离子探针锆石和斜锆石Pb-Pb年龄测定方法研究

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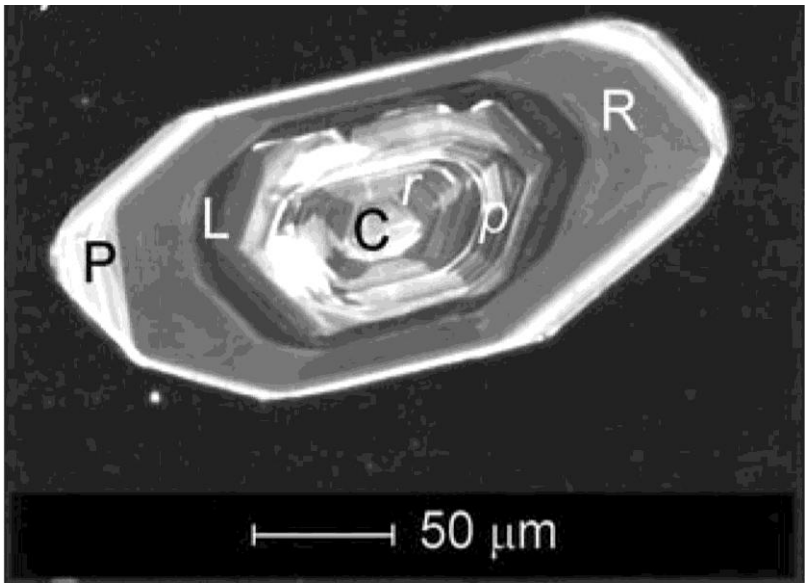
报告提纲

- 锆石铀-铅定年
- 斜锆石铀-铅定年光轴效应
- 铅-铅定年关键点与解决方案
- 数据结果
- 总结

锆石铀-铅(U-Pb)定年

- 锆石定年是地质测年最重要的方法



^{238}U - ^{206}Pb

^{235}U - ^{207}Pb

$$(^{206}\mathrm{Pb})^{*} = {}^{238}U(e^{\lambda_{238}t} - 1)$$

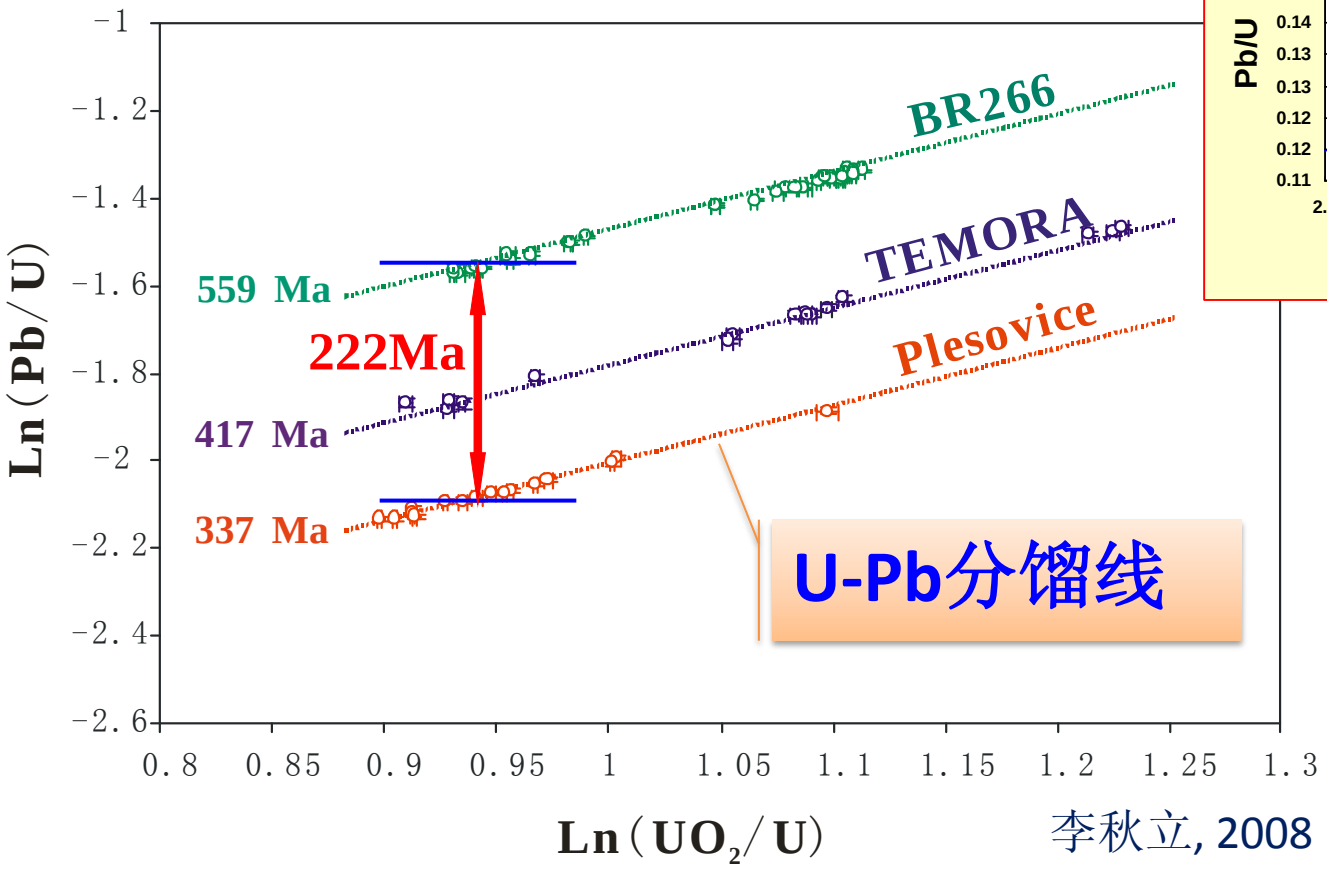
$$(^{207}\mathrm{Pb})^{*} = {}^{235}U(e^{\lambda_{235}t} - 1)$$

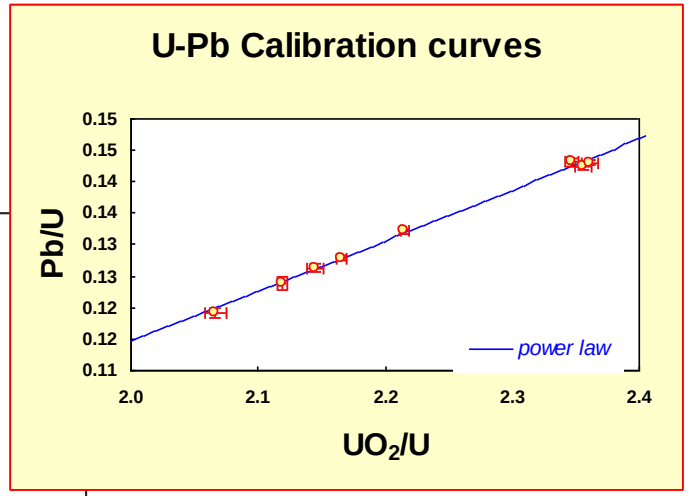
锆石 $ZrSiO_4$

需要测量 U–Pb比值

SIMS 锆石铀-铅(U-Pb) 定年原理

- 质量分辨率： 7000
- 一次束 10-15 nA O_2^-





李秋立, 2008

锆石铀-铅(U-Pb)定年优缺点

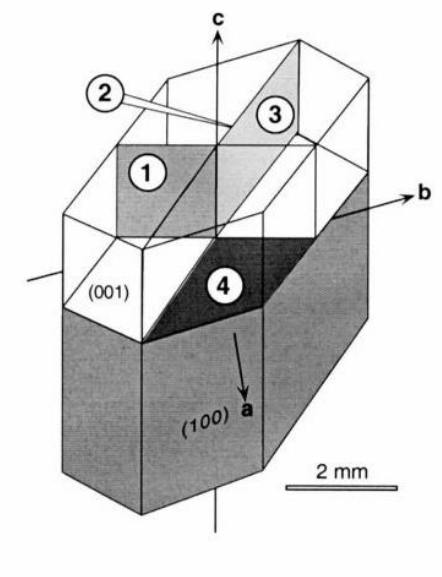
- 定年准确
- 方法成熟
- 信息丰富
- 操作简单
- 是SIMS锆石定年的标准方法

- 需要外部标准样品进行校正
- 不适用于**斜锆石**定年

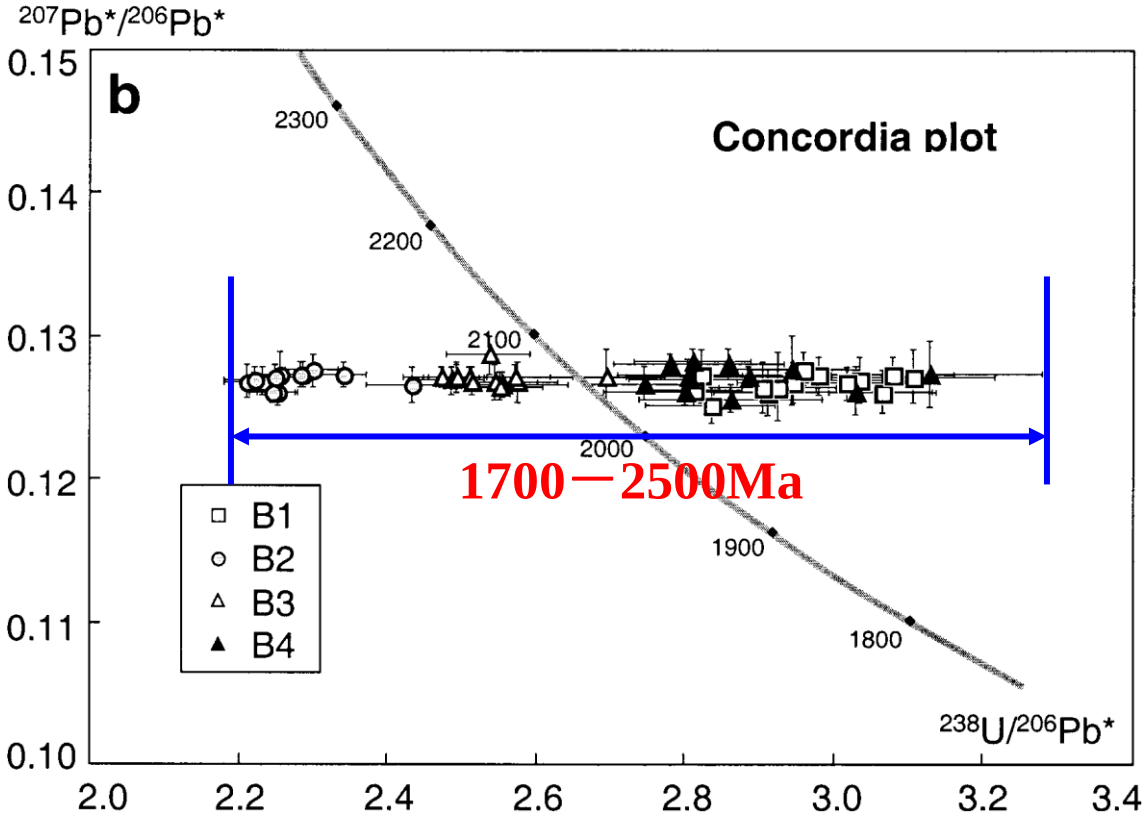
斜锆石光轴效应……

斜锆石铀-铅定年光轴效应

- 光轴效应使离子探针不能准确测定斜锆石的U-Pb年龄*
- 离子探针对斜锆石采用$^{207}Pb/^{206}Pb$定年

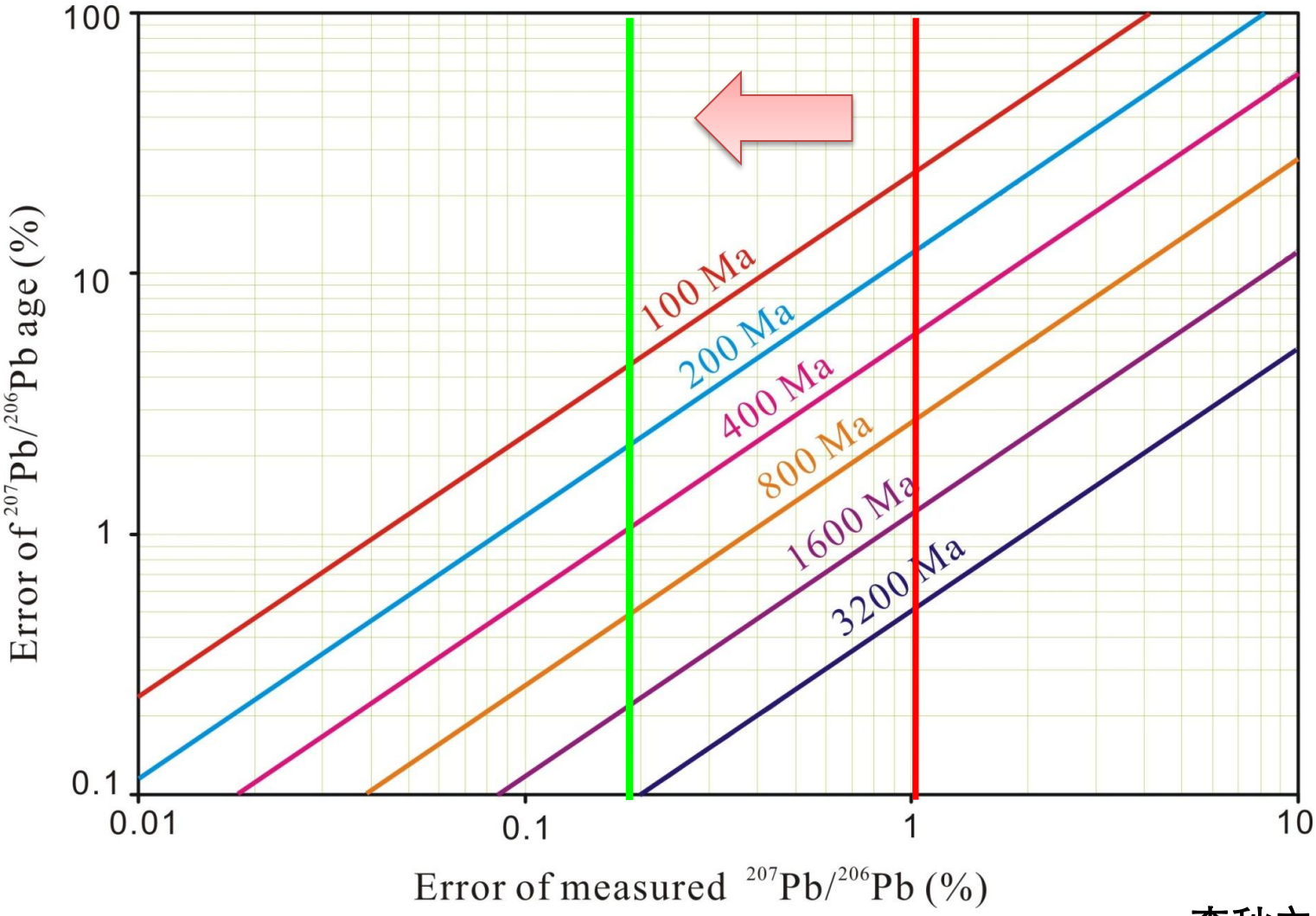


斜锆石: ZrO_2



Wingate et al. , Chemical Geology. 2000. 168,75–97.

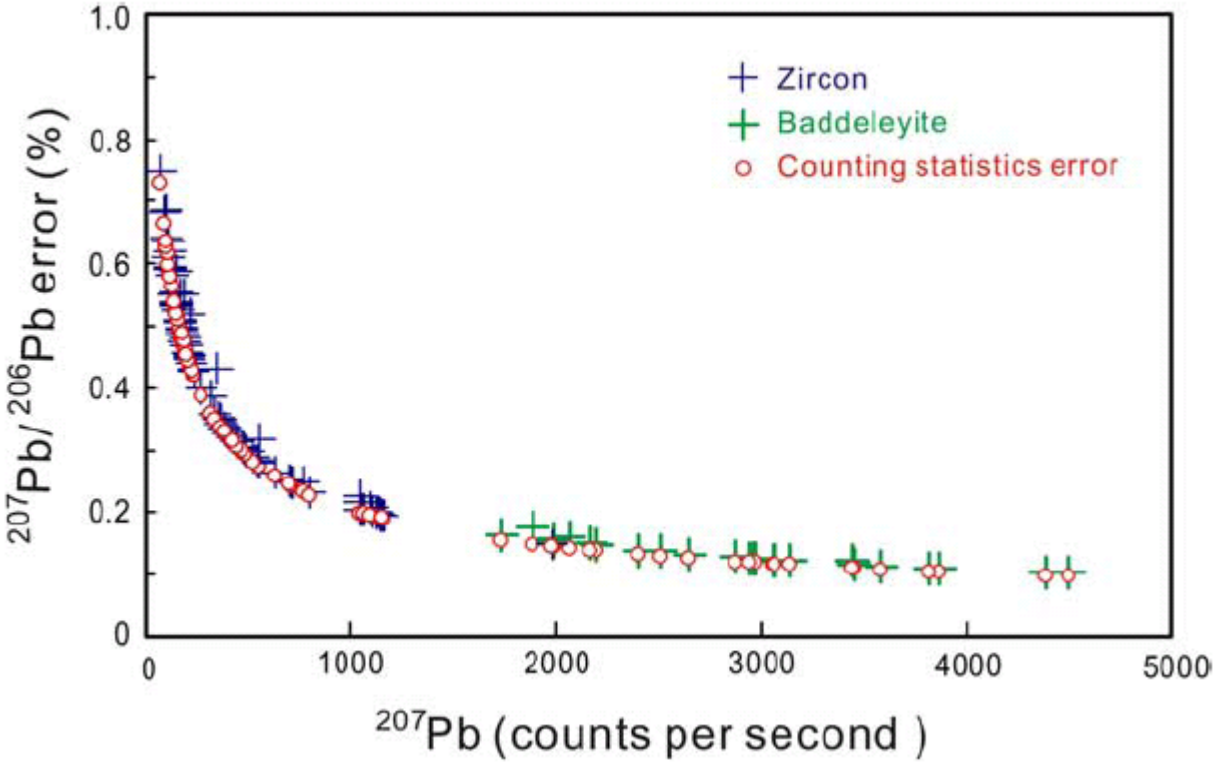
Pb-Pb定年分析误差与年龄误差对照



李秋立， 2008

Pb-Pb定年精度影响因素

$$\left(\frac{^{207}Pb}{^{206}Pb}\right)^{*} = \frac{rat76 - ratPb_c \times f_{204}}{1 - f_{204}}$$



$$f_{204} = \frac{^{206}Pb_c}{^{204}Pb_c} \times \frac{^{204}Pb}{^{206}Pb}$$

1. 提高铅的分析精度

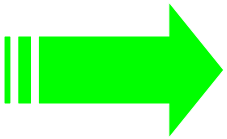
2. 准确的普通铅校正

(斜)锆石Pb-Pb定年的关键点与解决方案

- 提高$^{207}Pb/^{206}Pb$ 的分析精度
- 准确的普通铅校正

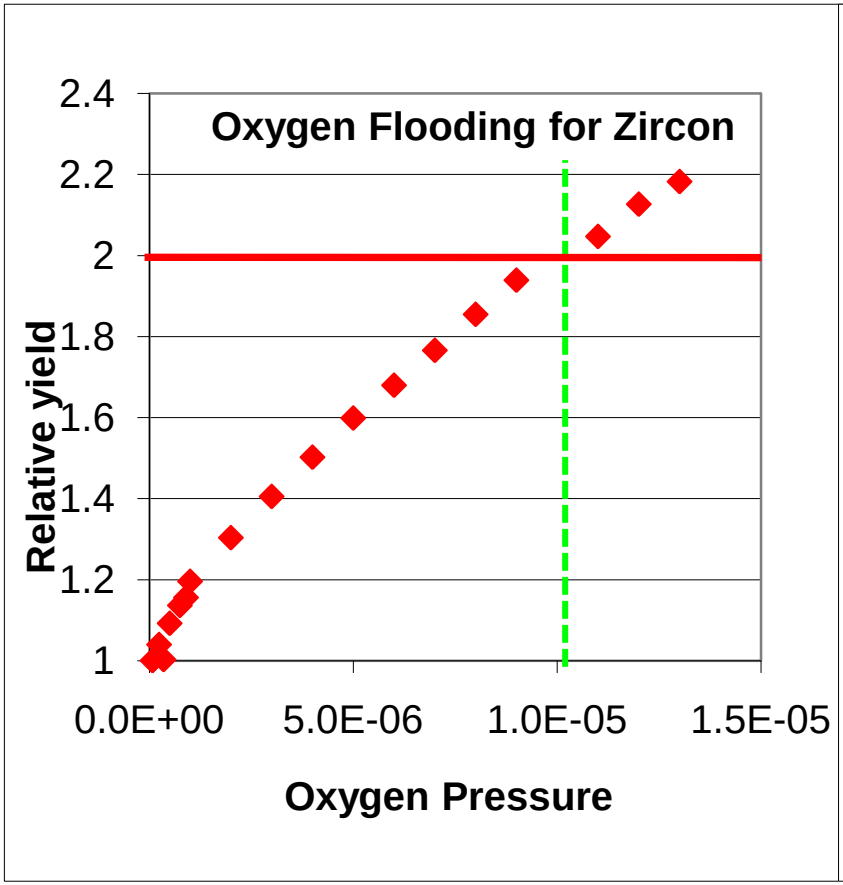
$^{207}Pb/^{206}Pb$ 的分析精度？

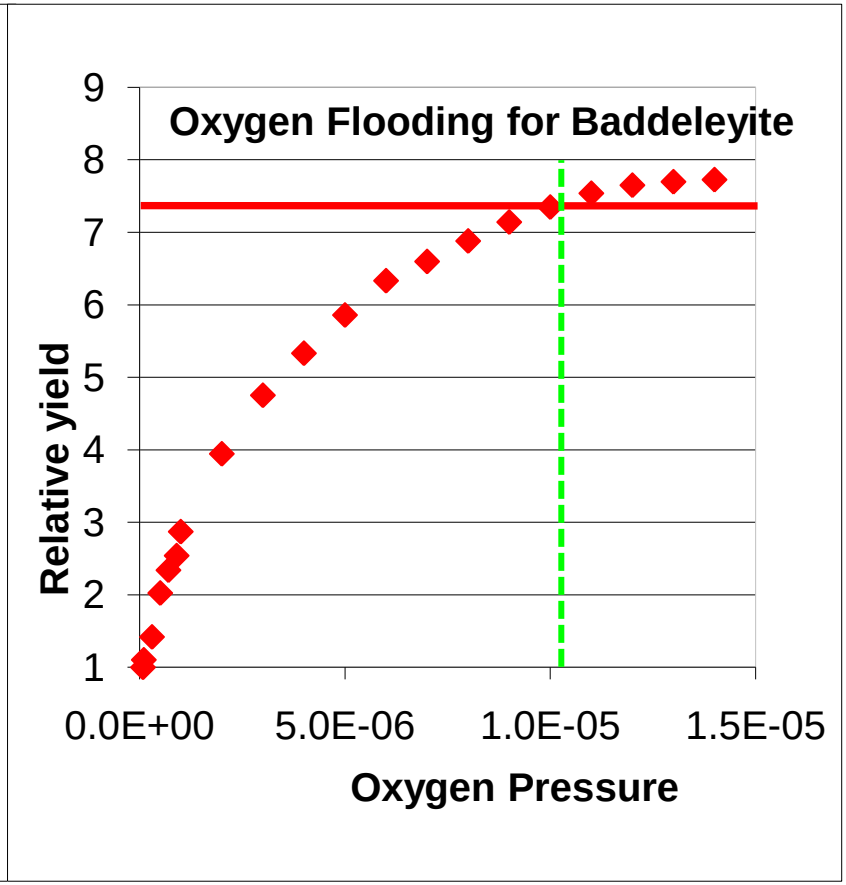
1. 提高Pb产率
2. 提高传输效率
3. 减小一次束变化对测量的影响
4. 提高磁场稳定性



1. 吹氧技术
2. 调整二次光学系统，使用XY透镜
3. 使用多接收器
4. 使用NMR装置

Oxygen-Flooding 增加Pb^+产率



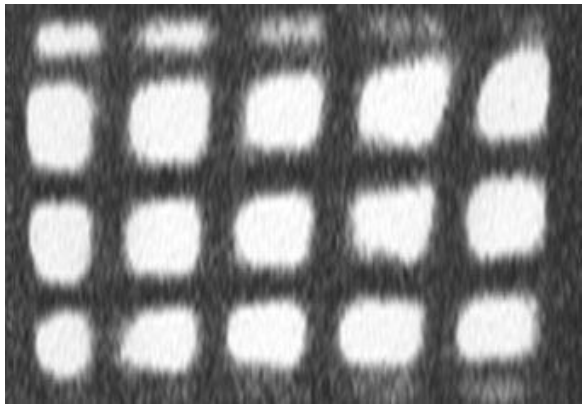


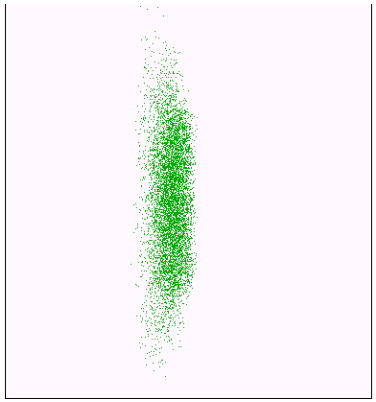
斜锆石Pb产率可达到原来的7倍以上！！！

XY mode 提高高分辨下传输效率

Circular mode

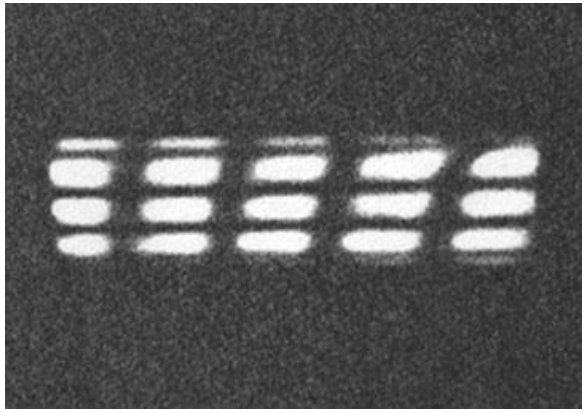
T1=66.1%,
MR(10%)=5085

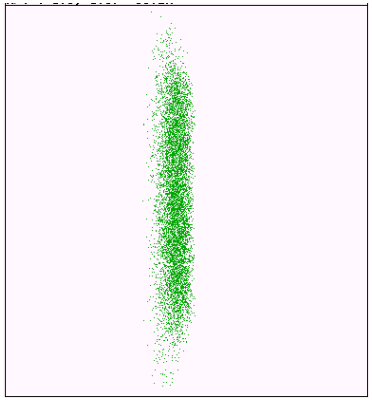




XY mode

T1=66.2%,
MR(10%)=6139

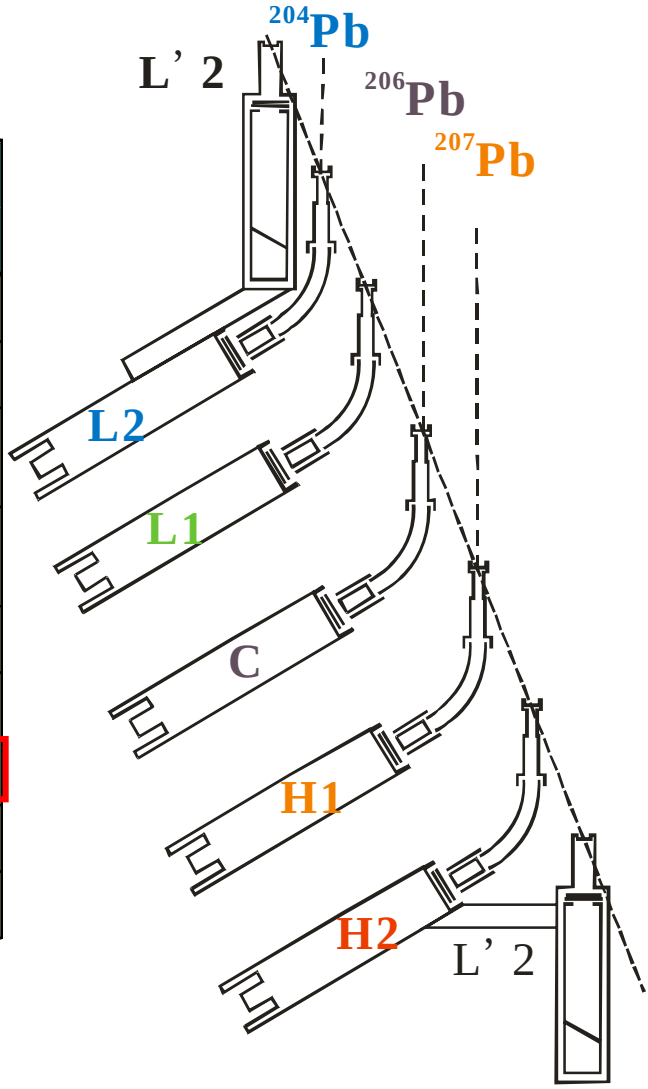




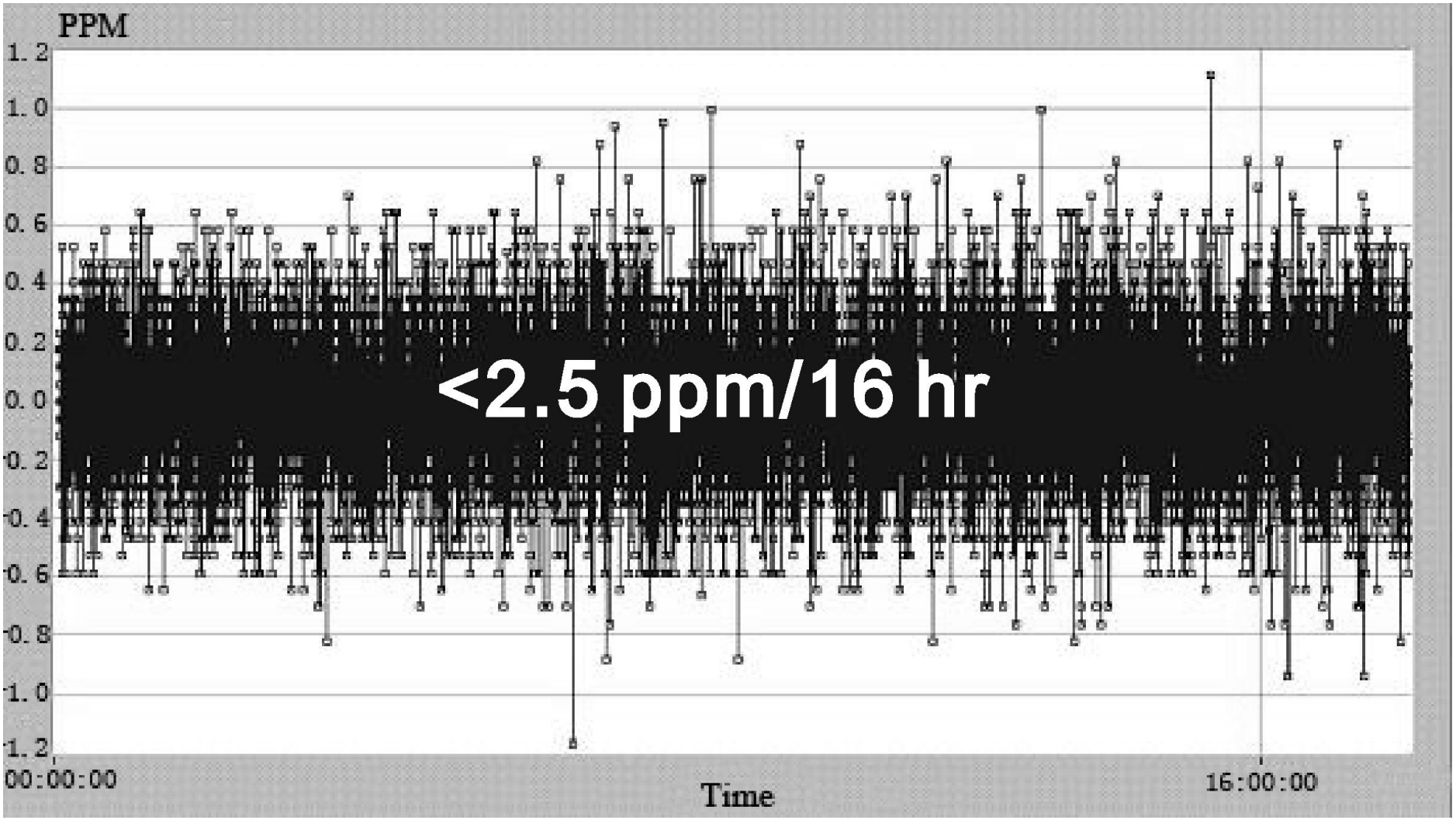
一般情况下，XY mode只应用于单接收模式!

IMS 1280多接收器

Trolley Detector	L'2 FC	L2 EM	L1 FC	C EM	H1 EM	H2 EM	H'2 FC
Li		6				7	
B		10				11	
C	12			13 (or Axial EM)			
O	16			17(Axial EM) (met only)		18 (met)	18 (earth)
Mg		24		25	26		27
Ti		46	47	48	49	50	
Pb		204		206	207	208	
Th		230	232				
U				235		238	



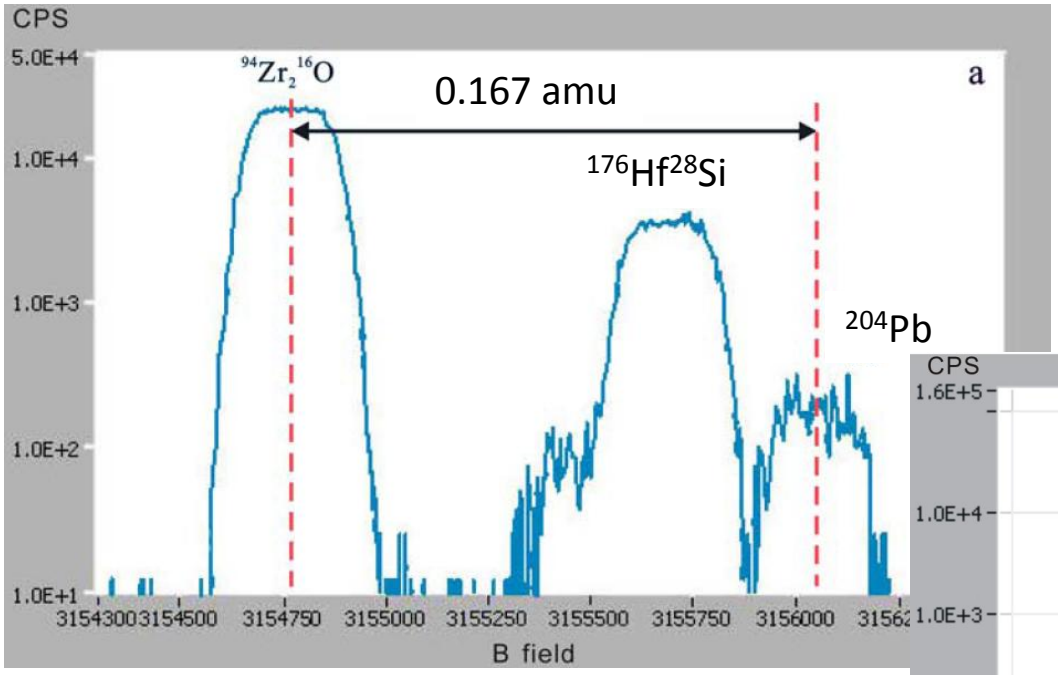
NMR技术一 高精度磁场控制



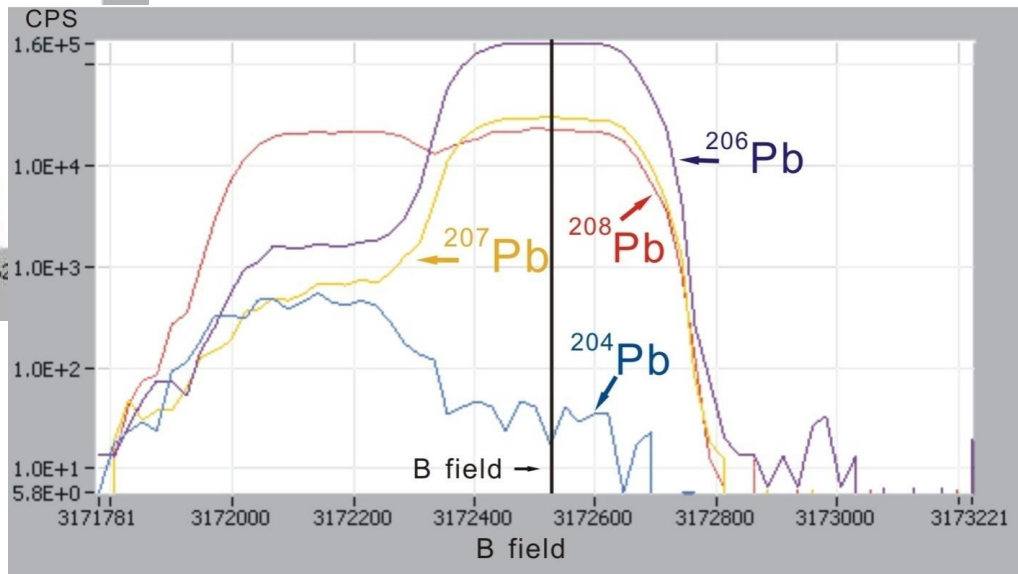
普通铅校正

- 准确的^{204}Pb质量位置锁定

$$f_{204} = \frac{^{206}Pb_c}{^{204}Pb_c} \times \frac{^{204}Pb}{^{206}Pb}$$

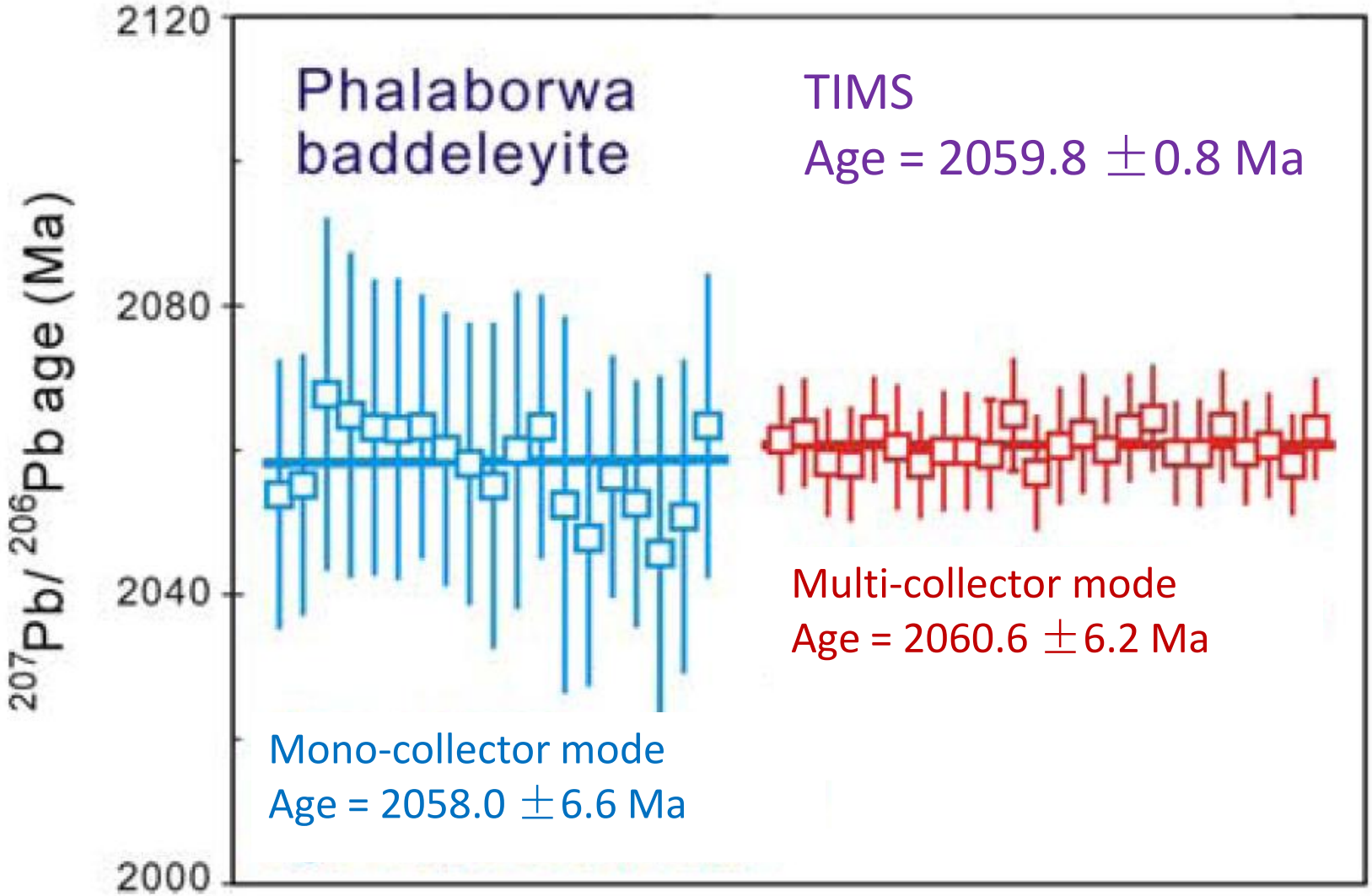


a.单接收谱图

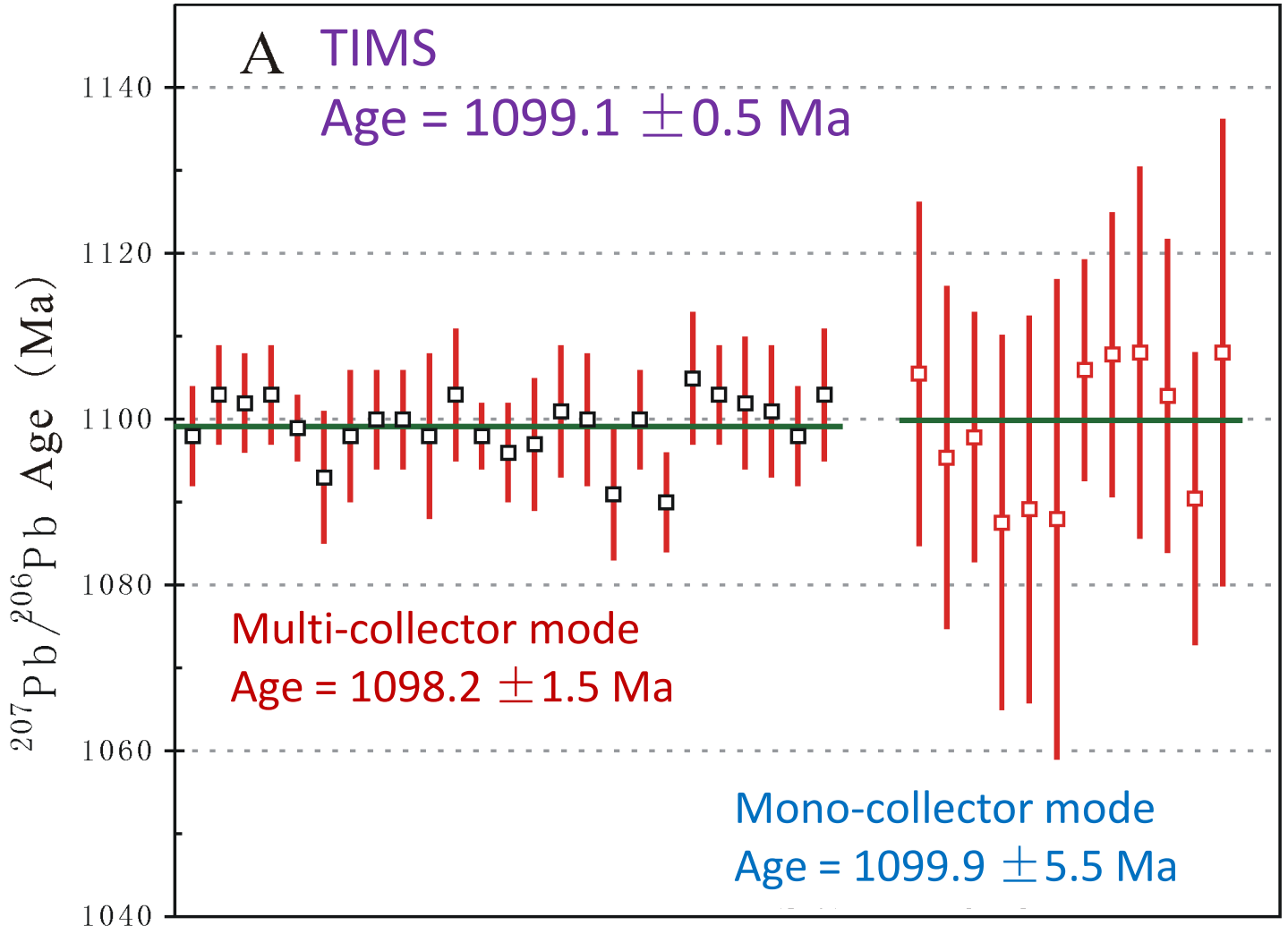


b.多接收谱图

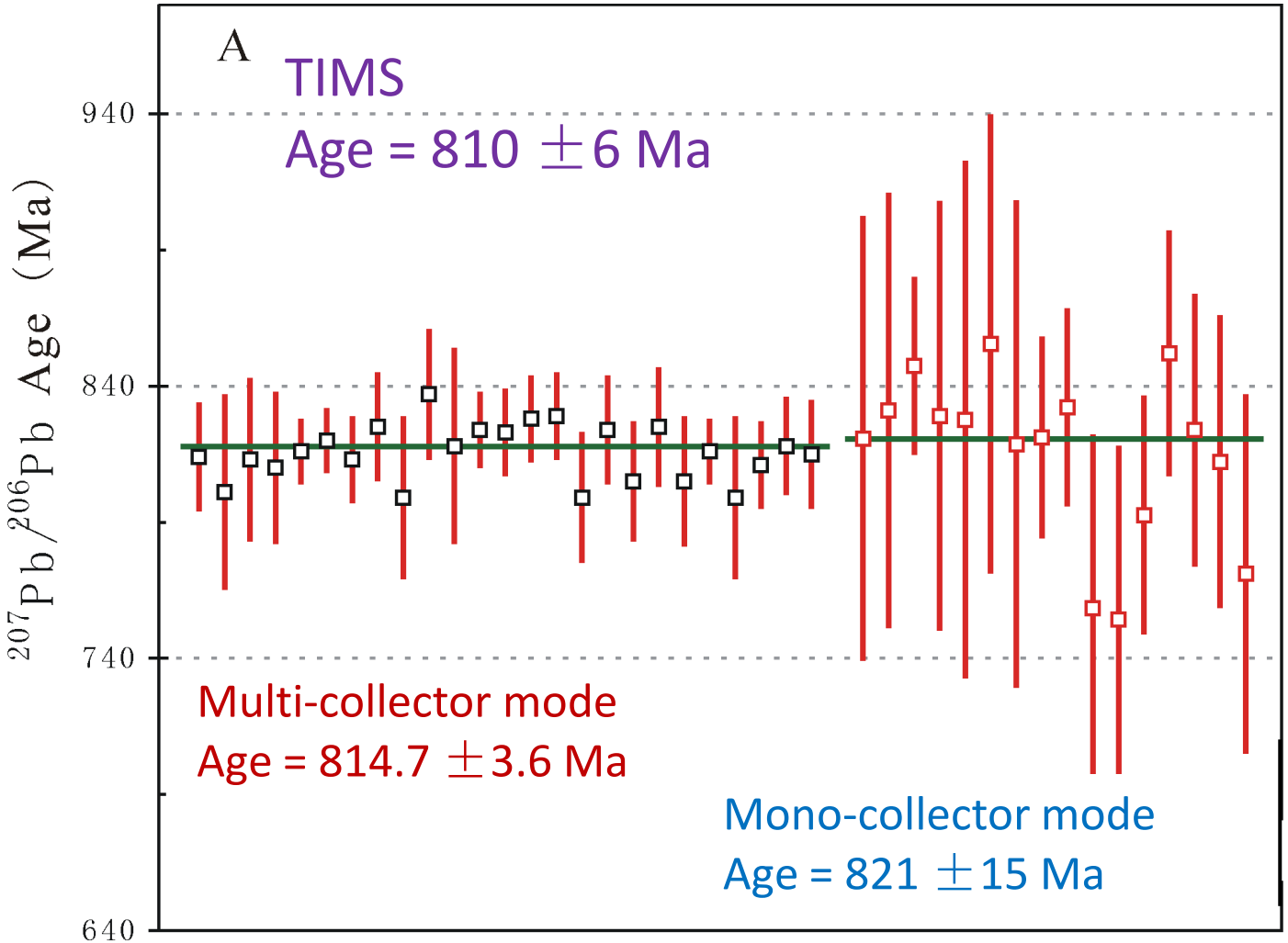
斜锆石定年结果


2120
2080
2040
2000
$^{207}Pb/^{206}Pb$ age (Ma)
Phalaborwa
baddeleyite
TIMS
Age = 2059.8 ±0.8 Ma
Multi-collector mode
Age = 2060.6 ±6.2 Ma
Mono-collector mode
Age = 2058.0 ±6.6 Ma

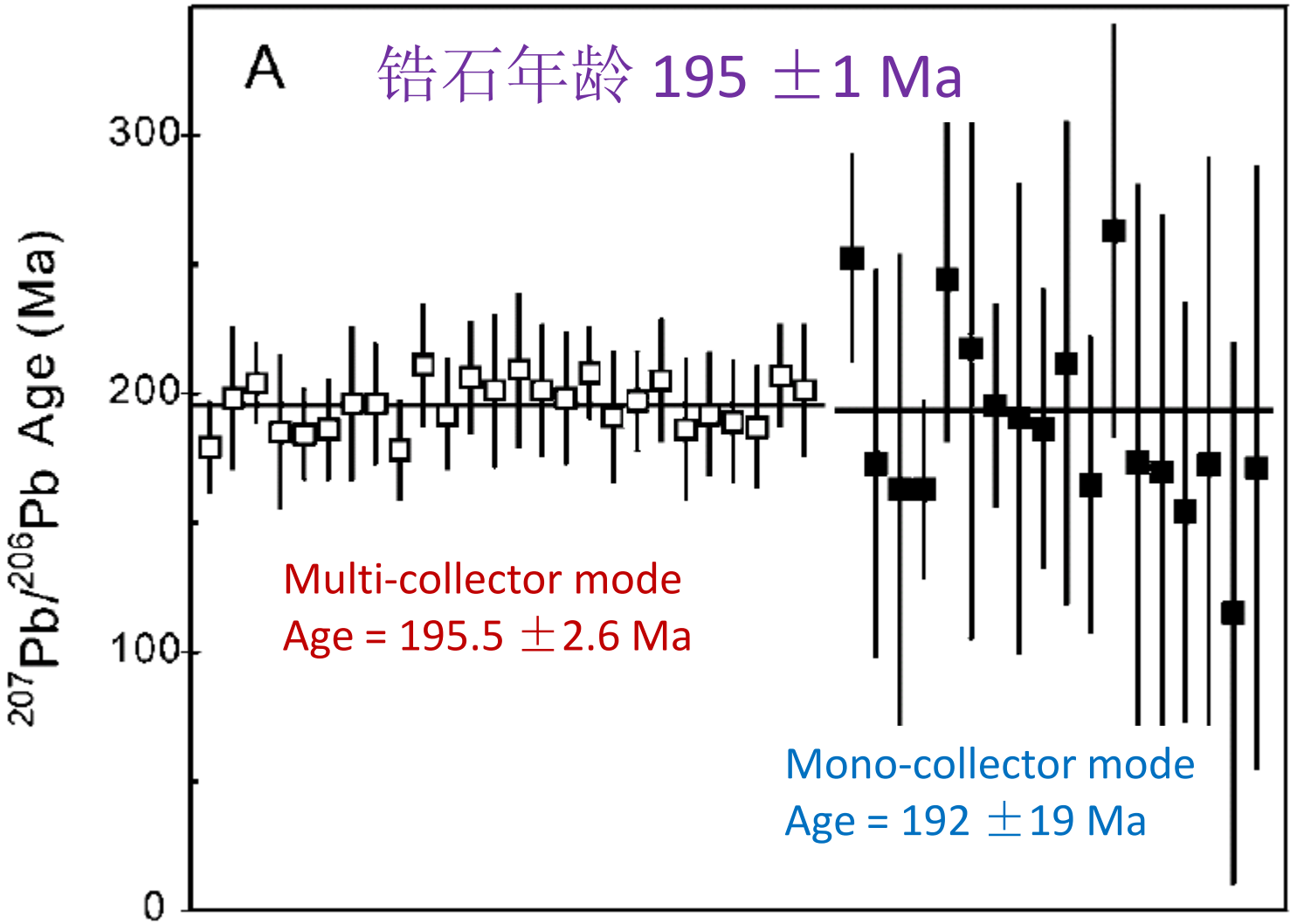
斜锆石定年结果


A
TIMS
Age = 1099.1 ±0.5 Ma
Multi-collector mode
Age = 1098.2 ±1.5 Ma
Mono-collector mode
Age = 1099.9 ±5.5 Ma
$^{207}Pb/^{206}Pb$ Age (Ma)
1140
1120
1100
1080
1060
1040

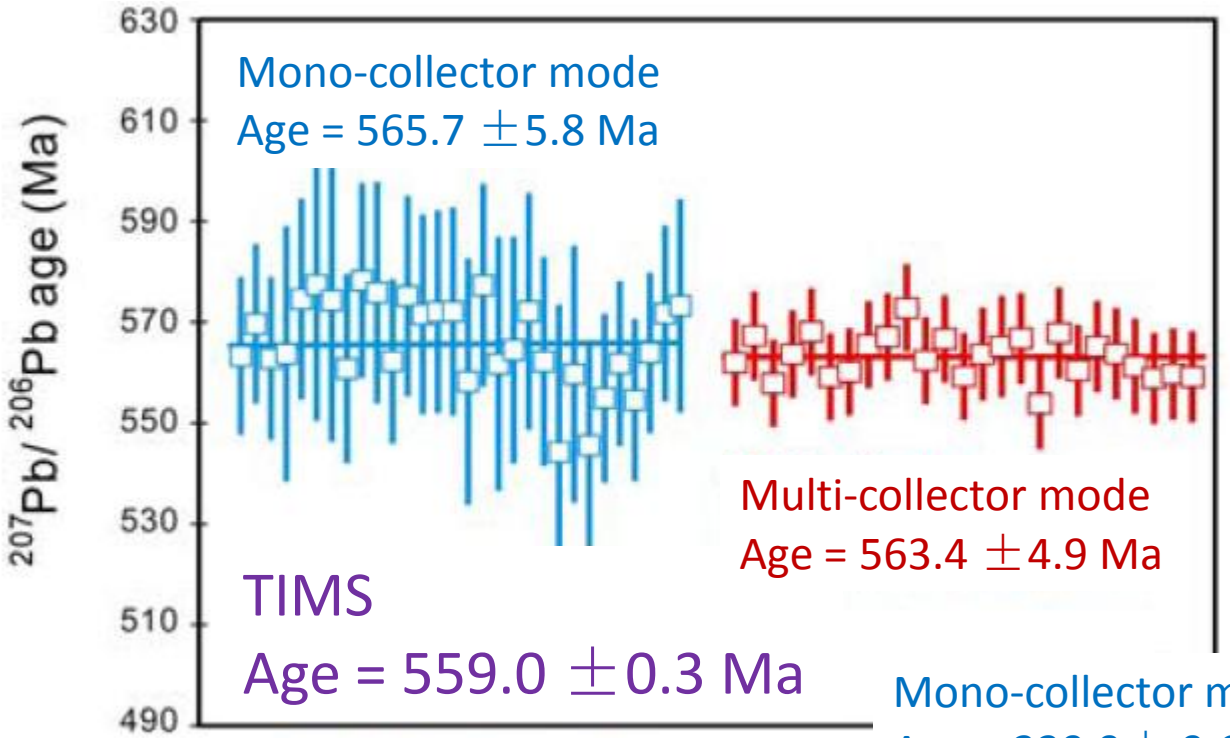
斜锆石定年结果

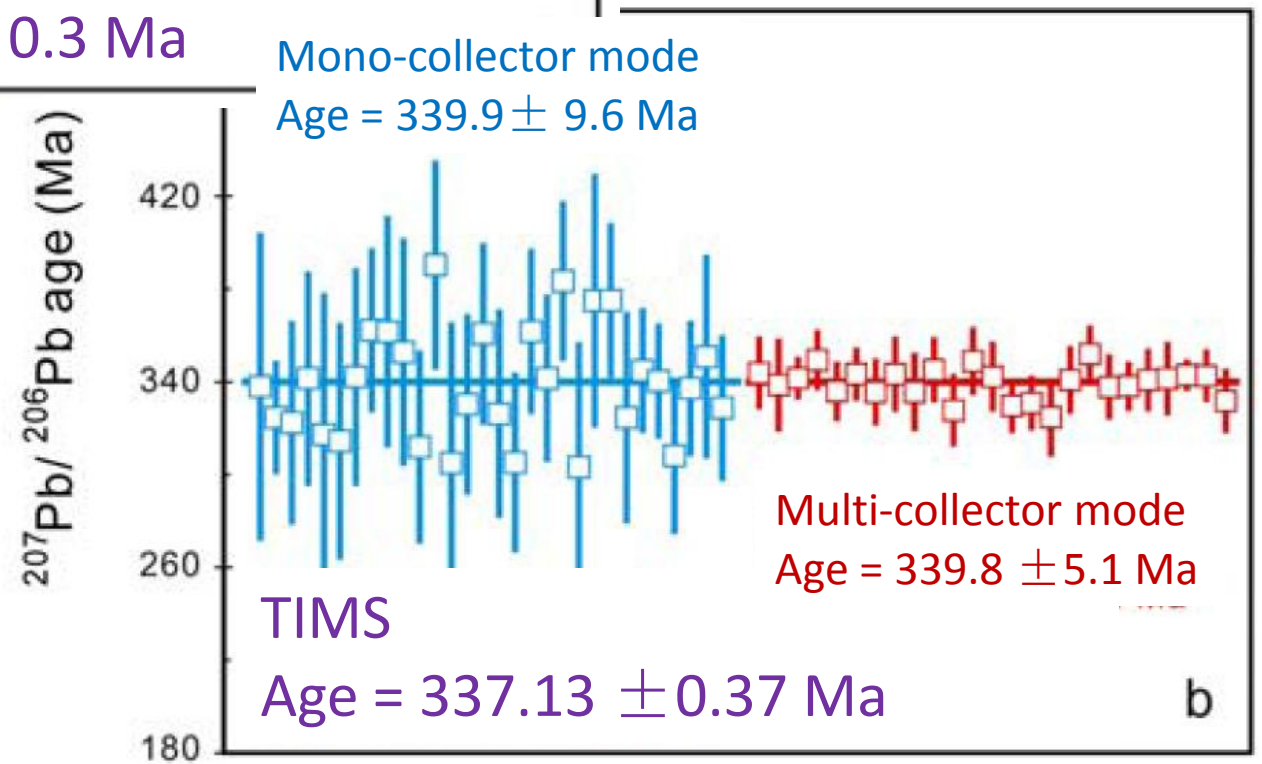

A
TIMS
Age = 810 ±6 Ma
940
840
740
640
$^{207}Pb/^{206}Pb$ Age (Ma)
Multi-collector mode
Age = 814.7 ±3.6 Ma
Mono-collector mode
Age = 821 ±15 Ma

斜锆石定年结果

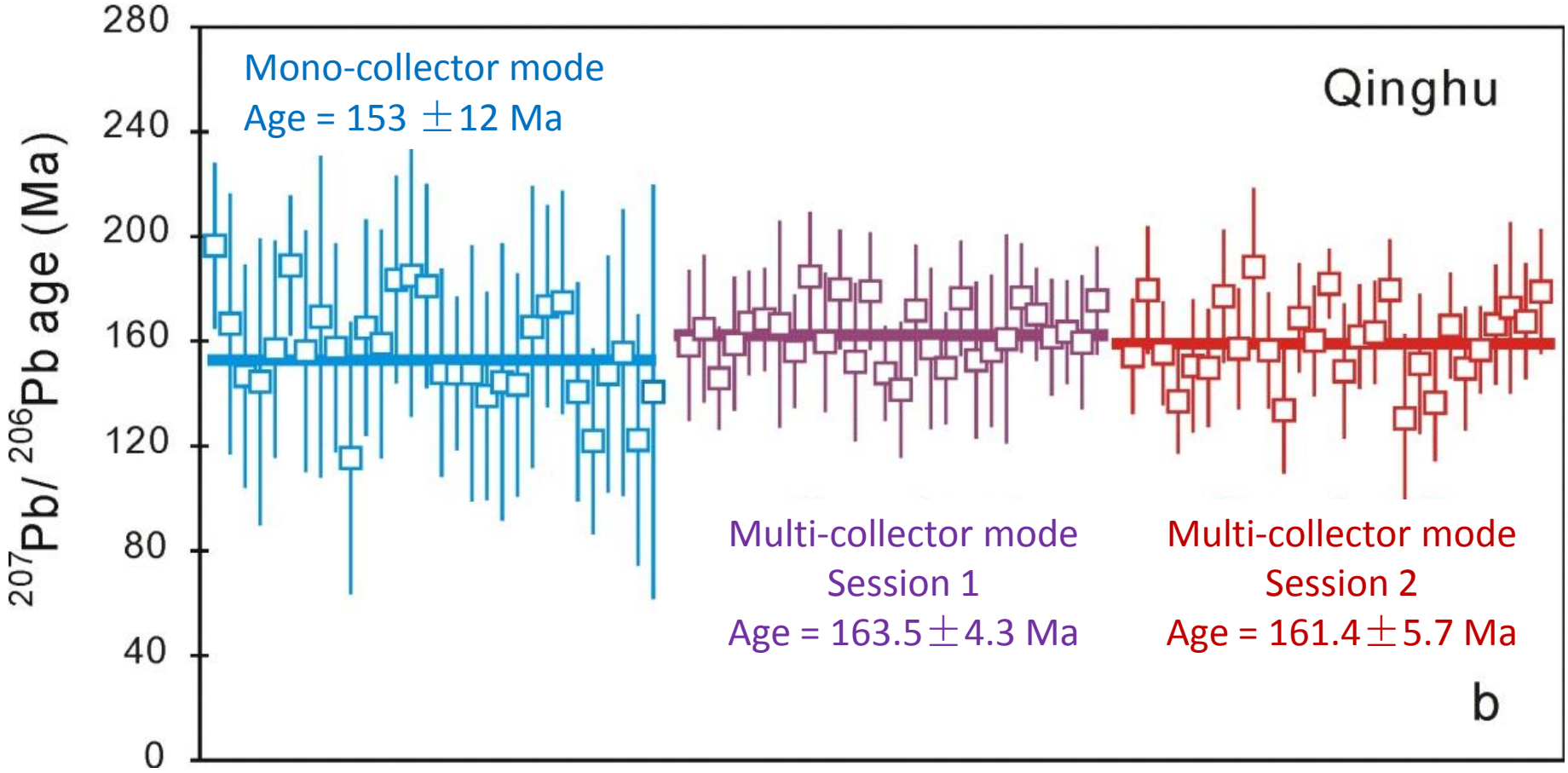

A
锆石年龄 195 ±1 Ma
300
200
100
0
$^{207}Pb/^{206}Pb$ Age (Ma)
Multi-collector mode
Age = 195.5 ±2.6 Ma
Mono-collector mode
Age = 192 ±19 Ma

锆石Pb-Pb定年


Mono-collector mode
Age = 565.7 ±5.8 Ma
Multi-collector mode
Age = 563.4 ±4.9 Ma
TIMS
Age = 559.0 ±0.3 Ma
$^{207}Pb/^{206}Pb$ age (Ma)
630
610
590
570
550
530
510
490


Mono-collector mode
Age = 339.9± 9.6 Ma
Multi-collector mode
Age = 339.8 ±5.1 Ma
TIMS
Age = 337.13 ±0.37 Ma
b
$^{207}Pb/^{206}Pb$ age (Ma)
420
340
260
180

锆石Pb-Pb定年


Mono-collector mode
Age = 153 ±12 Ma
Qinghu
Multi-collector mode
Session 1
Age = 163.5±4.3 Ma
Multi-collector mode
Session 2
Age = 161.4±5.7 Ma
b
$^{207}Pb/^{206}Pb$ age (Ma)
280
240
200
160
120
80
40
0

总结

通过本项目开发的方法，可以在20微米一次离子束的条件下对显生宙的斜锆石和锆石进行精确定年。

对一定量的数据(n<30)进行统计后，其精度达到<3%(锆石)和<1.5%(斜锆石)的水平。可满足实际应用。

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Precise determination of Phanerozoic zircon Pb/Pb age by multicollector SIMS without external standardization

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CASIMS

谢　谢！