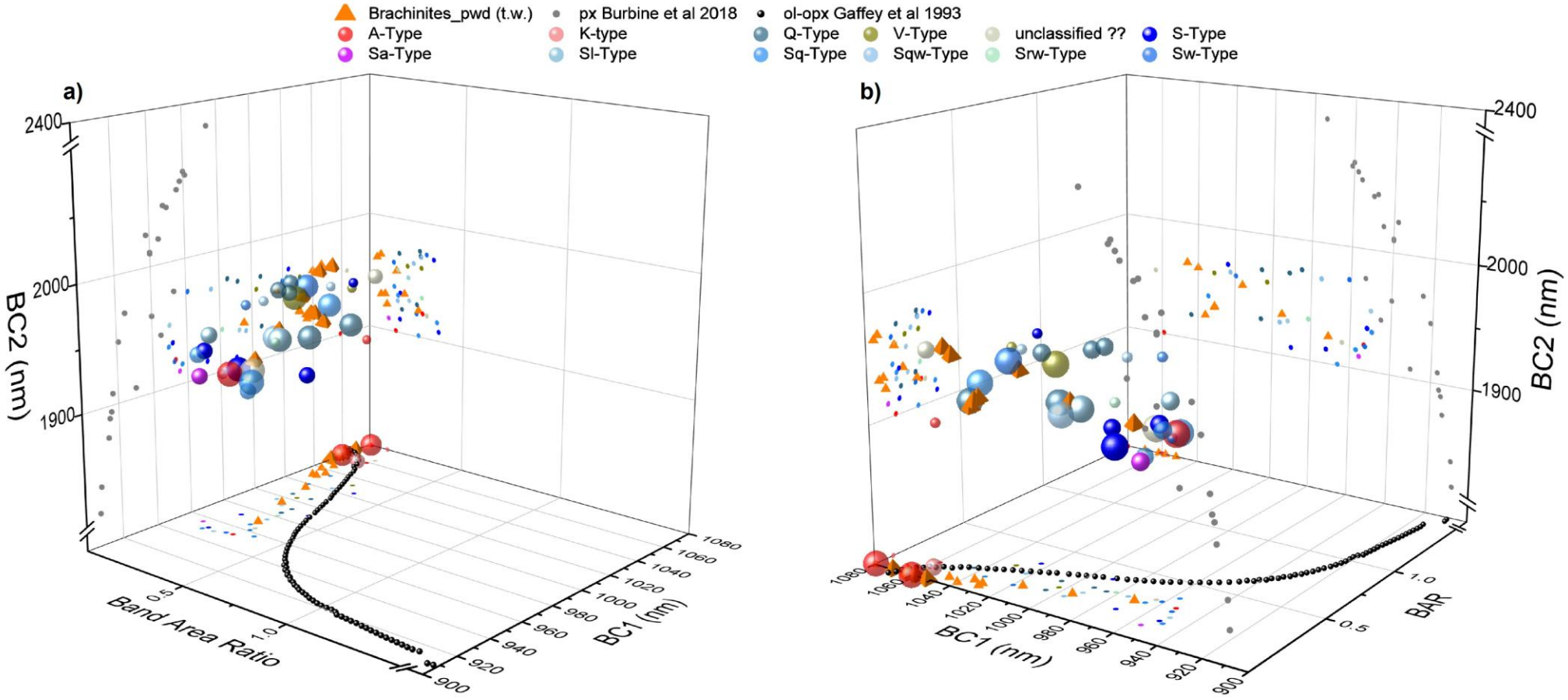
Brachinites vs Asteroids



- Small bodies from:
- DeLeon et al. (2006; 2010);
- Lazzarin et al. (2005; 2006);
- Polishook et al. (2022)
- McGraw et al. (2025)
- Binzel et al. (2019, indices calculated by Rider-Stokes et al. 2026)

Carli et al. In preparation

Brachinites vs Asteroids



Carli et al. In preparation

Small bodies from:

- Both NEA and MBA
- Mainly from S-type (Sq, Sa, Sw, Sl), A-Type, Q-Type
- Some of them could be compatible with Flora family (or NEA potentially coming from that family)
- Some other have high inclination (more compatible with Hungaria?, or more complex dinamic?)

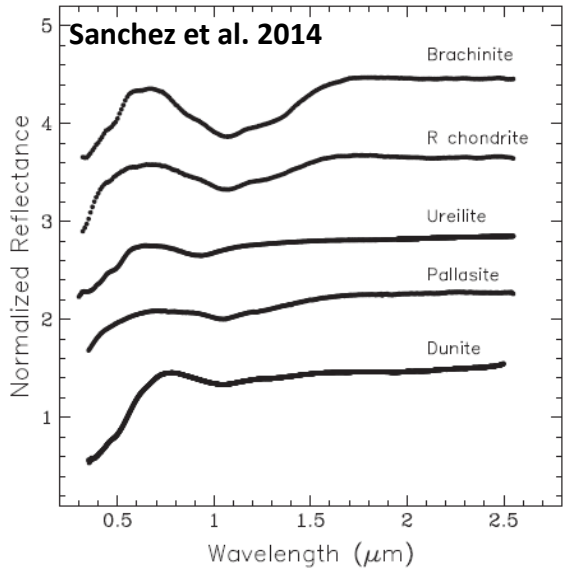
Take Home Message

- Brachinites and, previously, UBA are part of the same group, attributable probably to the same parent body.
- Reflectance varies with reduced-oxidized variation, coherent with main mafic minerals variation, defining a specific field in B1C vs BAR (+ BC2).
- This field is compatible with object from S-type up to A-Type (or olivine dominated) asteroids.
- Material from the same parental body is expected to be part of more asteroid types, with a continued variation from the px/ol endmembers.

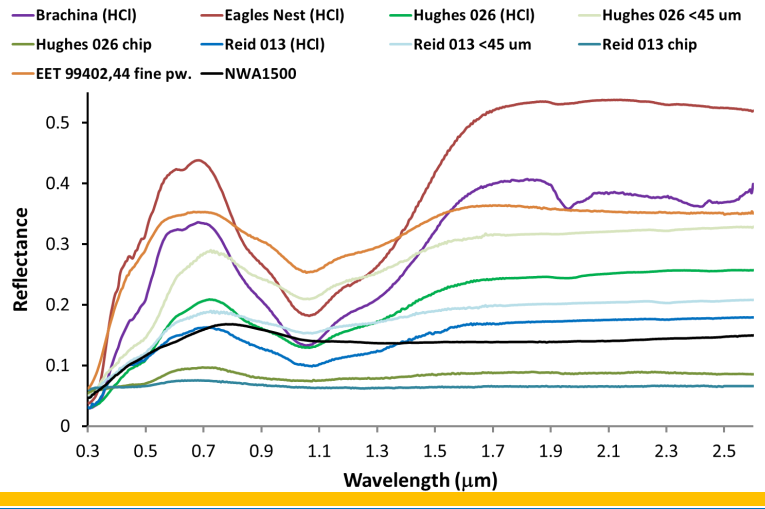
Acknowldgements

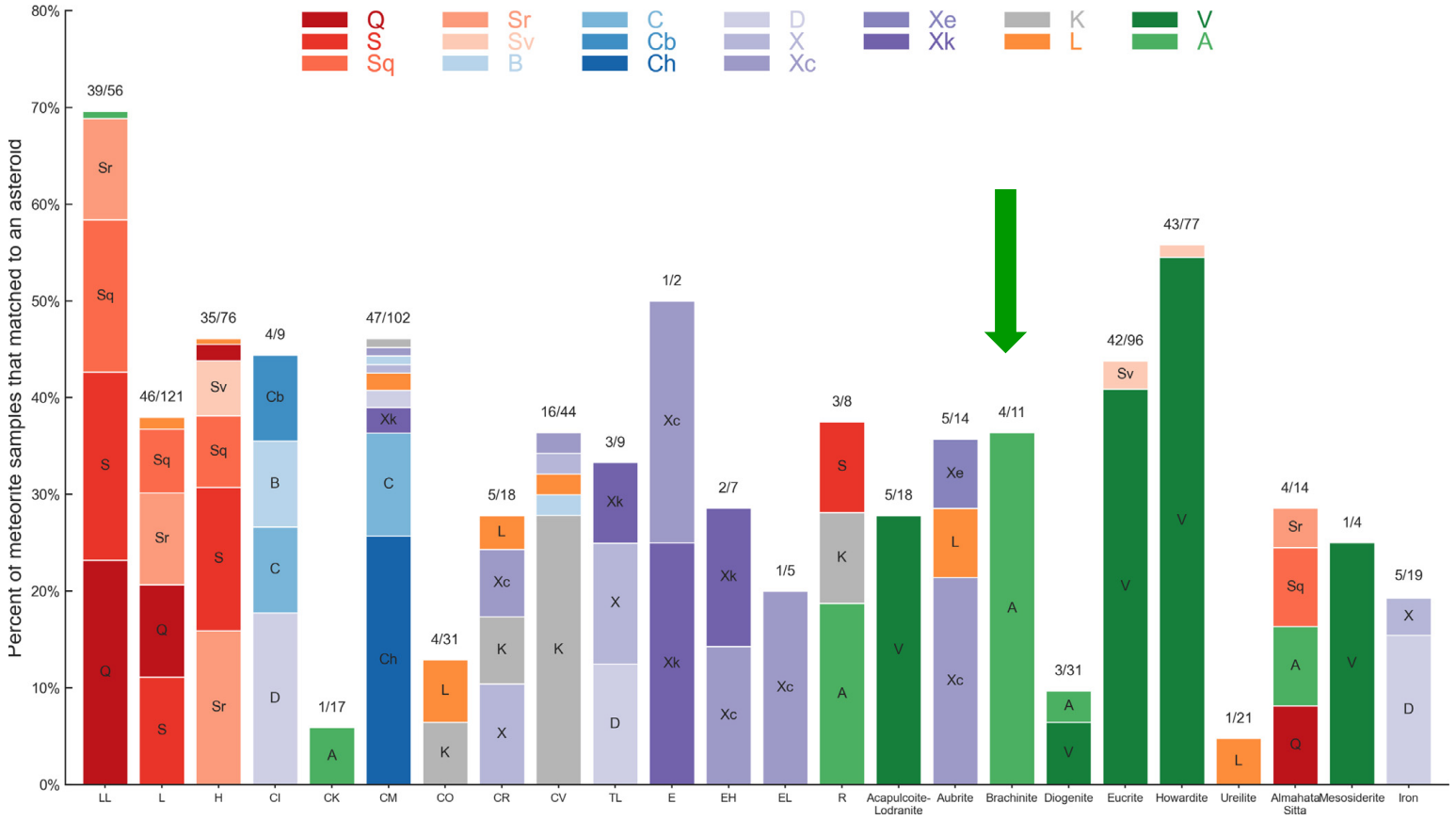
- This research was supported by:
  - ASI-INAF n.2018-16-HH.0 Ol-BODIES project
  - ASI agreement n. 2022-8-HH.0 for ESA’s Hera mission

Reflectance of Brachinites so far

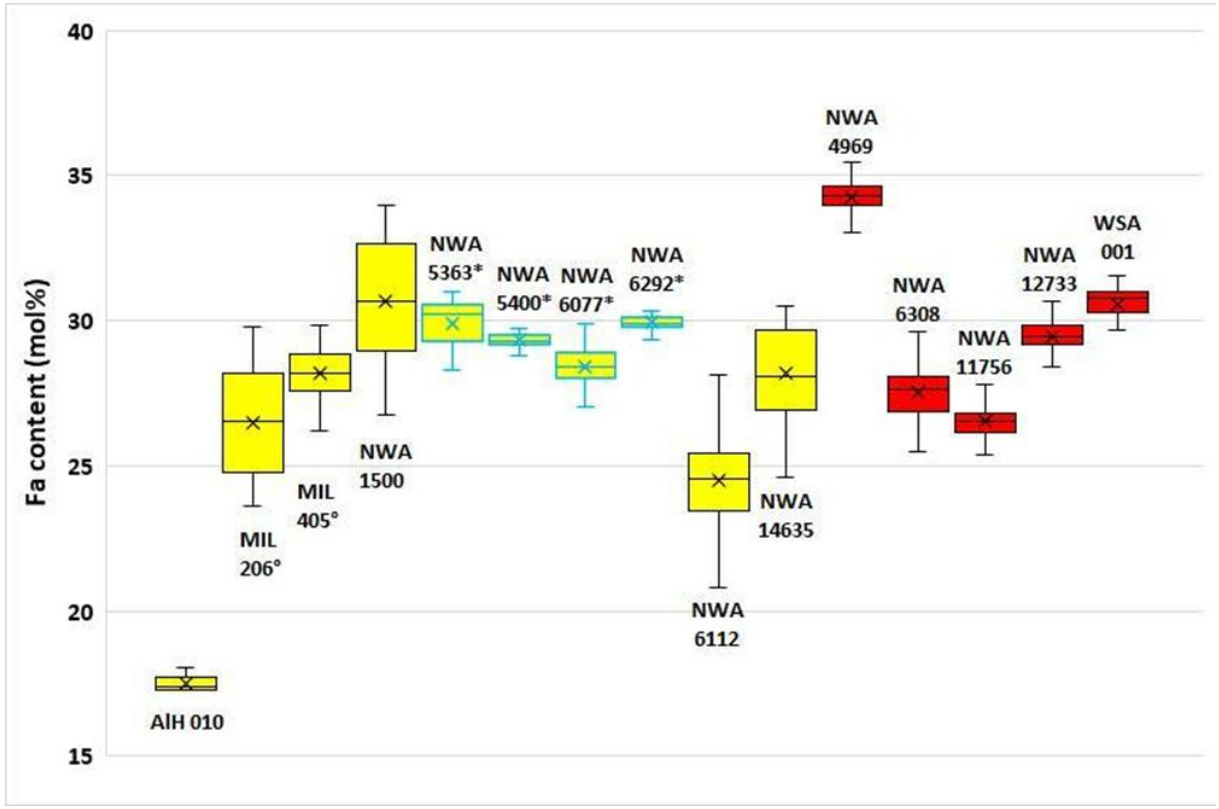


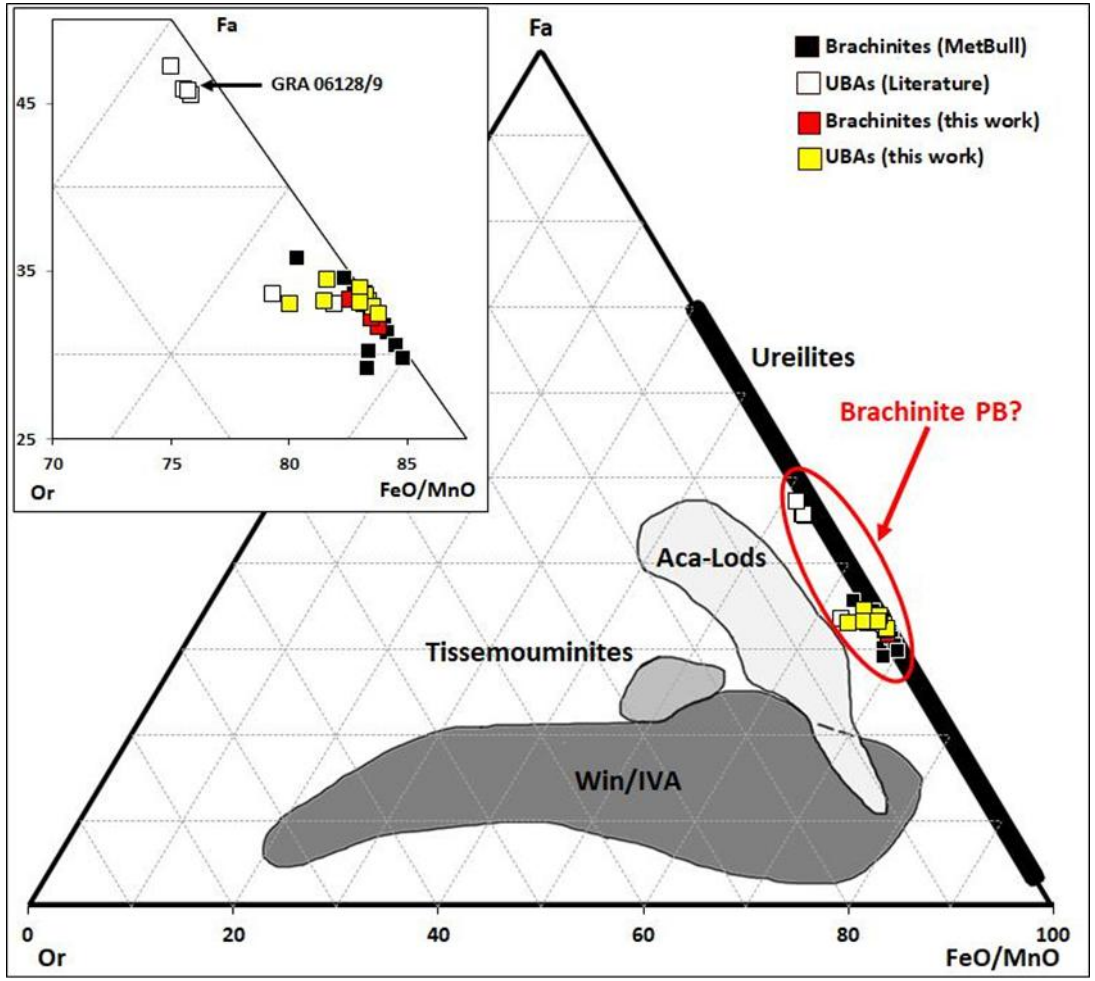
Spectra from Relab:

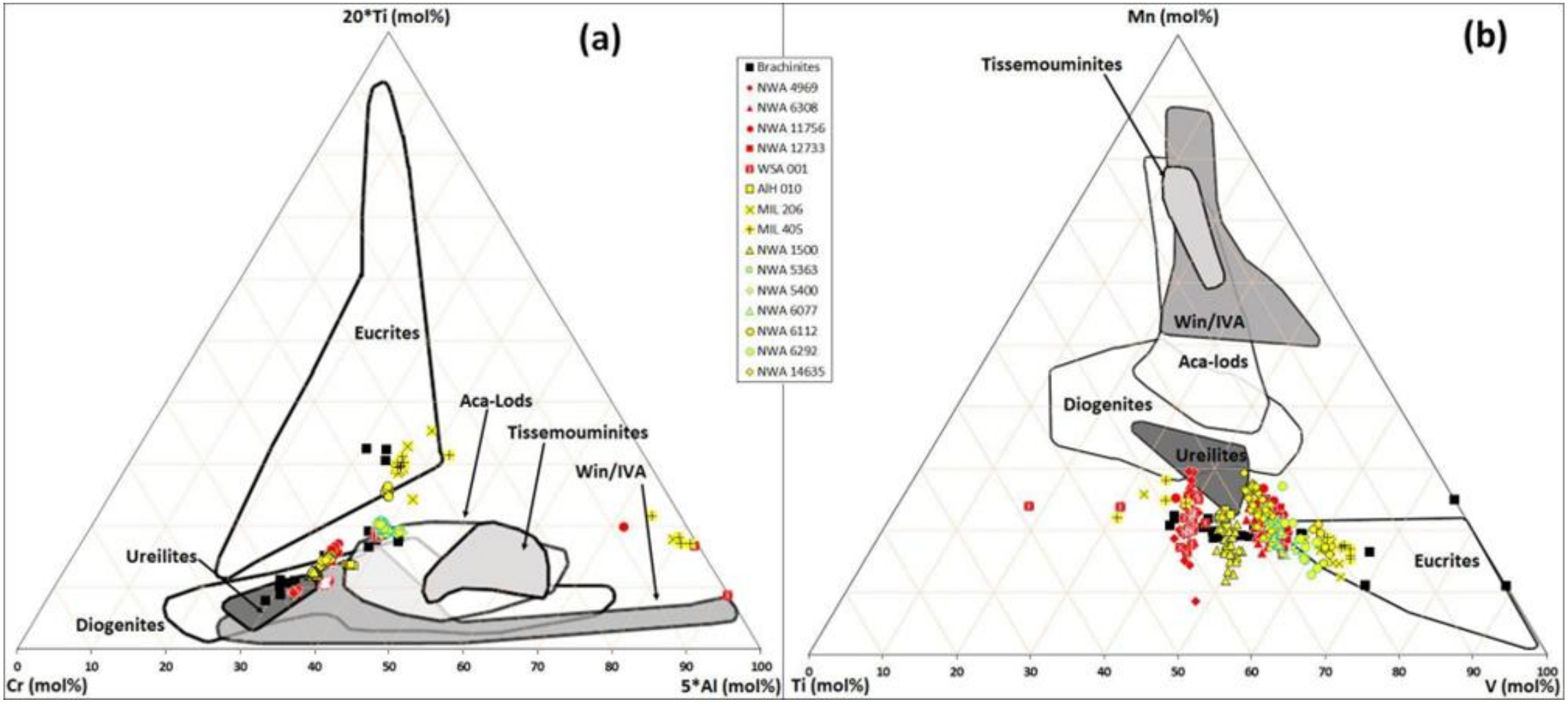


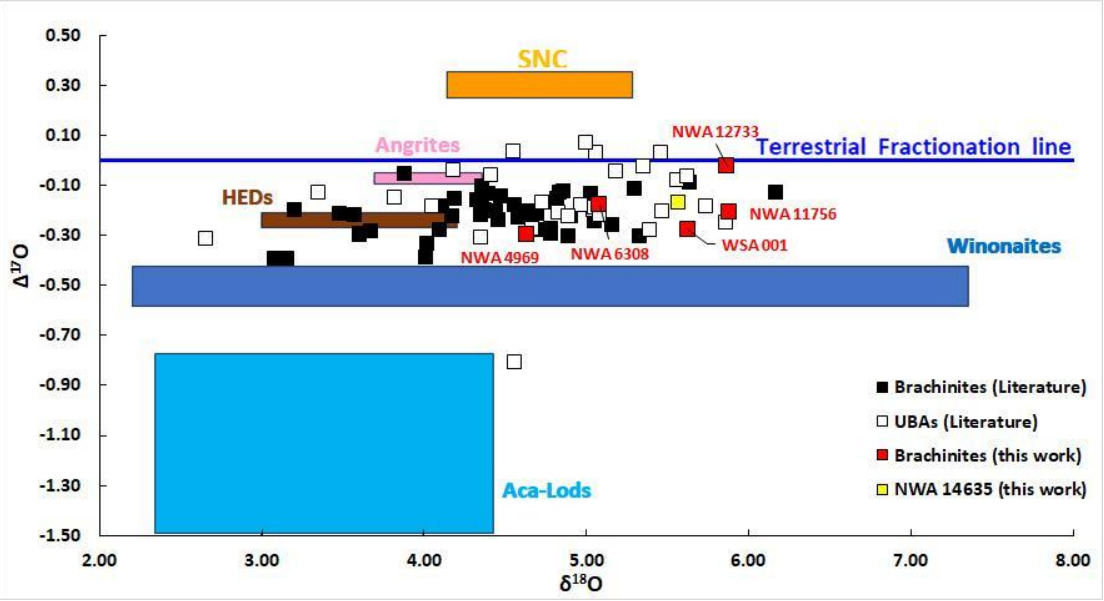


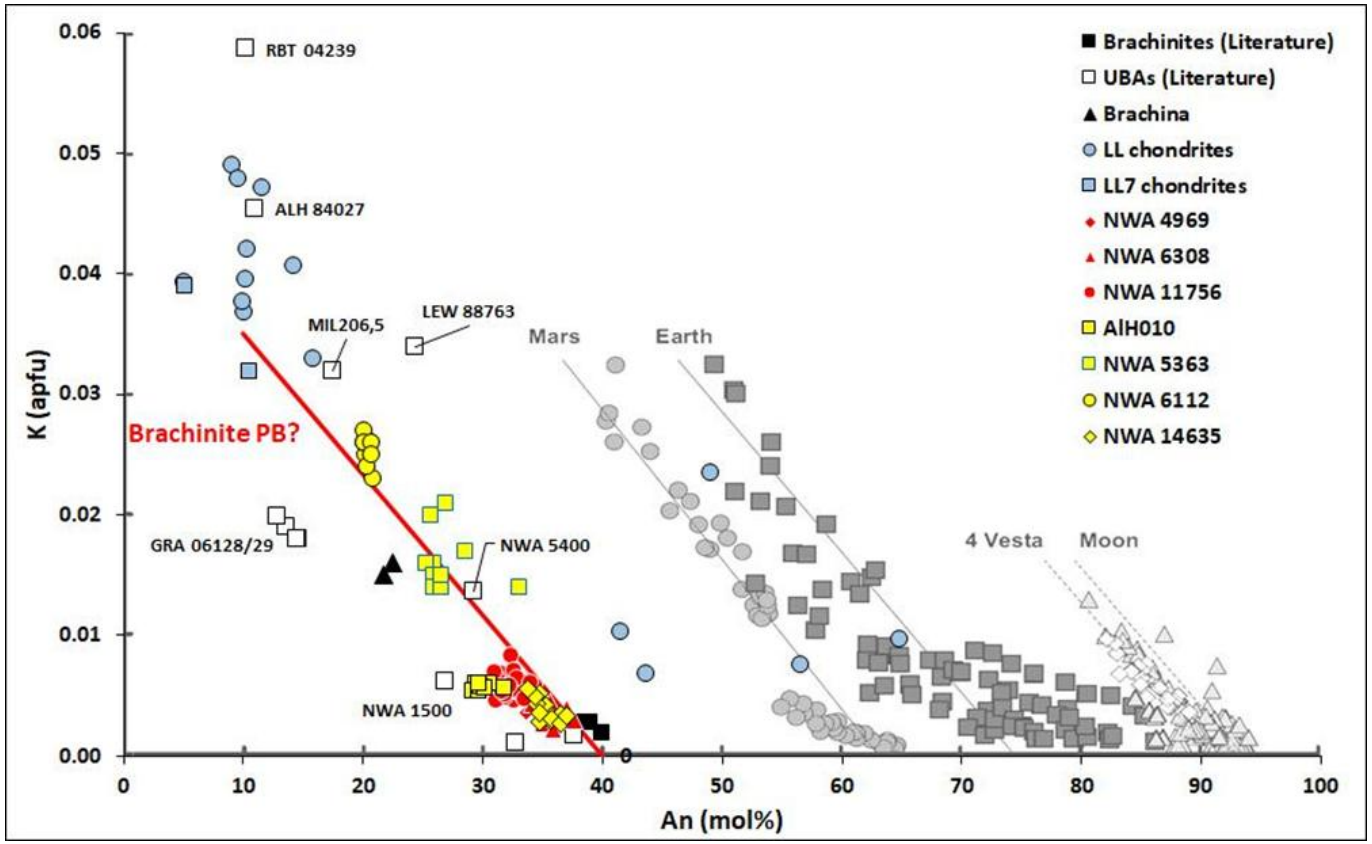
De Meo et al. 2022


Fa content (mol%)
40
35
30
25
20
15
AlH 010
MIL 206°
MIL 405°
NWA 1500
NWA 5363*
NWA 5400*
NWA 6077*
NWA 6292*
NWA 6112
NWA 14635
NWA 4969
NWA 6308
NWA 11756
NWA 12733
WSA 001


Fa
GRA 06128/9
45
35
25
70
75
80
85
Or
FeO/MnO
Brachinites (MetBull)
UBAs (Literature)
Brachinites (this work)
UBAs (this work)
Ureilites
Brachinite PB?
Aca-Lods
Tissemouminites
Win/IVA
0
20
40
60
80
100
Or
FeO/MnO


(a)
20*Ti (mol%)
Cr (mol%)
5*Al (mol%)
Eucrites
Aca-Lods
Tissemouminites
Win/IVA
Ureilites
Diogenites
Brachinites
NWA 4969
NWA 6308
NWA 11756
NWA 12733
WSA 001
AlH 010
MIL 206
MIL 405
NWA 1500
NWA 5363
NWA 5400
NWA 6077
NWA 6112
NWA 6292
NWA 14635
(b)
Mn (mol%)
Ti (mol%)
V (mol%)
Tissemouminites
Win/IVA
Aca-lods
Diogenites
Ureilites
Eucrites


SNC
Angrites
NWA 12733
Terrestrial Fractionation line
HEDs
NWA 11756
WSA 001
NWA 4969
NWA 6308
Winonaites
Aca-Lods
Brachinites (Literature)
UBAs (Literature)
Brachinites (this work)
NWA 14635 (this work)
Δ17O
δ18O


RBT 04239
ALH 84027
MIL206,5
LEW 88763
Mars
Earth
Brachinite PB?
GRA 06128/29
NWA 5400
4 Vesta
Moon
NWA 1500
Brachinites (Literature)
UBAs (Literature)
Brachina
LL chondrites
LL7 chondrites
NWA 4969
NWA 6308
NWA 11756
AlH010
NWA 5363
NWA 6112
NWA 14635
K (apfu)
An (mol%)

Band minimum

energy

ions in selected site of coordination

Band depth

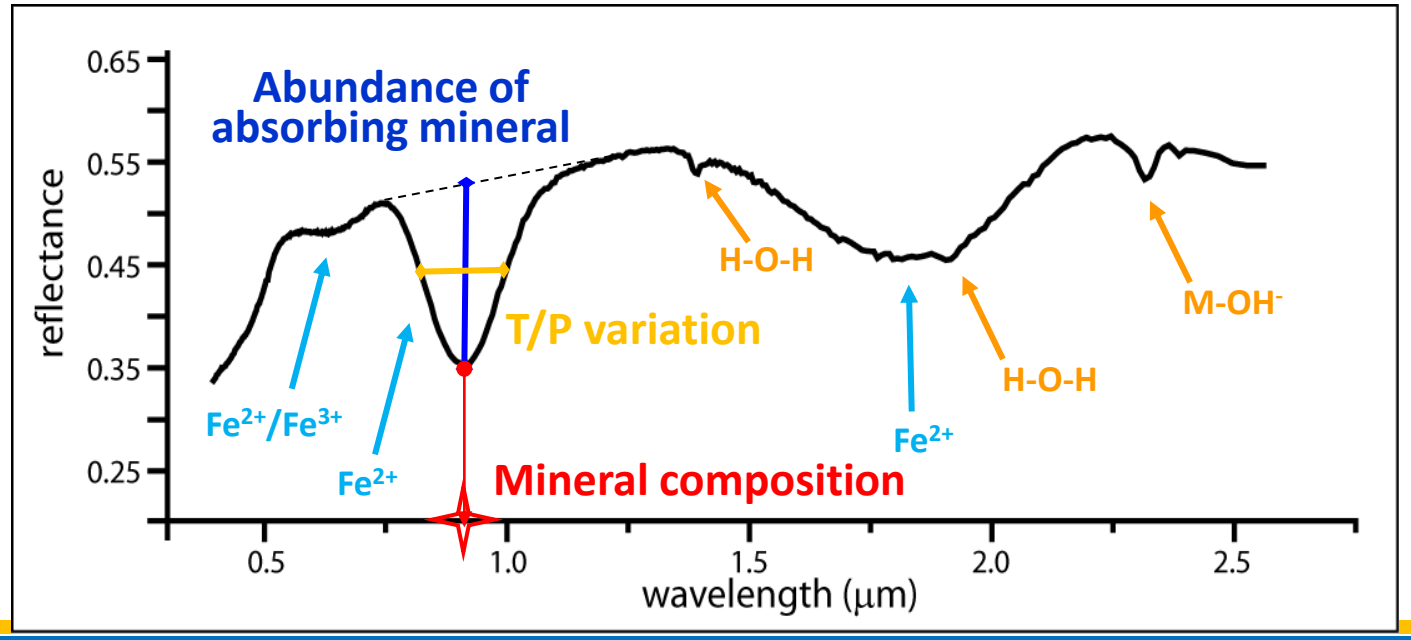
intensity of absorption

probability that transition occurs

Band width

vibronic process

geometry variation of site



Asteroid name	Tassonomy	NEA/MBA	Paper	a (AU)	i (°)	e (°)	BAR	BC1 (nm)	BC2 (nm)	rating	closest brachinite
1100 Jaroslawa	- S??	Main Belt	DeLeon et al. 2010	2.22	5.99	0.24	0.309	964	1920	1	**NWA 14635**
5641 McCleese	A	Mars crossing	De Leon et al. 2010	1.82	22.20	0.13	0.287	953	1921	1	**NWA 14635**
3199 Nefertiti	A	NEA (Amor)	De Leon et al. 2010	1.57	32.96	0.28	0.000	1060	0	1	**NWA 4969, NWA 6077, NWA 6112, NWA 16170, AsH 001**
289 Nenetta	A	Main Belt	DeLeon et al. 2010	2.88	6.68	0.20	0.007	1080	0	1	**NWA 4969, NWA 6077, NWA 6112, NWA 16170, AsH 001**
(85867) 1999 BY9	Q	NEA (Amor)	De Leon et al. 2010	1.83	0.95	0.30	0.256	1006	1928	1	**NWA 5400*, NWA 12733*, NWA 5363, NWA 6292, NWA 6308**
(85867) 1999 BY9	Q	NEA (Amor)	Binzel et al. 2019°	1.83	0.95	0.30	0.176	1044	1921	1	**NWA 5400*, NWA 12733*, NWA 5363, NWA 6292, NWA 6308**
532 Herculina	S	Main Belt	DeLeon et al. 2010	2.77	16.31	0.18	0.166	972	1912	1	**NWA 14635**
2002 AL14	Sl	NEA (Apollo)	Lazzarin et al. 2005	1.04	23.00	0.13	0.215	992	1930	1	**Al Huwaysah 010**
1374 Isora	Sq	Mars crossing	Binzel et al. 2019°	2.25	5.29	0.28	0.135	1034	1940	1	**NWA 5400*, NWA 12733*, NWA 5363, NWA 6292, NWA 6308**
11 Parthenope	Sq	Main Belt	DeLeon et al. 2010	2.45	4.63	0.10	0.363	957	1916	1	**NWA 14635**
12711 Tukmit	Sqw	NEA (Apollo)	Binzel et al. 2019°	1.19	38.49	0.27	0.154	996	1928	1	**Al Huwaysah 010**
241662 2000KO44	Sw	NEA (Amor)	Binzel et al. 2019°	1.83	28.62	0.39	0.132	1020	1961	1	**NWA 5400*, NWA 12733*, NWA 5363, NWA 6292, NWA 6308**
1123 Shapleya	V	Main Belt	DeLeon et al.2010	2.23	6.42	0.16	0.206	1003	1960	1	**NWA 5400*, NWA 12733*, NWA 5363, NWA 6292, NWA 6308**
136617 - 1994CC	- Sq/Sa??	NEA (Apollo)	Binzel et al. 2019°	1.64	4.68	0.42	0.154	1064	1955	2	**NWA 5400*, NWA 12733*, NWA 5363, NWA 6292, NWA 6308**
42 Isis	K	Main Belt	DeLeon et al.2010	2.44	8.50	0.22	0.100	1058	*0*	2	**NWA 4969, NWA 6077, NWA 6112, NWA 16170, AsH 001**
1862 Apollo	Q	NEA (Apollo)	De Leon et al. 2010	1.47	6.35	0.56	0.271	985	1975	2	**NWA 11756**
66146 1998 TU3	Q	NEA (Aten)	Binzel et al. 2019°	0.79	5.41	0.48	0.274	991	1971	2	**NWA 11756**
5143 Heracles	Q	NEA (Apollo)	Binzel et al. 2019°	1.83	9.03	0.77	0.161	1006	*1970*	2	**NWA 11756**
30825 - 1990 TG1	S	NEA (Apollo)	De Leon et al. 2010	2.44	8.74	0.68	0.372	990	1908	2	**Al Huwaysah 010**
3102 Krok	S	NEA (Amor)	Lazzarin et al. 2005	2.15	8.44	0.45	0.168	952	1935	2	**NWA 14635**
66251 - 1999 GJ2	Sa	NEA (Amor)	Lazzarin et al. 2005	1.54	11.28	0.20	0.105	955	1911	2	**NWA 14635**
1980 Tezcatlipoca	Sl	NEA (Amor)	De Leon et al. 2010	1.71	26.87	0.36	0.210	950	1950	2	**NWA 14635**
2000 EZ148	Sq	NEA (Apollo)	De Leon et al. 2010	2.58	11.19	0.61	0.266	966	1901	2	**NWA 14635**
154302 - 2002 UQ3	Sq	NEA (Apollo)	Binzel et al. 2019°	1.72	*28.83*	0.56	0.155	949	1933	2	**NWA 14635**
354 Eleonora	A	Main Belt	DeLeon et al. 2010	2.80	18.36	0.11	0.144	1059	1901	3	**NWA 5400*, NWA 12733*, NWA 5363, NWA 6292, NWA 6308**
25143 Itokawa	Sqw	NEA (Apollo)	Binzel et al. 2019°	1.32	1.62	0.28	0.238	1023	1963	3	**between NWA 11756 and Al Huwaysah 010**
163000 - 2001 SW169	Sw	NEA (Amor)	Binzel et al. 2019°	1.25	3.55	0.05	0.255	953	1920	3	**NWA 14635**
1620 Geographos	S	NEA (Apollo)	Binzel et al. 2019°	1.25	13.34	0.34	0.344	1024	1970	3	**between NWA 11756 and Al Huwaysah 010**
1494 Savo	Sqw	Main Belt	DeLeon et al. 2010	2.19	2.46	0.13	0.278	975	1970	3	**between NWA 11756 and Al Huwaysah 010**
6455 - 1992 HE	Srw	NEA (Apollo)	Binzel et al. 2019°	2.24	37.34	0.57	0.283	981	1935	3	**Al Huwaysah 010**
433 Eros	Sw	NEA (Amor)	Binzel et al. 2019°	1.46	10.83	0.22	0.306	961	1973	3	**Al Huwaysah 010**
25916 - 2001 CP44	Vw	NEA (Amor)	Binzel et al. 2019°	2.56	15.75	0.50	0.279	1031	1961	3	**between NWA 11756 and Al Huwaysah 010**