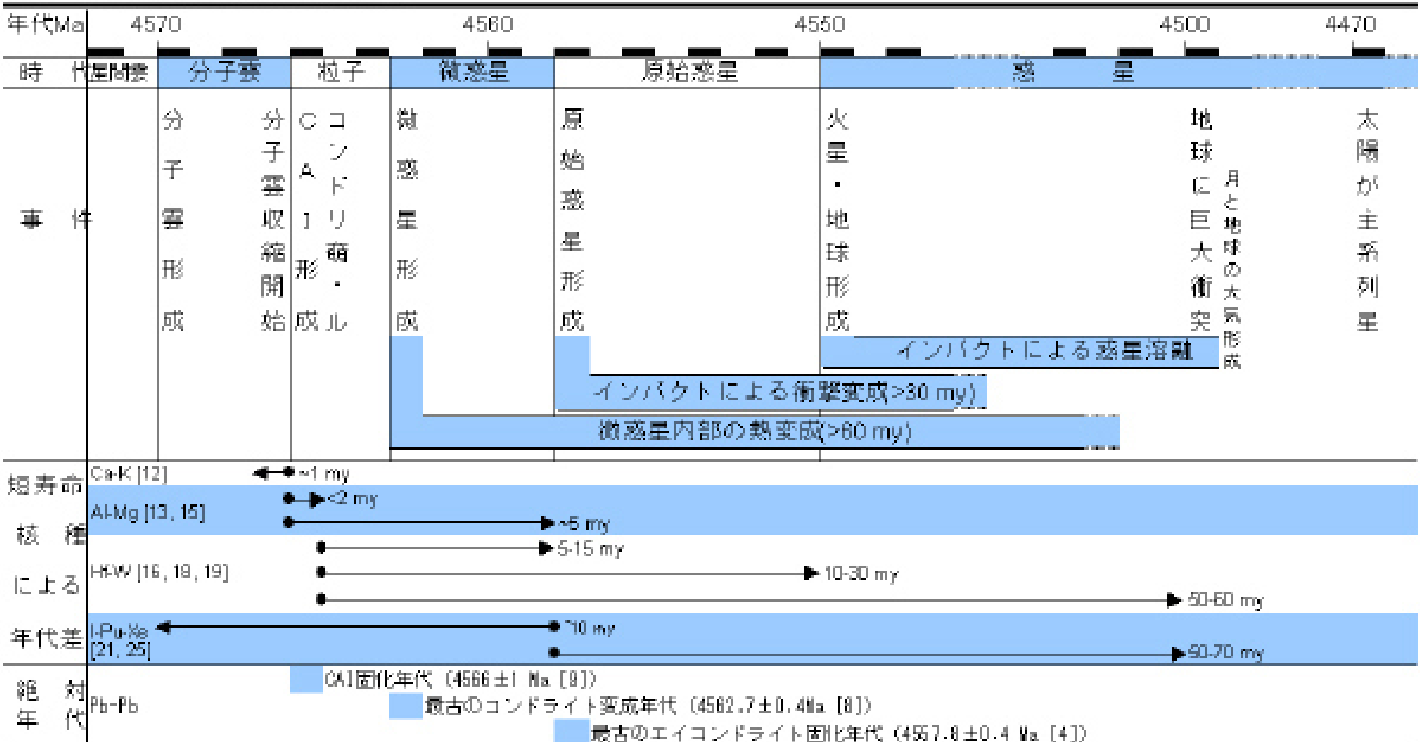
太陽系の年代学

創世期年表（圦本，2000）

表1　太陽系創世期の天体進化年表



記号Maは100万年前，myは100万年間．Pb-Pb等は年代測定法を示す．［　］内の数字は年代出典元の文献番号に対応．

放射性同位元素

- 長寿命核種
  - ^{147}Sm—^{143}Nd ($1.06x10^{11}y$)
  - ^{187}Re—^{187}Os ($\sim 5x10^{10}y$)
  - ^{87}Rb—^{87}Sr ($4.99x10^{10}y$)
  - ^{232}Th—^{208}Pb ($1.40x10^{10}y$)
  - ^{238}U—^{206}Pb ($4.47x10^{9}y$)
  - ^{235}U—^{207}Pb ($7.04x10^{8}y$)
  - ^{40}K—^{40}Ar ($1.25x10^{9}y$)
- 短寿命核種
  - ^{244}Pu—^{136}Xe ($8.2x10^{7}y$)
  - ^{129}I—^{129}Xe ($1.57x10^{7}y$)
  - ^{182}Hf—^{182}W ($9x10^{6}y$)
  - ^{107}Pd—^{107}Ag ($6.5x10^{6}y$)
  - ^{53}Mn—^{53}Cr ($3.7x10^{6}y$)
  - ^{60}Fe—^{60}Ni ($1.5x10^{6}y$)
  - ^{10}Be—^{10}B ($1.5x10^{6}y$)
  - ^{26}Al—^{26}Mg ($7.2x10^{5}y$)
  - ^{41}Ca—^{41}K ($1.03x10^{5}y$)

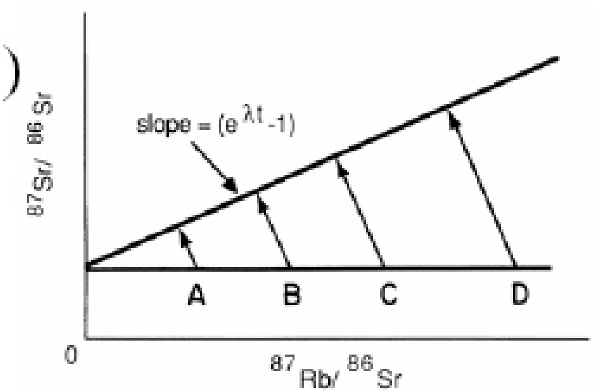
放射壊変

$$N_t = N_0 e^{-\lambda t}$$

$$N_d^r = N_0 - N_t = N_0(1 - e^{-\lambda t}) = N_t(e^{\lambda t} - 1)$$

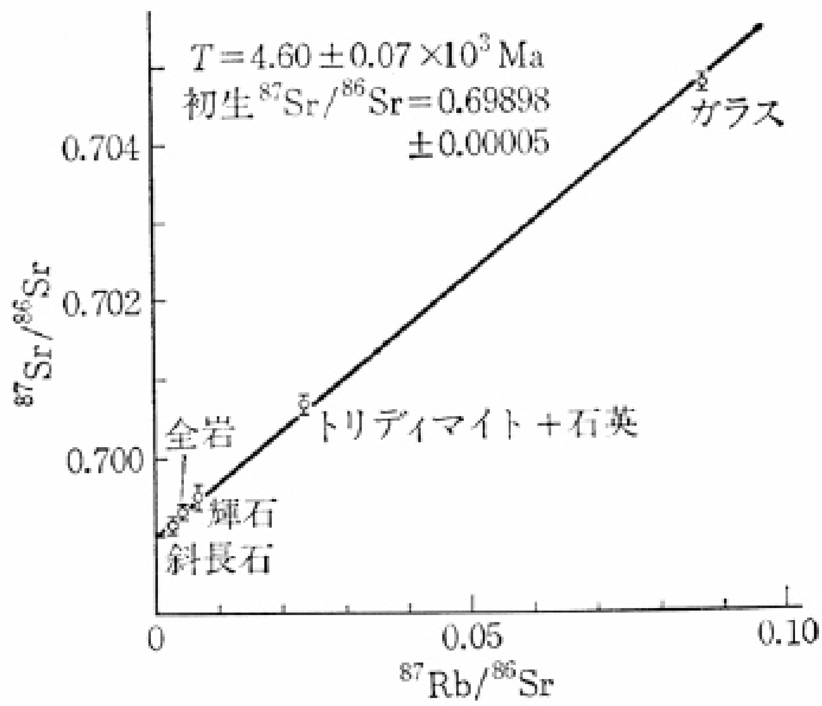
$$N_d^r = N_d - N_d^0 = N_t(e^{\lambda t} - 1)$$

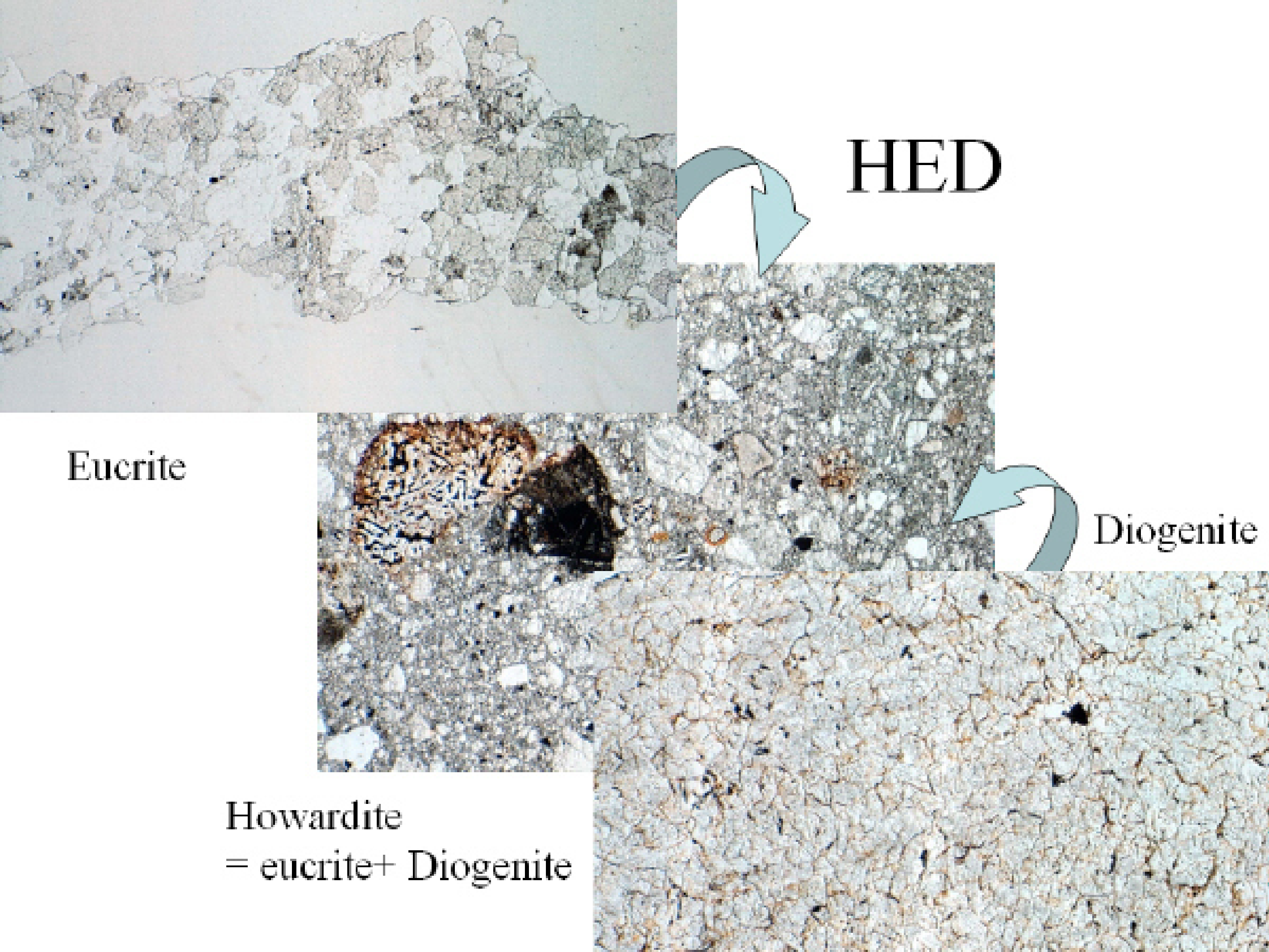
$$\frac{N_d^r}{N_d^s} = \frac{N_d}{N_d^s} - \frac{N_d^0}{N_d^s} = \frac{N_t}{N_d^s}(e^{\lambda t} - 1)$$



Rb-Sr isochron of Juvinas eucrite

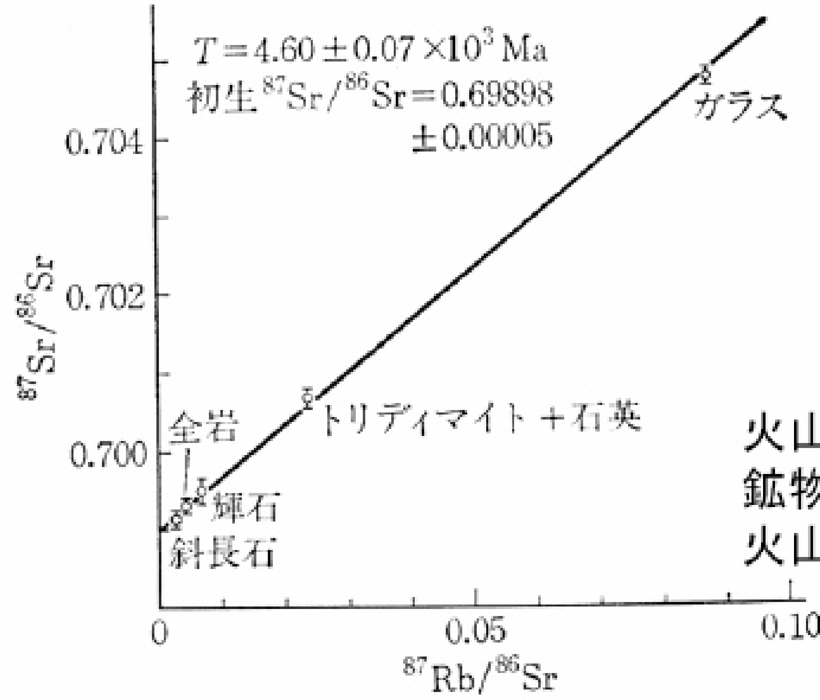
(Allégre et al., 1975)




HED
Eucrite
Diogenite
Howardite
= eucrite+ Diogenite

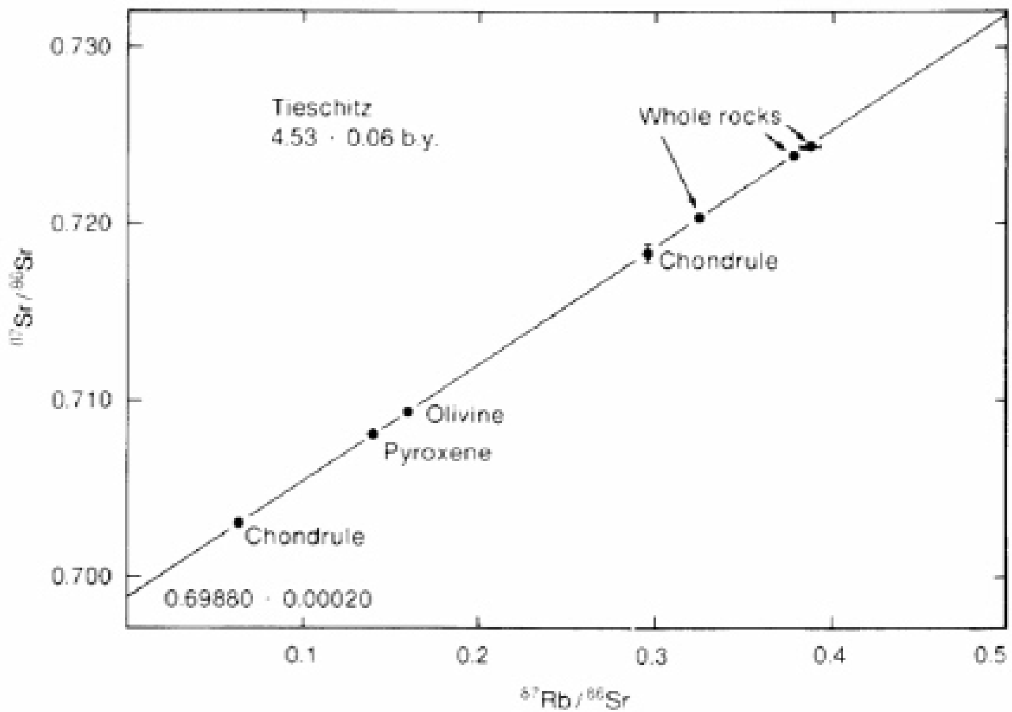
Rb-Sr isochron of Juvinas eucrite

(Allégre et al., 1975)

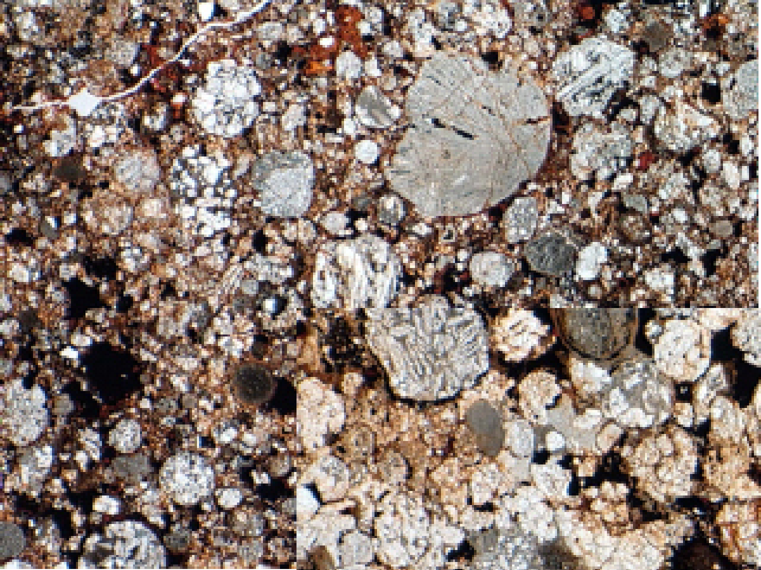


火山岩
鉱物アイソクロン
火山岩の固化年代

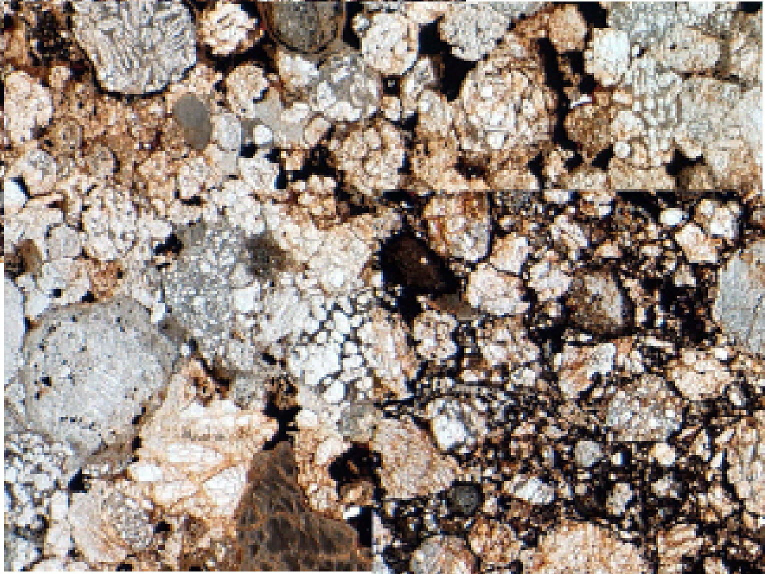
Rb-Sr isochron for chondrules from Tieschiz H3
(Minster et al., 1979)



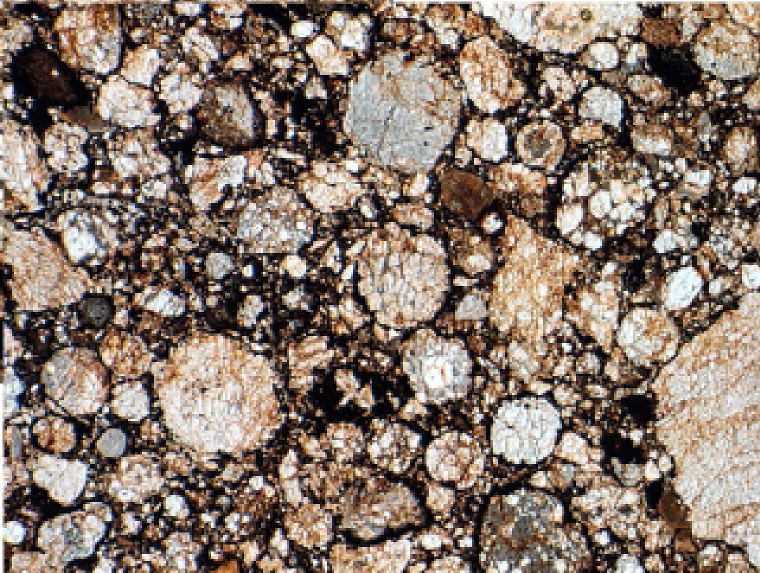
O chondrites



H

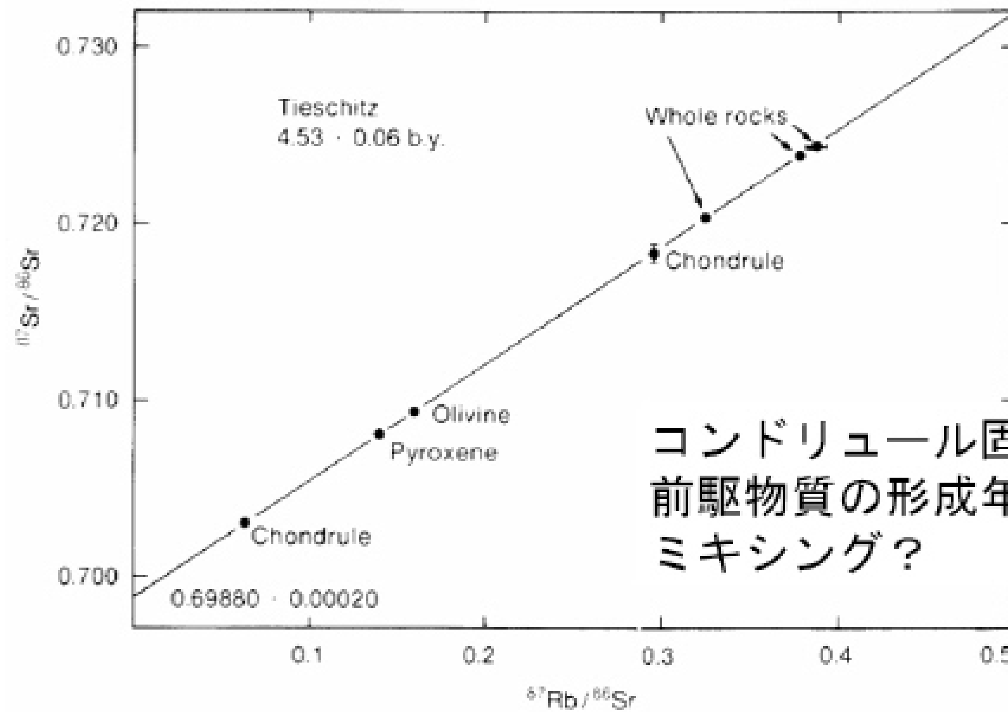


L



LL

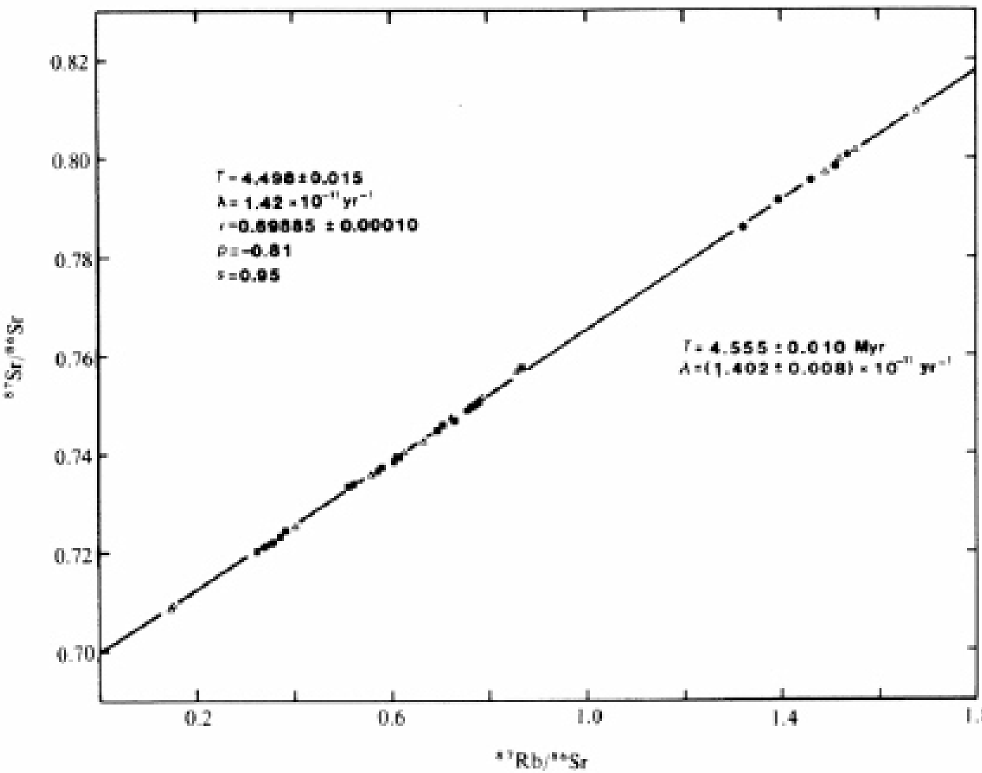
Rb-Sr isochron for chondrules from Tieschiz H3
(Minster et al., 1979)



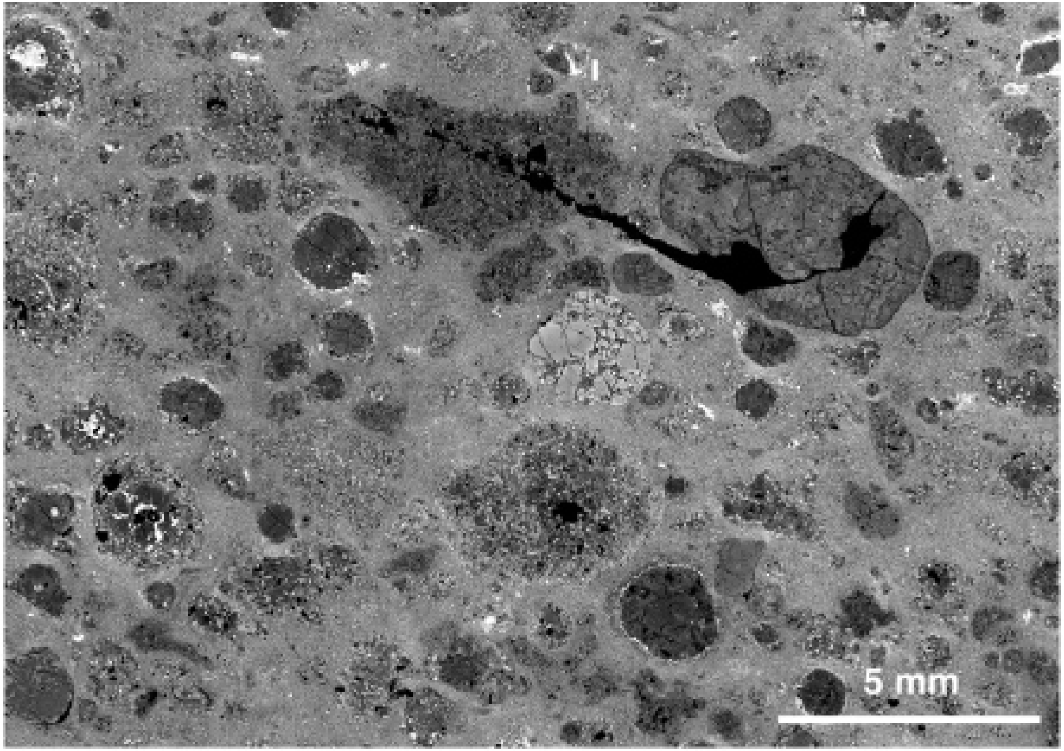
コンドリュール固化年代？
前駆物質の形成年代？
ミキシング？

Rb-Sr isochron for chondrites

(■: H, △: LL, ●: E; Minster et al., 1982)



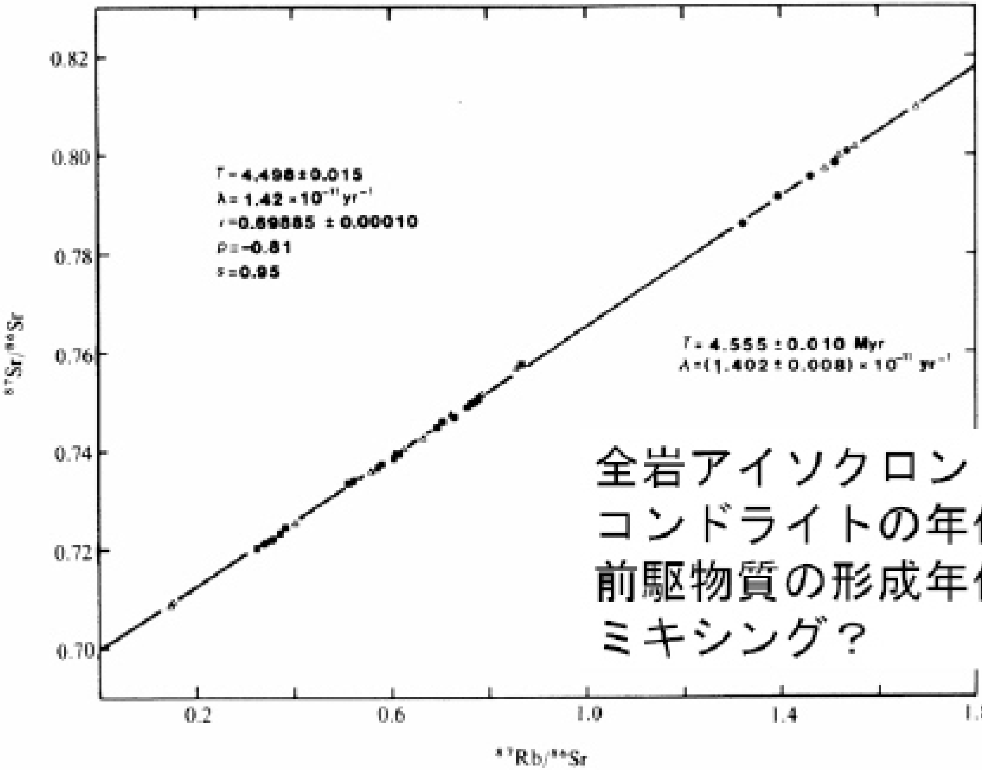
Chondriteの反射電子像



Allende CV3

Rb-Sr isochron for chondrites

(■: H, △: LL, ●: E; Minster et al., 1982)



全岩アイソクロン

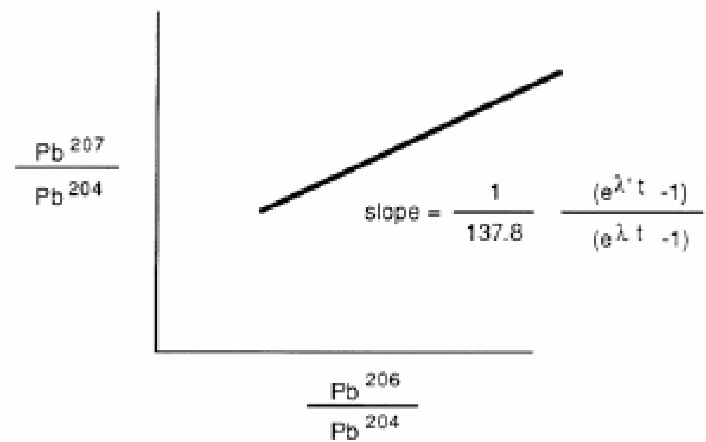
コンドライトの年代？

前駆物質の形成年代？

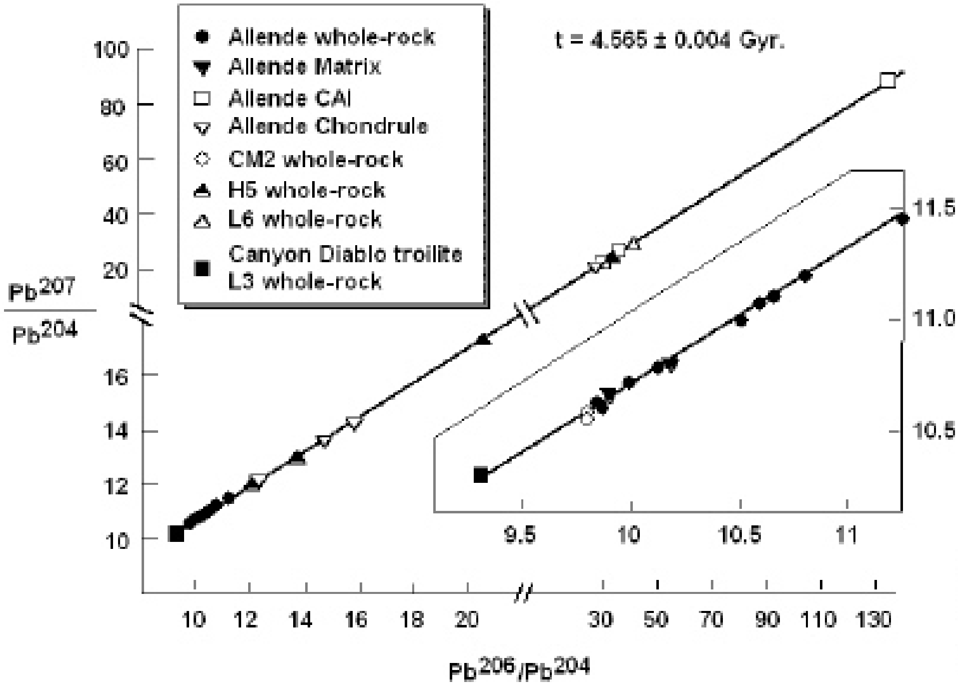
ミキシング？

Pb-Pb isochron

$$\frac{^{207}Pb^*}{^{206}Pb^*} = \frac{\left(\frac{^{207}Pb}{^{204}Pb}\right)_t - \left(\frac{^{207}Pb}{^{204}Pb}\right)_0}{\left(\frac{^{206}Pb}{^{204}Pb}\right)_t - \left(\frac{^{206}Pb}{^{204}Pb}\right)_0} = \left(\frac{^{235}U}{^{238}U}\right)_t \frac{(e^{\lambda' t} - 1)}{(e^{\lambda t} - 1)}$$



Pb-Pb isochron for chondrites & Pb-model age



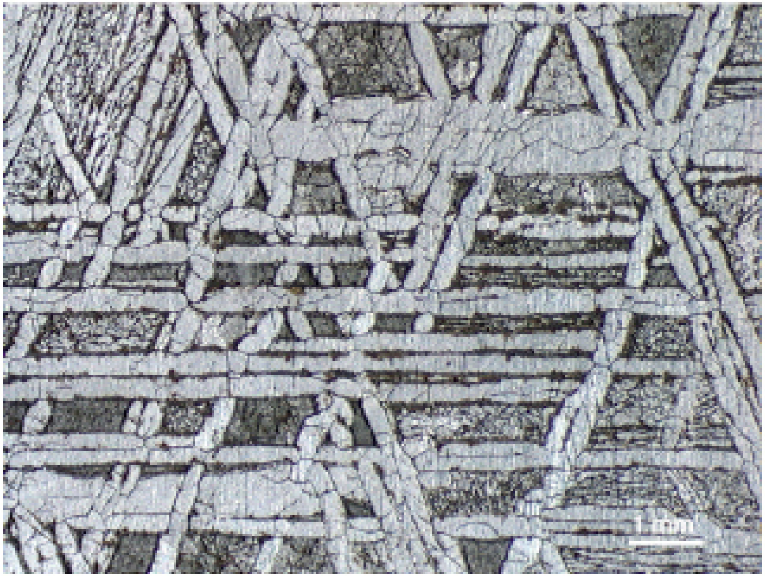
$^{238}U \rightarrow {}^{206}Pb$

$^{235}U \rightarrow {}^{207}Pb$

全岩アイソクロン
コンドライトの年代？
前駆物質の形成年代？
ミキシング？

(after Chen and Tilton, 1976)

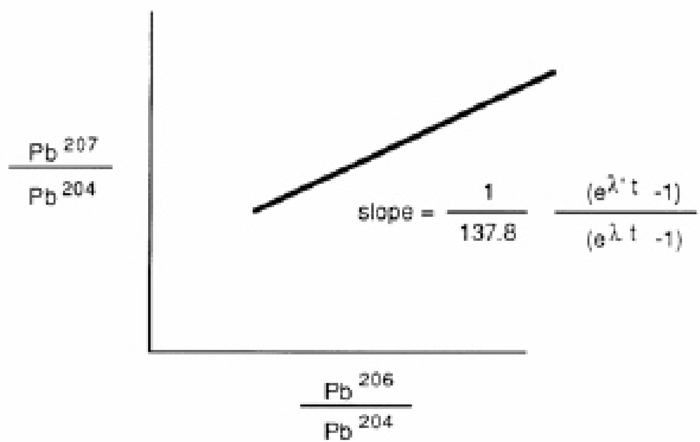
Irons



Gibeon (IVA)

Pb-Pb isochron

$$\frac{{}^{207}Pb^*}{{}^{206}Pb^*} = \frac{\left(\frac{{}^{207}Pb}{{}^{204}Pb}\right)_t - \left(\frac{{}^{207}Pb}{{}^{204}Pb}\right)_0}{\left(\frac{{}^{206}Pb}{{}^{204}Pb}\right)_t - \left(\frac{{}^{206}Pb}{{}^{204}Pb}\right)_0} = \left(\frac{{}^{235}U}{{}^{238}U}\right)_t \frac{(e^{\lambda' t} - 1)}{(e^{\lambda t} - 1)}$$

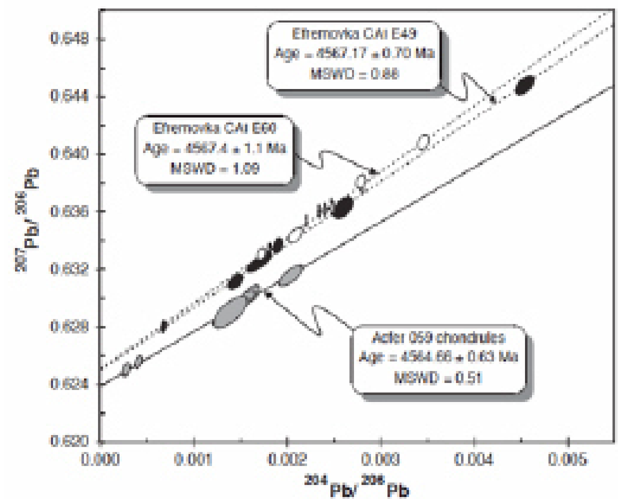


Pb-Pb isochron

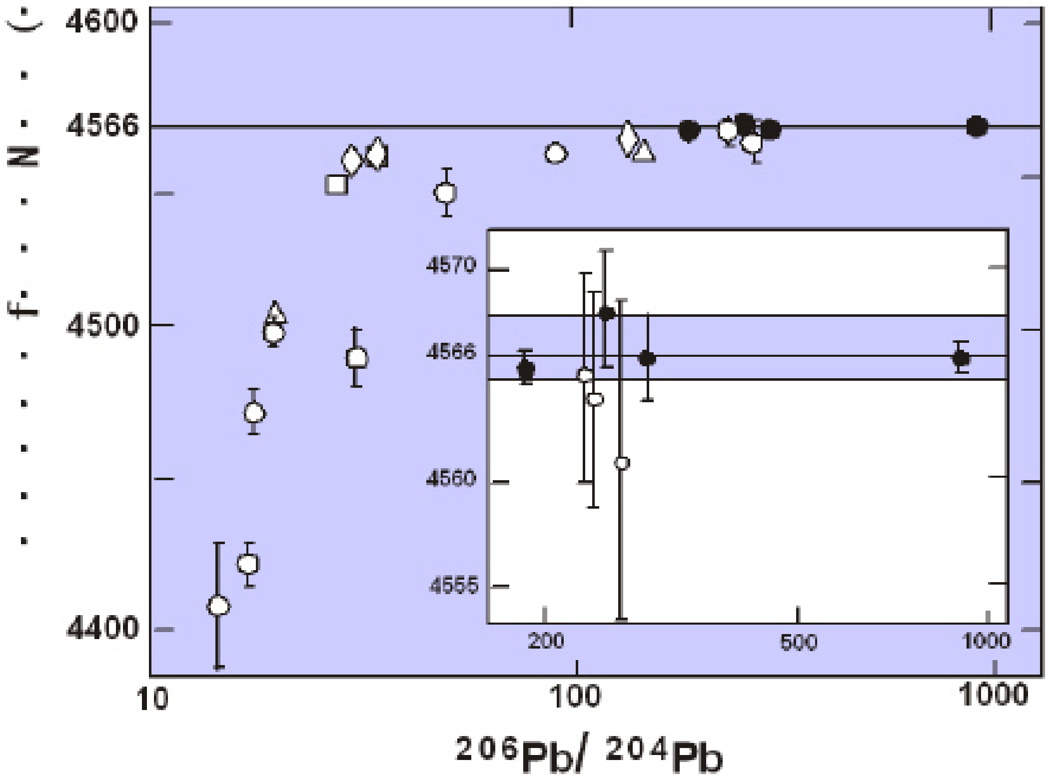
$$\frac{^{207}Pb^*}{^{206}Pb^*} = \frac{\left(\frac{^{207}Pb}{^{204}Pb}\right)_t - \left(\frac{^{207}Pb}{^{204}Pb}\right)_0}{\left(\frac{^{206}Pb}{^{204}Pb}\right)_t - \left(\frac{^{206}Pb}{^{204}Pb}\right)_0} = \left(\frac{^{235}U}{^{238}U}\right)_t \frac{(e^{\lambda' t}-1)}{(e^{\lambda t}-1)}$$

$$\frac{^{207}Pb}{^{206}Pb} = \left(\frac{^{207}Pb^*}{^{206}Pb^*}\right) + \left(\frac{^{204}Pb}{^{206}Pb}\right)\left\{\left(\frac{^{207}Pb}{^{204}Pb}\right)_0 - \left(\frac{^{207}Pb^*}{^{206}Pb^*}\right)\left(\frac{^{206}Pb}{^{204}Pb}\right)_0\right\}$$

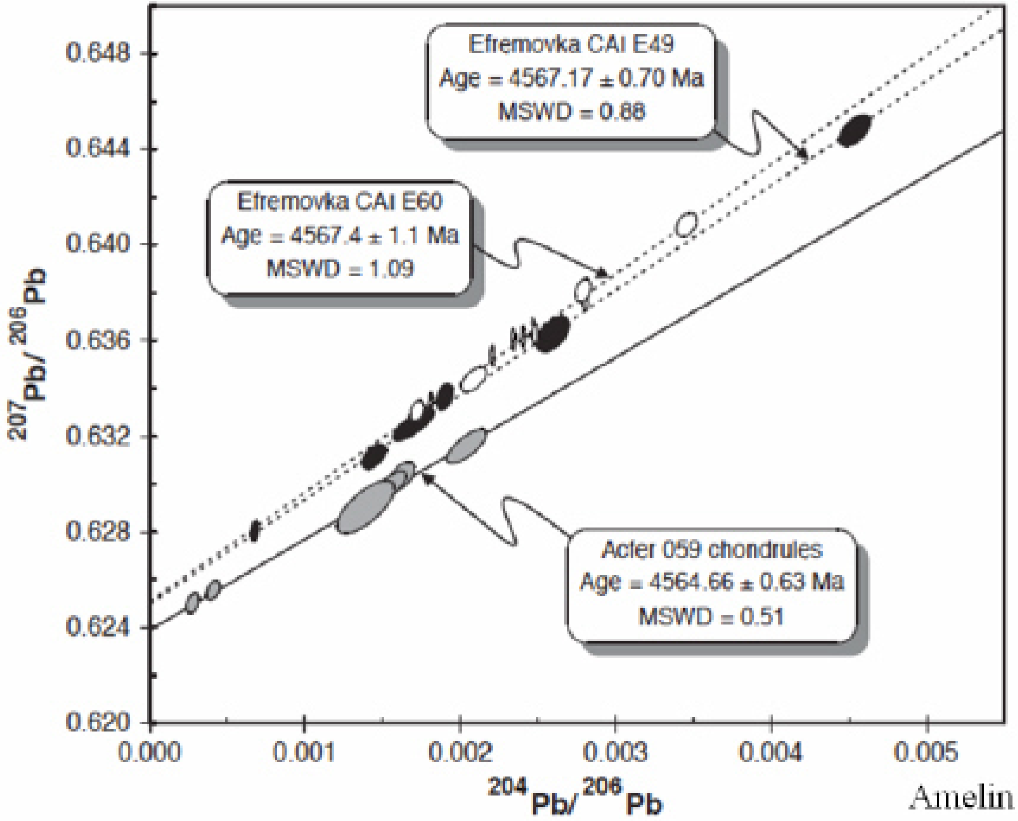
U：難揮発性
Pb：揮発性



CAIの形成年代


4600
4566
4500
4400
10
100
1000
4570
4566
4560
4555
200
500
1000
206Pb/ 204Pb

CAI，コンドリュールの形成年代

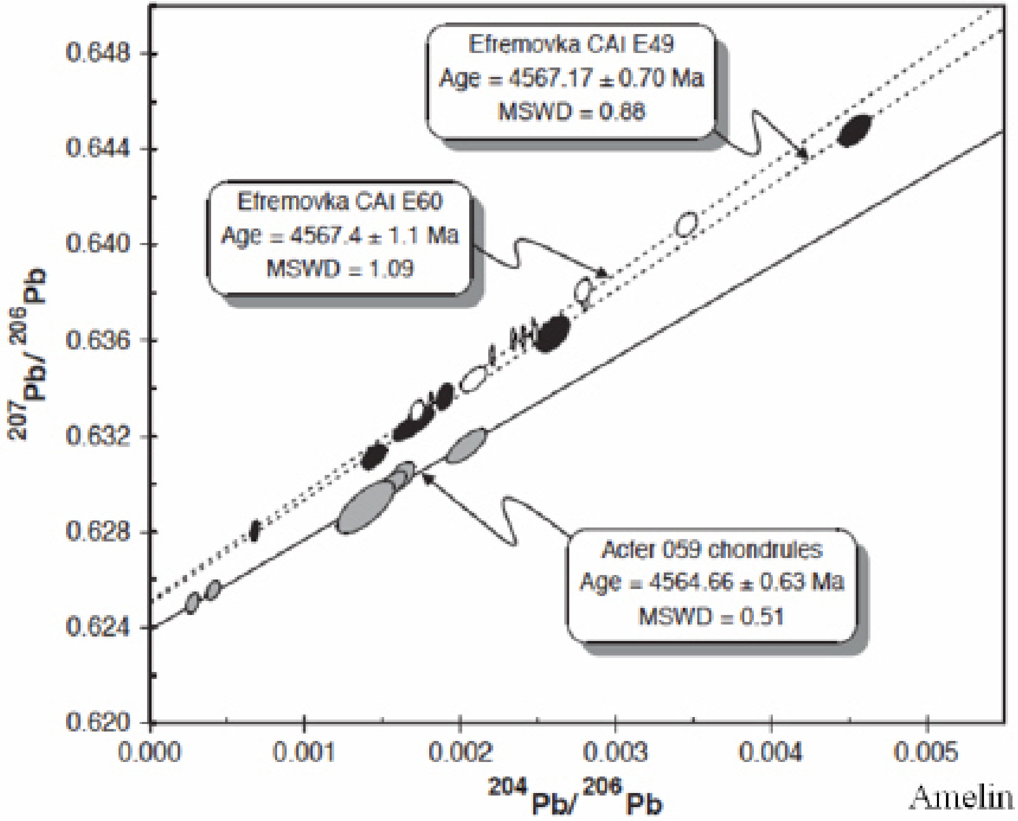


Amelin et al. (2002)

CAI，コンドリュールの形成年代

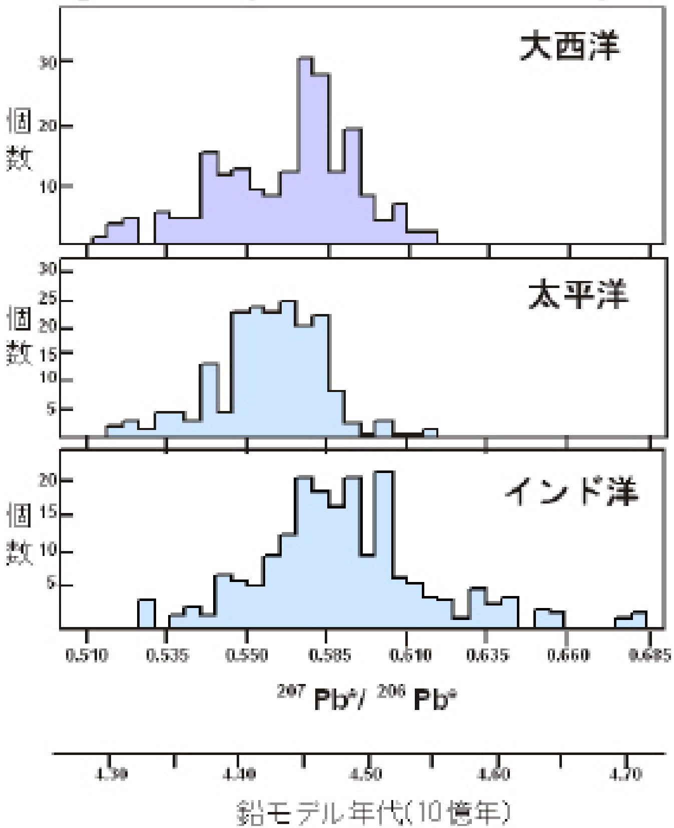
	隕石	Pb-Pb年代 (Ma)	年代差 (Ma)	Ref.
CAI (2)	Efremovka CV3	4567.2±0.6	0	Amelin et al. (2002)
Chondrules	Allende CV3	4566.7±1.0	0.5	Amelin et al. (2004)
Chondrules (6)	Acfer 059 CR2	4564.7±0.6	2.5	Amelin et al. (2002)
Chondrules (3)	Gujba CB	4562.7±0.5	4.5	Krot et al. (2005)
Chondrules	HH 237 CB	4562.8±0.9	4.4	Krot et al. (2005)

CAI，コンドリュールの形成年代



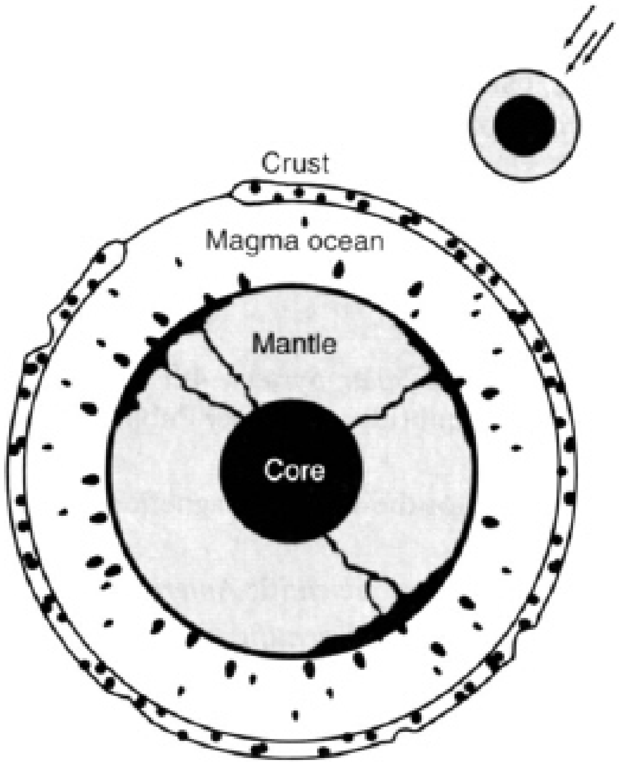
Amelin et al. (2002)

地球の鉛モデル年代



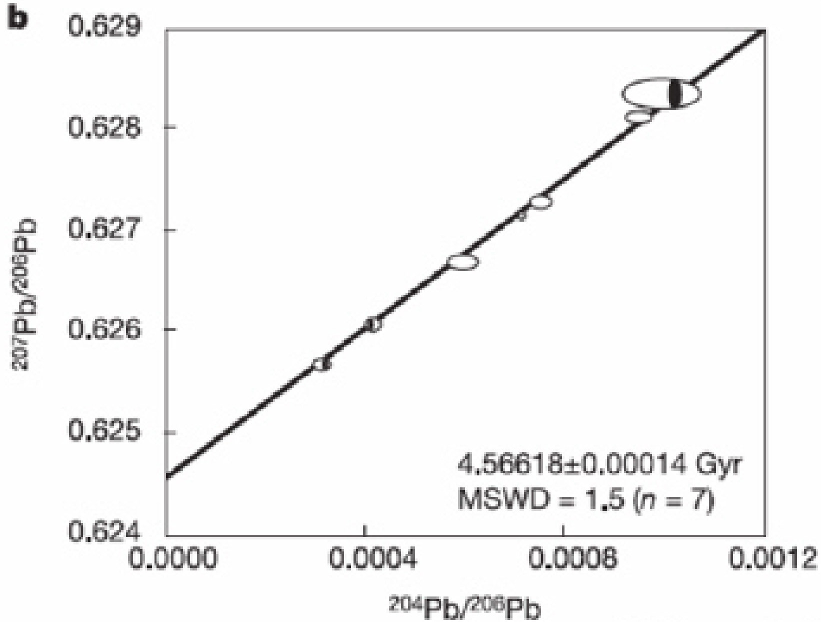
大西洋
個数
30
20
10
太平洋
30
25
20
15
10
5
インド洋
20
15
10
5
0.510
0.535
0.550
0.585
0.610
0.635
0.660
0.685
207 Pb*/ 206 Pb*
4.30
4.40
4.50
4.60
4.70
鉛モデル年代(10億年)

分化した隕石の母天体



Wood (2000)

Achondrite (angrite)の鉛年代

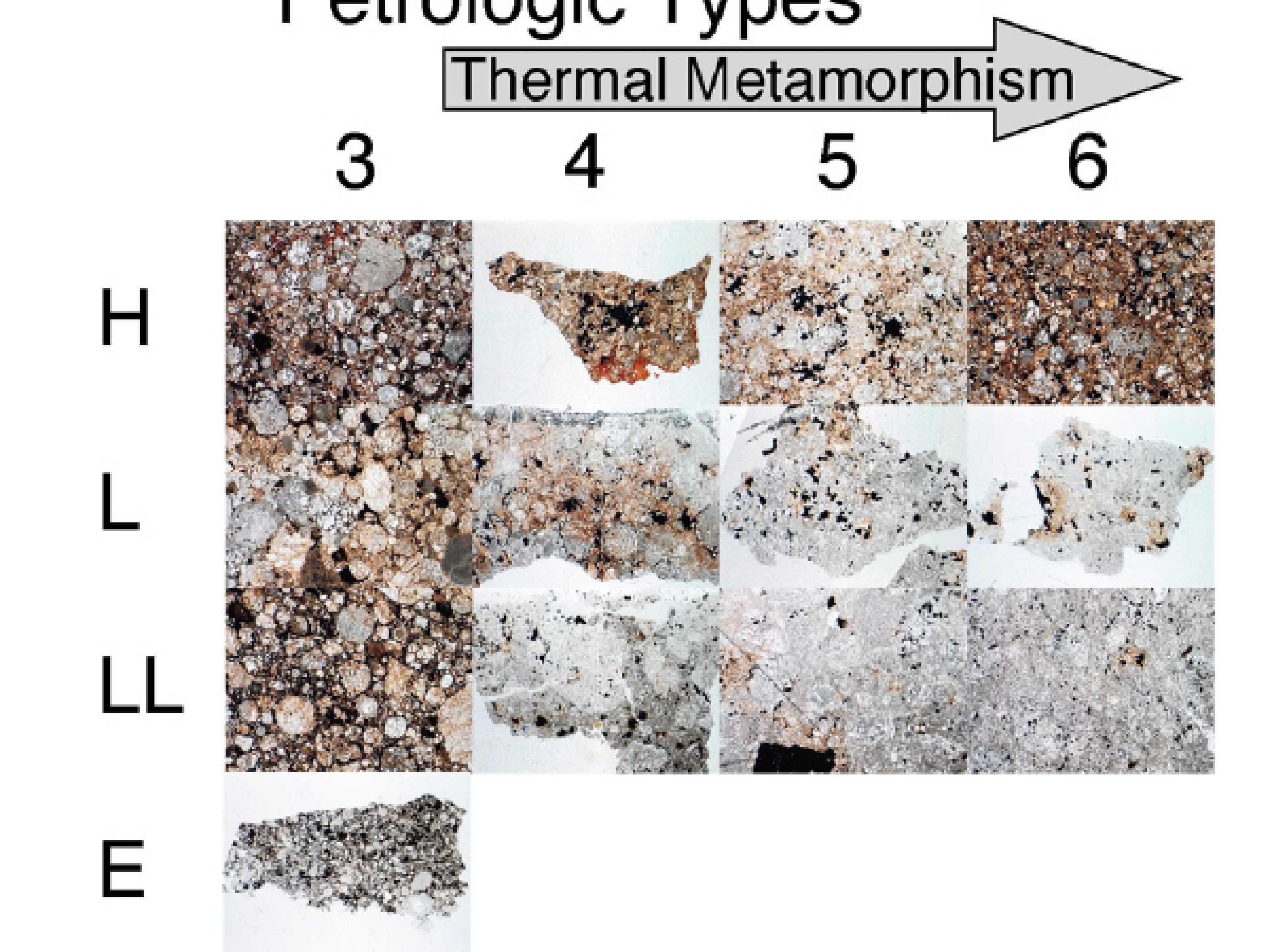


Baker et al. (2005)

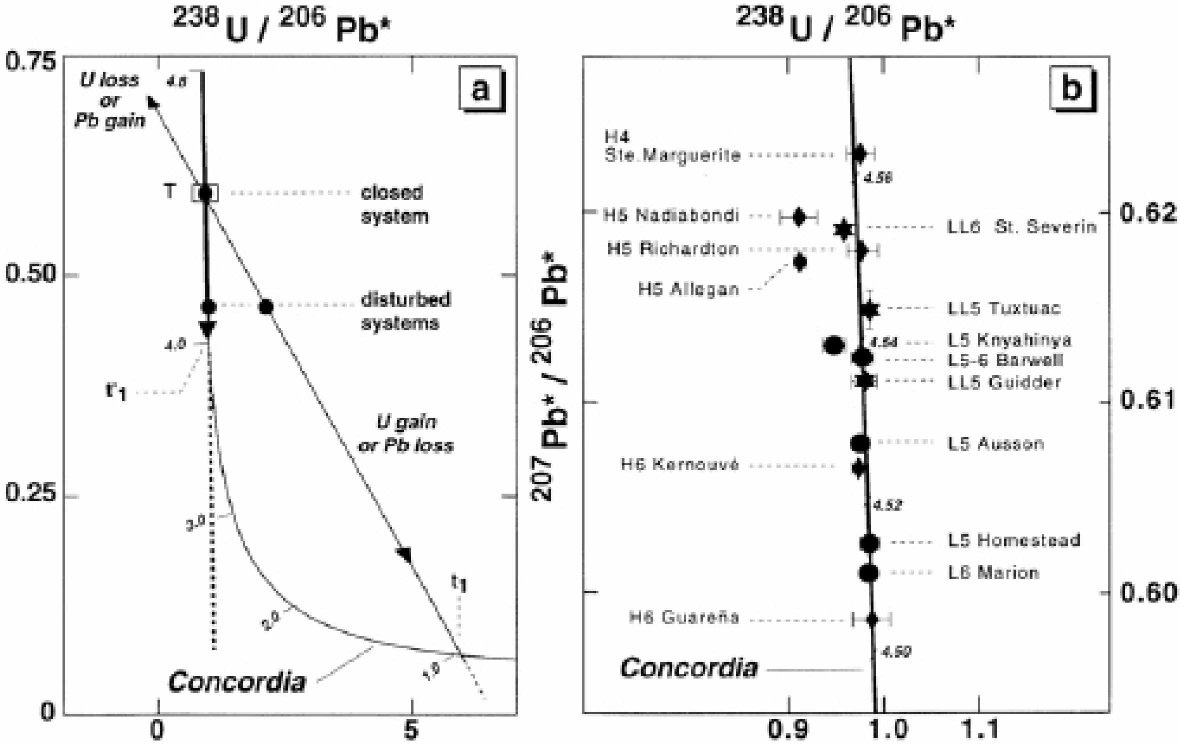
微惑星の変成年代 (after Göpel et al., 1994)

Phosphates from ordinary chondrites

Guareña	H6	746	±	11	4,5044	±	0,0005
Kernouvé	H6	1779	±	32	4,5211	±	0,0005
Allegan	H5	160	±	5	4,5502	±	0,0007
Richardton	H5	443	±	18	4,5514	±	0,0006
Nadiabondi	H5	109	±	29	4,5556	±	0,0034
Ste. Marguerite	H4	2960	±	228	4,5627	±	0,0006
Forest Vale	H4	364	±	1	4,5609	±	0,0007
Marion (Iowa)	L6	977	±	24	4,5107	±	0,0005
Barwell	L5-6	3468	±	753	4,5382	±	0,0007
Ausson	L5	557	±	10	4,5268	±	0,0009
Knyahinya	L5	266	±	61	4,5395	±	0,0010
Homestead	L5	1517	±	114	4,5142	±	0,0006
St.Séverin	LL6	270	±	5	4,5536	±	0,0007
Guidder	LL5	1445	±	182	4,5353	±	0,0006
Tuxtuac	LL5	514	±	38	4,5436	±	0,0021

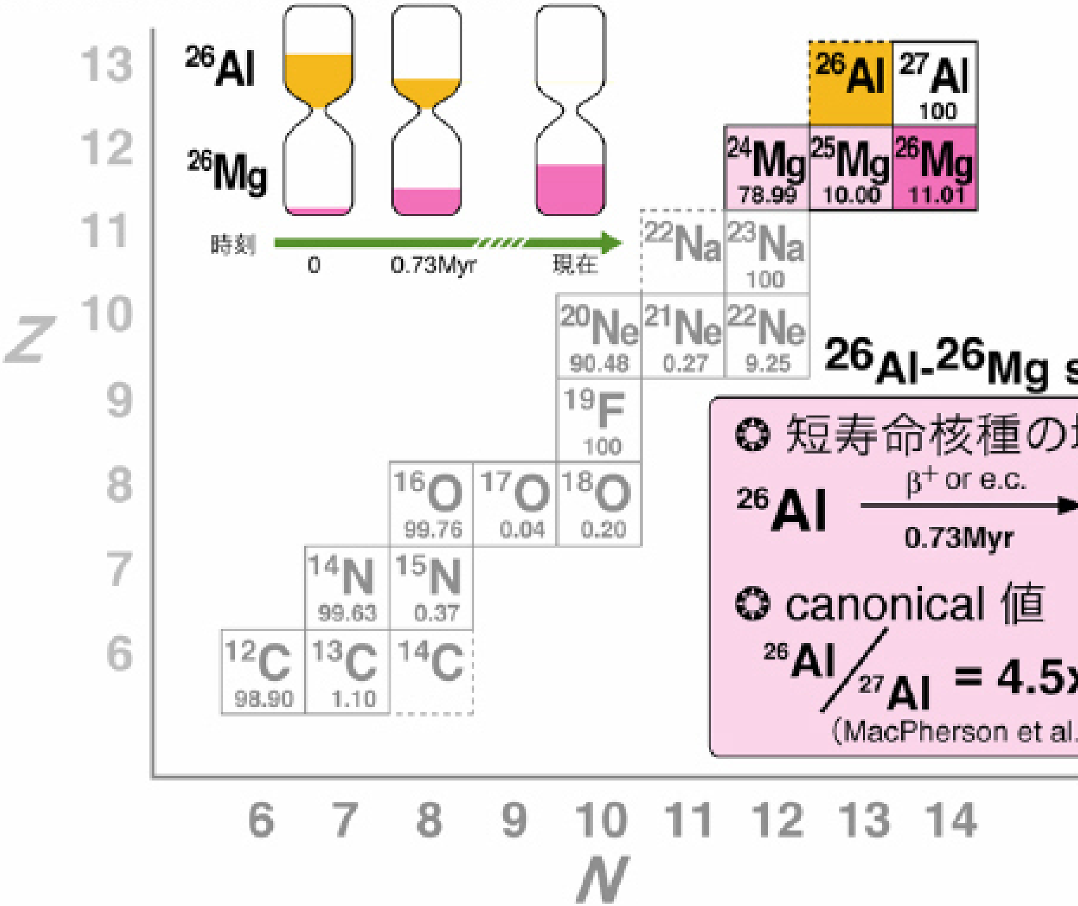

Petrologic Types
Thermal Metamorphism
3
4
5
6
H
L
LL
E

微惑星の変成年代 (after Göpel et al., 1994)



マグネシウム同位体

Capter 1 Introduction　Chart of the Nuclides



^{26}Al-^{26}Mg system

- 短寿命核種の壊変

$$^{26}\mathrm{Al} \xrightarrow[0.73\mathrm{Myr}]{\beta^+ \text{ or e.c.}} {}^{26}\mathrm{Mg}$$

- canonical 値

$$^{26}\mathrm{Al}/^{27}\mathrm{Al} = 4.5\mathrm{x}10^{-5}$$

(MacPherson et al., 1995)

アイソクロン（同時刻に結晶化した鉱物に対して）

$$ {}^{26}Al \xrightarrow[0.73Myr]{\beta^{+} \text{ or e.c.}} {}^{26}Mg^{*} $$

同じ時刻に結晶化したとき