朝鲜平南盆地古元古界-下古生界沉积岩碎屑锆石年龄谱对比及意义*

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Abstract The Pyongnam Basin of the Sino-Korean paleocontinent (the North China paleocontinent) is about ~25000km^2 and lies in Middle Korean Peninsula, with the low-grade metamorphosed (up to greenschist facies) Mesoproterozoic to Lower Paleozoic strata. There are also the Paleoproterozoic high-grade (amphibolite to granulite facies) strata in the basement. This paper reports LA-ICP MS U-Pb ages of detrital/metamorphic zircons to constrain the provenances of different strata, with implications for the regional evolution. The Jungsan Group/Complex belongs to the basement of the basin. The meta-sandstone shows distinct ca. 2500~2100Ma ages, and the ~3650Ma age was the oldest age known so far in Korean Peninsula. The sillimanite-garnet-bearing gneiss shows a prominent ~1850Ma age peak (1859±9Ma), which likely represents the age of metamorphism. It is thus suggested that the Jungsan Group was formed at 2100~1900Ma and metamorphosed at ~1850Ma. The Hwanghae Group distributes only in the center of Korean Peninsula, detrital zircons show significant ~1850Ma age peak, with minor ~1250Ma ages, and their provenance could be the Late Paleoproterozoic igneous and metamorphic rocks. Considering the deposition age of the Jikhyon Group, the Hwanghae Group was possibly deposited at 1250~1000Ma. The Jikhyon Group is widely distributed in the basin. Ages of detrital zircons from the first formation, the Jangbong Fm., show a distinct ~1850Ma peak, but there are only ca. 1000~1200Ma and ca. 1400~1600Ma peaks with few ages >1800Ma in the samples from the second and third groups, this indicates that the initial provenance of this group was the Paleoproterozoic basement, but then changed to the Mesoproterozoic rocks. It is further concluded that the deposition age of the Jikhyon Group is ca. 1000~900Ma. The Hwangju Group has two age peaks, i.e., the ~1850Ma and the ~2500Ma, with minor ca. 1000~1200Ma and 1400~1600Ma ages, this indicate that the provenance is the Late Archean-Paleoproterozoic basement with some re-deposited materials possibly from the Mesoproterozoic sediments (e.g., Jikhyon Group and/or Hwanghae Group). These age spectrums of the Pyongnam Basin are quite similar to those coeval sediments in the Liaodong and Shandong peninsulas, and the Mesoproterozoic-Neoproterozoic strata show distinguish ca. 1000~1200Ma and ca. 1400~1600Ma provenances. These rocks might be from other block(s) such as the São Francisco craton other than the North China continent itself.

Key words Korean Peninsula; Sino-Korean paleocontinent (North China paleocontinent); Pyongnam Basin; Ages of detrital zircon; Mesoproterozoic; Lower Paleozoic

摘 要 中朝古陆(华北古陆)平南盆地面积~25000km^2,位于朝鲜半岛中部,发育从中元古界到下古生界地层,但经历了低级变质作用(绿片岩相及以下)。变质基底岩石中有一套角闪岩相-麻粒岩相的变质的古元古界地层。本文根据盆地不同时代沉积岩碎屑锆石/变质锆石 U-Pb LA-ICP MS 年龄数据讨论沉积源区的变化,并对区域演化进行制约。甑山群/杂岩为盆

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地基底岩系,变质砂岩样品中碎屑锆石出现 ca. 2500 ~ 2100Ma 的年龄峰值。另外,36.5 亿年的碎屑锆石是朝鲜迄今发现的最古老碎屑锆石;夕线榴片麻岩样品记录了 ~1850Ma(1859 ±9Ma)的变质年龄;推测甑山群沉积于 ca. 2100 ~ 1900Ma,变质于 1850Ma。黄海群局限分布于朝鲜半岛中部,碎屑锆石年龄谱显示 ~1850Ma 的峰值,可见 ~1250Ma 的年龄,推测对应物源为古元古代基底岩浆岩和变质岩系;结合其上覆直峴群的沉积时代,推测地层沉积于 ca. 1250 ~ 1000Ma。直峴群是平南盆地分布最广的地层之一,底部长峰组样品显示明显的 ~1850Ma 的峰值,而其上第二个和第三个组则显示明显的 ca. 1400 ~ 1600Ma 和 ca. 1000 ~ 1200Ma 年龄峰值, ~1850Ma 年龄很少;推测直峴群开始沉积时,物源主体是盆地基底岩系,但之后出现大量中元古代物质;推测其沉积时代为 ca. 1000 ~ 900Ma。黄州群有 ~1850Ma 和 ~2500Ma 的峰值,另外,还有较少的 ca. 1000 ~ 1200Ma 及 1400 ~ 1600Ma 年龄,表明沉积物源主体仍是基底岩系,可能有中新元古代沉积岩(黄州群-直峴群)的再沉积。这些沉积岩碎屑锆石年龄峰值与辽东和山东半岛沉积地层相似,并且中新元古代地层中均有大量 1000 ~ 1200Ma 及 1400 ~ 1600Ma 的物质,推测可能来自华北古陆之外,如圣弗朗西斯科克拉通。

关键词 朝鲜半岛;中朝古陆(华北古陆);平南盆地;碎屑锆石年龄;元古宇;下古生界

中图法分类号 P534; P597.3

1 引言

平南盆地是中朝古陆(华北古陆)朝鲜半岛分布面积最大且演化时间最长的盆地,主体位于平城以南,开城以北,盆地中广泛发育古元古界-古生界地层(图 1)。大部分研究者认为平南盆地地层可以与邻区华北进行对比(Paek *et al.*, 1993; Choi and Kim, 1997; Park *et al.*, 2004; Park, 2012; Kim *et al.*, 2006, 2008; Zhai *et al.*, 2015)。最近,通过中朝两国科学院地质学研究团队的合作,在朝鲜半岛与华北地质对比研究,尤其是结晶基底对比方面,取得了重要成果(Zhao *et al.*, 2006; Wu *et al.*, 2007a, b; Zhai *et al.*, 2007a, b)。赵磊等(2016)和李秋立等(2016)还报道了古元古界甑山群变质作用及其时代的研究成果,但地层对比工作相对薄弱,多仅涉及新元古代祥原超群(Peng *et al.*, 2011a; Hu *et al.*, 2012; 朴贤旭等,2016a)。本文利用古元古界甑山群和中元古界黄

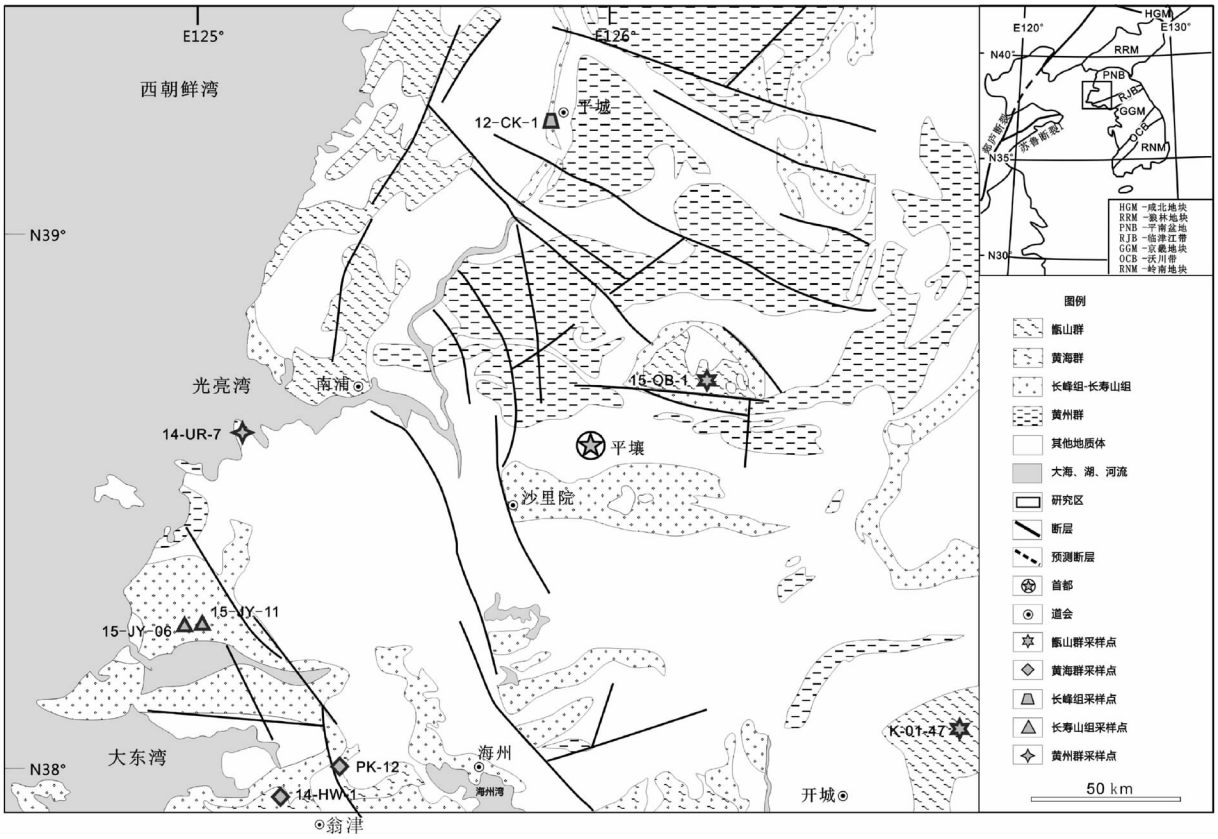

图 1 平南盆地西部地质简图(据 Paek *et al.*, 1993 改编)

图中样品 15-OB-1 附近甑山群范围即为店古隆起

Fig. 1 Simplified geological map of the western part of the Pyongnam Basin (revised after Paek *et al.*, 1993)

海群、新元古界直岘群、下寒武统黄州群中和组的碎屑锆石年龄，解释平南盆地古元古代-寒武纪沉积物源区的演化特征，通过与华北其他地区的对比，探讨其地质意义。

2 地质概况与样品描述

古元古界甑山群（杂岩）原始地层包括富铝质的片麻岩，基性火山岩和碳酸盐岩互层，以及变砂泥质岩石，可能形成于弧后盆地（Kim *et al.*，2006，2008；彭澎等，2016）。Paek *et al.*（1993）曾将甑山群分为 5 个组，后来把部分片麻岩和混合岩归属于狼林群（杂岩）（Kim *et al.*，2006，2008；Han *et al.*，2011）。甑山群主要分布在南浦-甑山-平原地区，变质级别达高角闪岩相-麻粒岩相，但店古隆起带等其它地区变质相只达到角闪岩相（Paek *et al.*，1993；Han *et al.*，2011）。店古隆起是平南盆地内部前寒武纪基底地层出露最广的隆起带之一。在这一地区，甑山群岩石与太古宙莲花山花岗岩以韧性剪切带为界相接（Kim *et al.*，2006），出露面积各占百分之五十（Paek *et al.*，1993），甑山群主要出露于隆起带的边缘地区，主要以长英质片麻岩和变质砂岩组成，夹少量石墨片麻岩和斜长角闪岩、大理岩。其中，变质砂岩主要出露于祥源-燕滩地区。本研究采集燕滩地区变质石英砂岩样品（15-OB-1）。该岩石几乎全部为石英，定向分布，残留半径大于 0.5mm 的碎斑（图 2a），发育的定向（图 2b）。开城东部甑山群分布于泥盆系（?）临津群东侧，与临津群构造较好接触，变质程度较高（Han *et al.*，2011），我们在这一地区采集了 1 件样品（K-01-47），岩性为夕线榴片麻岩，采样点位置如图 1。

中元古界黄海群分布于平南盆地南部瓮津-碧城-率拉地区（Paek *et al.*，1993），可以分为三个部分，最下部是泥质片岩为主，中部以石英片岩为主，上部由酸性火山岩和斜长角闪岩、大理岩组成（Kim *et al.*，2006，2008；Han *et al.*，2011）。酸性火山岩岩性为石英斑岩和长石斑岩等，与瓮津花岗岩均形成于 ~12.5 亿年（朴贤旭等，2016b）。本研究在碧城地区黄海群下部层位石英片岩（PK-12）和瓮津地区火山沉积岩（含云母长石石英片岩，原岩或为变质长石石英砂岩，14-HW-1）中各取样品做碎屑锆石年龄谱分析。

新元古界直岘群是平南盆地中分布最广的地层之一，从下往上由长峰组砾岩-砂岩、五峰组泥质-石灰质片岩、长寿山组砂岩-砂质片岩、安心岭组泥灰岩组成，长峰组砾岩主要在平南盆地中南部地区，北部地区未见，但可见砂岩，主要由中细粒石英砂岩、石英长石砂岩组成，夹 1 ~ 2m 硅质千枚岩（Han *et al.*，2011；Park，2012）。平城附近砂岩层厚度 10 ~ 20m，样品 12-CK-1 来自该层。第三个组长寿山组分布广，平南盆地南部地层厚，分层性好；北部薄，分层性差。盆地西南部长渊地区厚度尤其大，自下而上可以划分 4 个段：第 1 段厚度 120m，主要由灰白色厚层状细粒砂岩、互层状砂岩、石英质千枚岩、灰白色细粒砂岩、薄层状石英质千枚岩组成；第 2 段厚 350m，主要由厚层状灰白色层状细粒砂岩、灰白色厚层状中细粒砂岩、砂岩组成；第 3 段厚度为 100m 左右，含铁矿，称为中部含矿段（Ryu *et al.*，1990；Park *et al.*，2012），岩石组成较复杂，主要由砾岩（图 2g，h）、石英质千枚岩、浅灰绿色砂岩、暗灰色磁铁矿石英千枚岩、含铁砂岩、铁绿泥石砂岩、紫红色千枚岩、灰黄色千枚岩等组成；第 4 段厚 400m，由厚层状细粒砂岩、灰白色中细粒砂岩、砂岩状硅岩、薄层状砂岩组成，最上部广泛发育薄层状砂岩，是与其上安心岭组之间界限标志层（Han *et al.*，2011；Park *et al.*，2012）。本研究对第 2 段和第 3 段分别采样：第 2 段上部砂岩（样品号 15-JY-06）为灰白色细粒砂岩，由 90% 石英和 1% ~2% 的黏土矿物组成，含少量金属矿物，石英粒度 0.45 ~ 0.95mm（图 2c，d）；第 3 段上部砂岩（样品号 15-JY-11）为浅灰绿白色砂岩，椭圆形或角砾状，无定向，主体为石英，可分 0.15 ~ 0.35mm 的砂质（60%）和 0.03 ~ 0.1mm 的粉砂质（40%）（图 2e，f）。

下古生界黄州群共分 4 个组，从下往上为坪山组、中和组、黑桥组、林村组（Park *et al.*，2012）。以前所称的黄州系（Paek *et al.*，1993），现在称为黄州超群（Park *et al.*，2012），包括黄州群与法洞群。黄州群属于下寒武-中寒武统，而法洞群属于上寒武统-志留系。黄州群的最下部层位为含磷硫化物的坪山组黑色页岩粉砂岩，仅见于盆地南部（Choi and Kim，1997；Park *et al.*，2004）。其上中和组由砂岩，粉砂岩，板岩、碳酸盐组成，底部有含磷粉砂岩，本研究在最底部砂岩中取样（14-UR-7），该砂岩层厚 10 ~ 15m，白色，或浅黄色，石英含量 95%，含绢云母、长石、金属矿物、粘土矿物，石英颗粒大小为 0.03 ~ 0.9mm，有粘土矿物胶结，砂状结构，绢云母无定向排列。

图 3 是平南盆地古元古界-古生界地层柱状图及取样位置图。

3 测试方法

将样品粉碎至 60 目以下，在双目镜下挑出锆石。将锆石粘在双面胶上，固定于透明的环氧树脂中，打磨抛光，分别照透射光和反射光照片，在中国科学院地质与地球物理研究所扫描电镜实验室用 LEO 1450VP 扫描电镜拍摄 CL 图像。锆石颗粒大小在 80 ~ 230μm 范围内。用带有 Geolas 200M 激光剥蚀系统的 Agilent 7500a ICP-MS 同时原位测定锆石 U-Pb 同位素和元素含量。U-Pb 同位素的外标为哈佛大学的标准锆石 91500，参考值加权平均 $^{206}Pb/^{238}U$ 年龄为 1065.4 ± 0.6Ma（Wiedenbeck *et al.*，1995）；元素含量的计算外标为硅酸盐玻璃 NIST SRM 610，内标为 ^{29}Si。年龄测试激光束斑直径为 40μm，剥蚀深度为 20 ~ 40μm。U-Pb 同位素和元素含量原始数据使用 GLITTER 4.0 软件进行处理。锆石的 U-Pb 年龄结果使用 Isoplot3.0 软件（Ludwig，2003）计算。

4 分析结果

所有样品，锆石晶体大多显示不同程度的磨圆，大部分

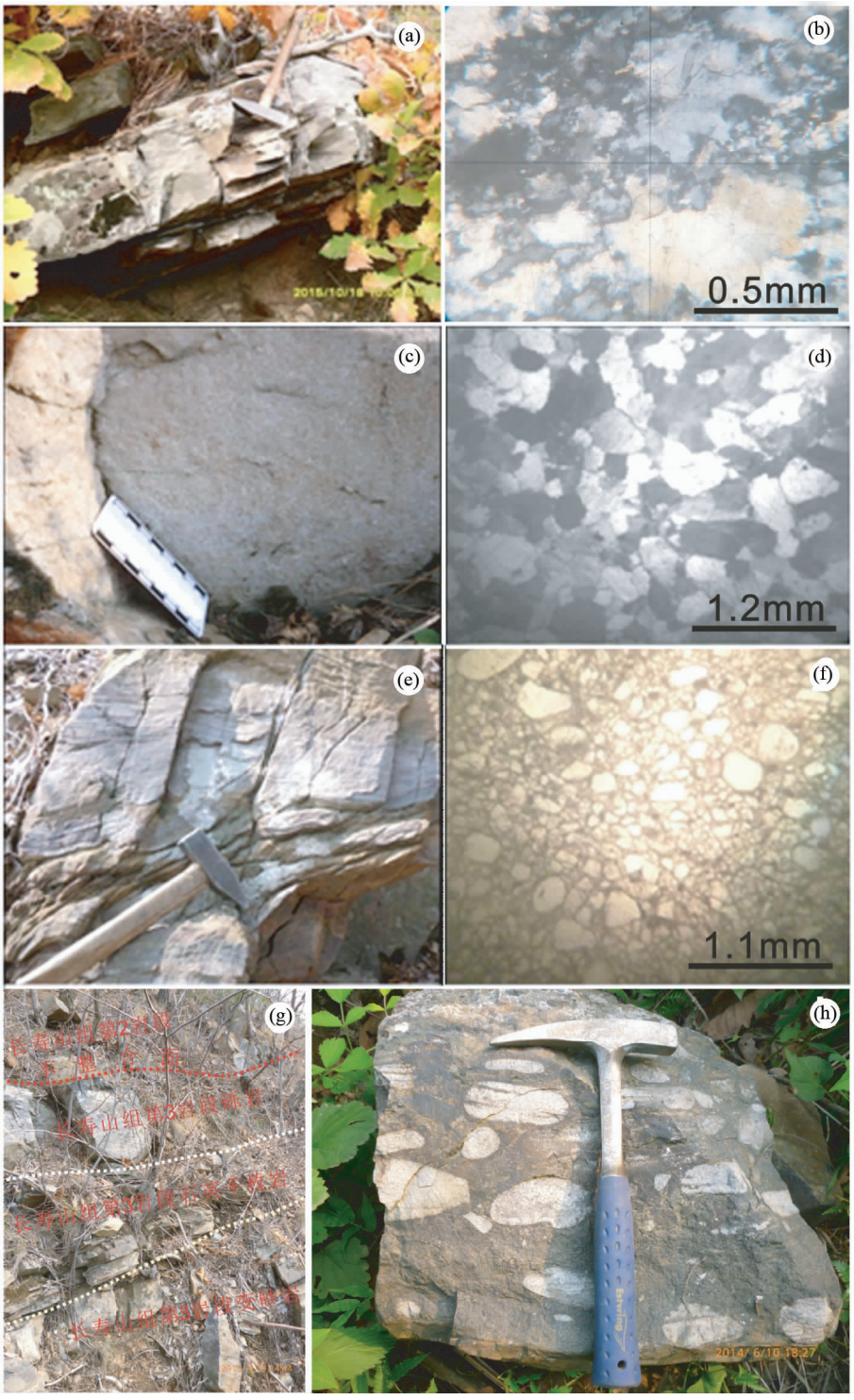

图 2 甑山群与直岘群部分露头和样品照片

(a)甑山群变砂岩(15-OB-1)(锤子手柄长为 30cm);(b)甑山群变砂岩偏光显微镜照片(正交偏光);(c)直岘群长寿山组第 2 段上部砂岩(15-JY-06);(d) 15-JY-06 的偏光显微镜照片(正交偏光);(e)直岘群长寿山组第 3 段下部砂岩(15-JY-11);(f) 15-JY-11 的偏光显微镜照片(单偏光);(g)直岘群长寿山组中砾岩野外剖面;(h)长寿山组砾岩岩石照片

Fig. 2 Representative photos for the Jungsan and Jikhyon groups

锆石发育岩浆环带(图 4)。锆石受后期变质作用等过程的影响,U-Pb 封闭体系可能发生破坏,一些年龄点可能不在谐和线上,并可能造成年龄误差较大,因此,我们去掉谐和度较差(谐和度低于 90%)或者年龄误差($^{207}Pb/^{206}Pb$ 年龄)大于

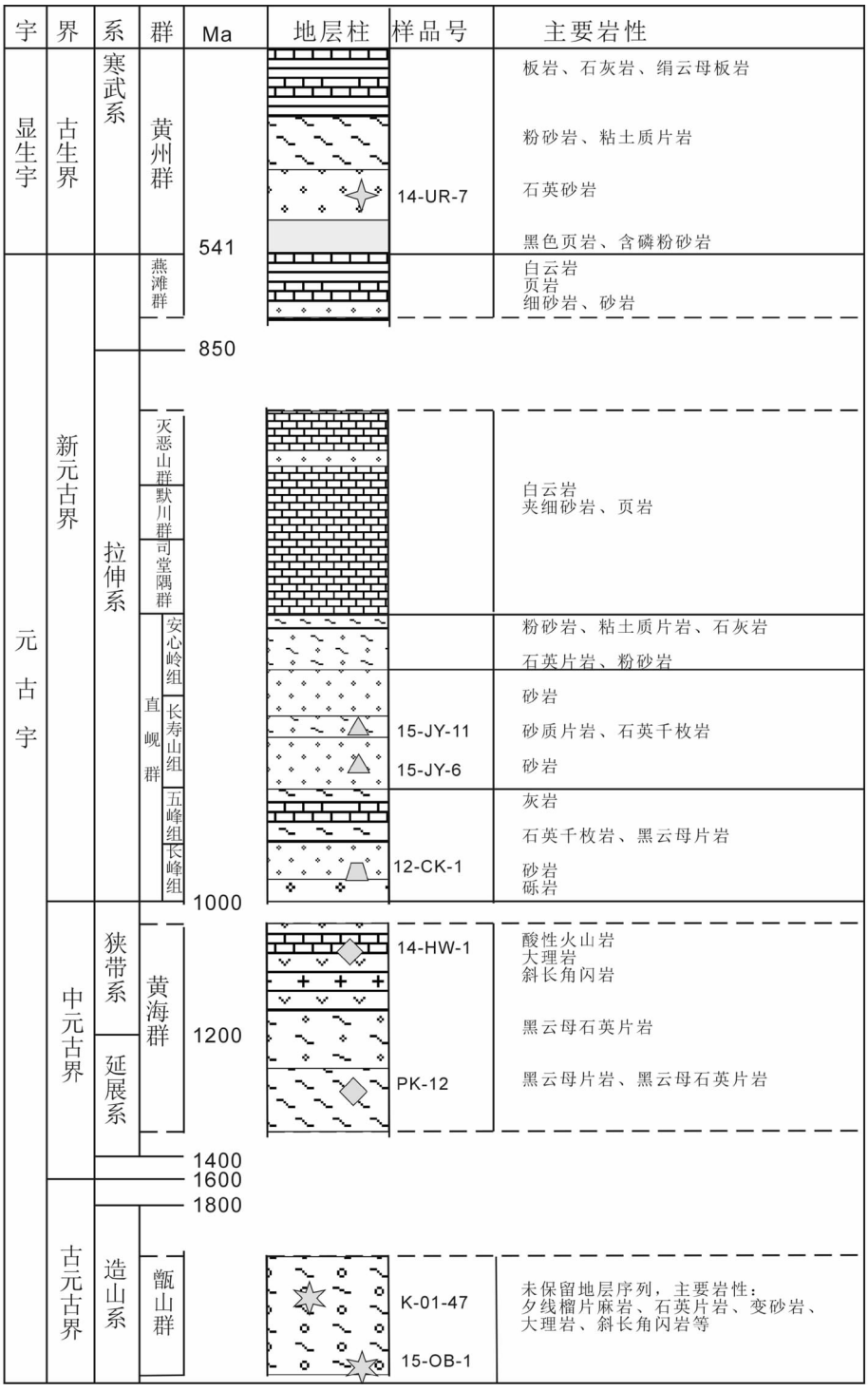

图 3　平南盆地甑山群、黄海群、直岘群、黄州群地层柱状图及取样位置图(据 Paek *et al.*，1993；Peng *et al.*，2011a；朴贤旭等，2016a 改编)

坐标轴为非等比例，地层柱高度不代表时限长短

Fig. 3　Stratigraphy column and the sampling localities for the Jungsan, Hwanghae, Jikhyon, Hwangju groups (modified after Paek *et al.*, 1993; Peng *et al.*, 2011a; Park *et al.*, 2016a)

50Ma 的数据点(表 1)。所有年龄统计结果见图 5。

店古隆起甑山群样品(15-OB-1)碎屑锆石年龄大部分为 2700 ~ 2100Ma，其中 1 个颗粒(15-OB-1-15) U-Pb 年龄为 3644 ± 17Ma($^{207}Pb/^{206}Pb$ 年龄与 $^{207}Pb/^{235}U$ 年龄，$^{206}Pb/^{238}U$ 年龄各为 3644Ma 与 3638Ma、3628Ma)。还有 1 个颗粒(15-OB-1-48) $^{207}Pb/^{206}Pb$ 年龄为 3560Ma，但年龄不谐和。这些锆

表 1　锆石 U-Pb LA-ICP MS 数据表

Table 1　Zircon LA-ICP MS U-Pb data

测点号	Th	U	Th/U	同位素比值						年龄(Ma)					
	($\times10^{-6}$)			$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)
15-OB-1 甑山群变质砂岩															
15-OB-1-1	307	393	0.78	0.16473	0.0022	10.79328	0.1395	0.47532	0.00944	2505	17	2505	12	2507	41
15-OB-1-2	107	162	0.66	0.1282	0.00194	6.69617	0.09774	0.3789	0.0076	2073	17	2072	13	2071	36
15-OB-1-3	94.4	129	0.73	0.18709	0.00237	13.5066	0.16603	0.52372	0.01034	2717	17	2716	12	2715	44
~~15-OB-1-4~~	~~262~~	~~360~~	~~0.73~~	~~0.18235~~	~~0.00274~~	~~12.06961~~	~~0.17711~~	~~0.48017~~	~~0.00988~~	~~2674~~	~~17~~	~~2610~~	~~14~~	~~2528~~	~~43~~
15-OB-1-5	131	144	0.91	0.16367	0.00308	10.31977	0.19029	0.45741	0.01001	2494	17	2464	17	2428	44
~~15-OB-1-6~~	~~646~~	~~803~~	~~0.80~~	~~0.15282~~	~~0.00701~~	~~5.2512~~	~~0.20213~~	~~0.24921~~	~~0.00621~~	~~2378~~	~~80~~	~~1861~~	~~33~~	~~1434~~	~~32~~
~~15-OB-1-7~~	~~196~~	~~409~~	~~0.48~~	~~0.1555~~	~~0.00439~~	~~9.17461~~	~~0.17947~~	~~0.42791~~	~~0.00873~~	~~2407~~	~~49~~	~~2356~~	~~18~~	~~2296~~	~~39~~
~~15-OB-1-8~~	~~728~~	~~1415~~	~~0.51~~	~~0.07039~~	~~0.00538~~	~~1.32807~~	~~0.0968~~	~~0.13683~~	~~0.00315~~	~~940~~	~~162~~	~~858~~	~~42~~	~~827~~	~~18~~
15-OB-1-9	127	256	0.50	0.17994	0.00233	12.59213	0.15785	0.50763	0.01003	2652	17	2650	12	2647	43
15-OB-1-10	56.5	113	0.50	0.17837	0.00383	12.39723	0.26464	0.50419	0.01185	2638	17	2635	20	2632	51
15-OB-1-11	26.8	43.3	0.62	0.15415	0.00438	9.5697	0.26903	0.45034	0.01176	2392	21	2394	26	2397	52
15-OB-1-12	77.5	73.3	1.06	0.15917	0.00276	10.12286	0.17175	0.46133	0.00977	2447	16	2446	16	2445	43
15-OB-1-13	242	163	1.48	0.17409	0.00325	11.88143	0.2194	0.49508	0.01092	2597	17	2595	17	2593	47
15-OB-1-14	140	154	0.91	0.14096	0.00242	8.06336	0.13437	0.41497	0.00863	2239	16	2238	15	2238	39
15-OB-1-15	237	205	1.15	0.33584	0.00609	34.9862	0.67676	0.75568	0.01844	3644	17	3638	19	3628	68
~~15-OB-1-16~~	~~161~~	~~645~~	~~0.25~~	~~0.13971~~	~~0.00364~~	~~7.0956~~	~~0.12114~~	~~0.36836~~	~~0.00725~~	~~2224~~	~~46~~	~~2123~~	~~15~~	~~2022~~	~~34~~
15-OB-1-17	34.9	59.3	0.59	0.13105	0.00415	7.00638	0.21708	0.3878	0.01023	2112	24	2112	28	2113	48
15-OB-1-18	141	265	0.53	0.19318	0.00232	14.30072	0.16556	0.53698	0.01042	2769	17	2770	11	2771	44
~~15-OB-1-19~~	~~403~~	~~671~~	~~0.60~~	~~0.15216~~	~~0.00247~~	~~4.98776~~	~~0.07604~~	~~0.23778~~	~~0.0048~~	~~2370~~	~~16~~	~~1817~~	~~13~~	~~1375~~	~~25~~
~~15-OB-1-20~~	~~814~~	~~1573~~	~~0.52~~	~~0.11882~~	~~0.00366~~	~~3.9117~~	~~0.09109~~	~~0.23877~~	~~0.00481~~	~~1939~~	~~56~~	~~1616~~	~~19~~	~~1380~~	~~25~~
~~15-OB-1-21~~	~~206~~	~~501~~	~~0.41~~	~~0.16915~~	~~0.00237~~	~~10.68686~~	~~0.14466~~	~~0.45828~~	~~0.00914~~	~~2549~~	~~17~~	~~2496~~	~~13~~	2432	~~40~~
15-OB-1-22	34.4	90.1	0.38	0.15653	0.00473	9.90104	0.29657	0.45882	0.01247	2419	23	2426	28	2434	55
15-OB-1-23	56.0	76.8	0.73	0.14671	0.00478	8.69597	0.27904	0.42993	0.01194	2308	25	2307	29	2305	54
15-OB-1-24	102	191	0.54	0.16078	0.00297	10.30953	0.18703	0.46511	0.01005	2464	16	2463	17	2462	44
15-OB-1-25	107	131	0.81	0.16672	0.00248	11.00088	0.15927	0.47861	0.00969	2525	16	2523	13	2521	42
15-OB-1-26	122	489	0.25	0.15858	0.0021	10.0568	0.12813	0.45999	0.00901	2441	17	2440	12	2440	40
~~15-OB-1-27~~	~~211~~	~~602~~	~~0.35~~	~~0.15919~~	~~0.00222~~	~~9.48116~~	~~0.12708~~	~~0.432~~	~~0.00854~~	~~2447~~	~~17~~	~~2386~~	~~12~~	~~2315~~	~~38~~
~~15-OB-1-28~~	~~323~~	~~501~~	~~0.65~~	~~0.1579~~	~~0.00314~~	~~7.64779~~	~~0.1459~~	~~0.35132~~	~~0.00763~~	~~2433~~	~~16~~	~~2190~~	~~17~~	~~1941~~	~~36~~
~~15-OB-1-29~~	~~545~~	~~655~~	~~0.83~~	~~0.12156~~	~~0.00264~~	~~2.96424~~	~~0.06016~~	~~0.17687~~	~~0.00374~~	~~1979~~	~~17~~	~~1399~~	~~15~~	~~1050~~	~~20~~
15-OB-1-30	63.8	86.9	0.73	0.16255	0.0032	10.53743	0.2041	0.47021	0.0104	2482	17	2483	18	2484	46
15-OB-1-31	119	190	0.62	0.16158	0.00282	10.41225	0.17793	0.4674	0.00988	2472	16	2472	16	2472	43
~~15-OB-1-32~~	~~188~~	~~364~~	~~0.52~~	~~0.15325~~	~~0.00449~~	~~9.01697~~	~~0.18964~~	~~0.42675~~	~~0.00872~~	~~2382~~	~~51~~	~~2340~~	~~19~~	~~2291~~	~~39~~
~~15-OB-1-33~~	~~606~~	~~419~~	~~1.45~~	~~0.16947~~	~~0.00283~~	~~7.86389~~	~~0.1249~~	~~0.33657~~	~~0.00693~~	~~2552~~	~~16~~	~~2216~~	~~14~~	~~1870~~	~~33~~

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$ 年龄(Ma)	(±%)	$\frac{^{207}Pb}{^{235}U}$ 年龄(Ma)	(±%)	$\frac{^{206}Pb}{^{238}U}$ 年龄(Ma)	(±%)
~~15-OB-1-34~~	~~128~~	~~113~~	~~1.14~~	~~0.15821~~	~~0.00274~~	~~9.48728~~	~~0.15971~~	~~0.43493~~	~~0.0091~~	~~2437~~	~~16~~	~~2386~~	~~15~~	~~2328~~	~~41~~
~~15-OB-1-35~~	~~89.5~~	~~1537.2~~	~~0.06~~	~~0.09339~~	~~0.00309~~	~~2.09241~~	~~0.05559~~	~~0.1625~~	~~0.0032~~	~~1496~~	~~64~~	~~1146~~	~~18~~	~~971~~	~~18~~
~~15-OB-1-36~~	~~434~~	~~633~~	~~0.69~~	~~0.1563~~	~~0.00237~~	~~8.54967~~	~~0.12442~~	~~0.39672~~	~~0.00795~~	~~2416~~	~~16~~	~~2291~~	~~13~~	~~2154~~	~~37~~
15-OB-1-37	148	195	0.76	0.1923	0.00361	14.05602	0.2627	0.53015	0.01181	2762	16	2753	18	2742	50
~~15-OB-1-38~~	~~375~~	~~285~~	~~1.32~~	~~0.15905~~	~~0.00292~~	~~9.61955~~	~~0.17216~~	~~0.43866~~	~~0.00937~~	~~2446~~	~~16~~	~~2399~~	~~16~~	~~2345~~	~~42~~
15-OB-1-39	10.8	169	0.06	0.14526	0.00224	8.54797	0.12684	0.42679	0.00855	2291	16	2291	13	2291	39
15-OB-1-40	184	629	0.29	0.15483	0.00214	9.28895	0.12282	0.43512	0.00852	2400	17	2367	12	2329	38
~~15-OB-1-41~~	~~120~~	~~370~~	~~0.32~~	~~0.17356~~	~~0.00209~~	~~11.06568~~	~~0.12643~~	~~0.46238~~	~~0.00883~~	~~2592~~	~~17~~	~~2529~~	~~11~~	~~2450~~	~~39~~
~~15-OB-1-42~~	~~436~~	~~763~~	~~0.57~~	~~0.19248~~	~~0.00607~~	~~4.31664~~	~~0.0987~~	~~0.16265~~	~~0.00353~~	~~2763~~	~~53~~	~~1697~~	~~19~~	~~972~~	~~20~~
15-OB-1-43	94.6	51.8	1.83	0.16048	0.00542	10.26625	0.34503	0.46395	0.01357	2461	25	2459	31	2457	60
15-OB-1-44	59.2	95.1	0.62	0.15923	0.00249	10.11731	0.15342	0.46082	0.00934	2448	16	2446	14	2443	41
15-OB-1-45	70.1	127	0.55	0.16541	0.00222	10.87074	0.14	0.47661	0.0093	2512	17	2512	12	2512	41
15-OB-1-46	70.2	131	0.53	0.16546	0.00277	10.66361	0.17369	0.46738	0.00971	2512	16	2494	15	2472	43
15-OB-1-47	34.9	123	0.28	0.15176	0.0058	9.05013	0.26777	0.4325	0.01045	2366	67	2343	27	2317	47
~~15-OB-1-48~~	~~343~~	~~545~~	~~0.63~~	~~0.31789~~	~~0.00474~~	~~25.62639~~	~~0.38105~~	~~0.5846~~	~~0.01239~~	~~3560~~	~~16~~	~~3332~~	~~15~~	~~2967~~	~~50~~
15-OB-1-49	74.5	61.4	1.21	0.16346	0.00354	10.6309	0.22729	0.47165	0.01081	2492	17	2491	20	2491	47
15-OB-1-50	233	396	0.59	0.16208	0.00317	10.2848	0.19716	0.46018	0.01007	2477	16	2461	18	2440	44
15-OB-1-51	215	328	0.66	0.13376	0.00155	7.30072	0.07942	0.39582	0.00742	2148	18	2149	10	2150	34
~~15-OB-1-52~~	~~170~~	~~421~~	~~0.40~~	~~0.12488~~	~~0.00505~~	~~4.9327~~	~~0.16333~~	~~0.28649~~	~~0.00664~~	~~2027~~	~~73~~	~~1808~~	~~28~~	~~1624~~	~~33~~
15-OB-1-53	111	249	0.45	0.15154	0.00365	9.26256	0.21954	0.44324	0.0105	2363	19	2364	22	2365	47
15-OB-1-54	157	151	1.04	0.15595	0.00319	9.83457	0.19732	0.4573	0.01013	2412	17	2419	18	2428	45
15-OB-1-55	104	209	0.50	0.15006	0.00328	9.07407	0.19408	0.43848	0.0099	2347	17	2345	20	2344	44
15-OB-1-56	774	543	1.43	0.16204	0.00294	10.32588	0.18306	0.46208	0.00981	2477	16	2464	16	2449	43
~~15-OB-1-57~~	~~339~~	~~796~~	~~0.43~~	~~0.14185~~	~~0.00419~~	~~5.60221~~	~~0.12081~~	~~0.28643~~	~~0.00577~~	~~2250~~	~~52~~	~~1916~~	~~19~~	~~1624~~	~~29~~
15-OB-1-58	28.5	323	0.09	0.15009	0.00273	8.96508	0.15842	0.43313	0.00909	2347	16	2334	16	2320	41
~~15-OB-1-59~~	~~2173~~	~~1844~~	~~1.18~~	~~0.12578~~	~~0.00928~~	~~2.14204~~	~~0.14705~~	~~0.12351~~	~~0.00333~~	~~2040~~	~~134~~	~~1162~~	~~48~~	~~751~~	~~19~~
15-OB-1-60	115	347	0.33	0.16019	0.00182	10.22661	0.10896	0.46291	0.00865	2458	18	2455	10	2452	38
15-OB-1-61	89.6	140	0.64	0.15481	0.00207	9.62338	0.12298	0.45073	0.0087	2400	17	2399	12	2398	39
~~15-OB-1-62~~	~~432~~	~~583~~	~~0.74~~	~~0.15359~~	~~0.00198~~	~~8.33175~~	~~0.10158~~	~~0.39334~~	~~0.0075~~	~~2386~~	~~17~~	~~2268~~	~~11~~	~~2138~~	~~35~~
K-01-47 甑山群夕线榴片麻岩															
~~K-01-47-01~~	~~464~~	~~636~~	~~0.73~~	~~0.11358~~	~~0.00134~~	~~4.82027~~	~~0.03032~~	~~0.30779~~	~~0.00309~~	~~1858~~	~~22~~	~~1788~~	~~5~~	~~1730~~	~~15~~
~~K-01-47-02~~	~~171~~	~~611~~	~~0.28~~	~~0.11314~~	~~0.00069~~	~~4.94687~~	~~0.02904~~	~~0.31719~~	~~0.00321~~	~~1850~~	~~10~~	~~1810~~	~~5~~	~~1776~~	~~16~~
~~K-01-47-03~~	~~258~~	~~370~~	~~0.70~~	~~0.11569~~	~~0.0008~~	~~4.80956~~	~~0.03151~~	~~0.3016~~	~~0.00312~~	~~1891~~	~~10~~	~~1787~~	~~6~~	~~1699~~	~~15~~

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$ 年龄(Ma)	(±%)	$\frac{^{207}Pb}{^{235}U}$ 年龄(Ma)	(±%)	$\frac{^{206}Pb}{^{238}U}$ 年龄(Ma)	(±%)
~~K-01-47-04~~	~~130~~	~~239~~	~~0.55~~	~~0.14932~~	~~0.00126~~	~~8.1521~~	~~0.06479~~	~~0.39606~~	~~0.00442~~	~~2338~~	~~9~~	~~2248~~	~~7~~	~~2151~~	~~20~~
K-01-47-05	43.7	91.5	0.48	0.11343	0.00142	5.20624	0.06066	0.33297	0.00421	1855	10	1854	10	1853	20
~~K-01-47-06~~	~~122~~	~~219~~	~~0.56~~	~~0.115~~	~~0.0011~~	~~5.1534~~	~~0.0458~~	~~0.3251~~	~~0.00368~~	~~1880~~	~~9~~	~~1845~~	~~8~~	~~1815~~	~~18~~
K-01-47-07	35.0	51.8	0.67	0.11604	0.00268	5.50501	0.11753	0.34416	0.00641	1896	17	1901	18	1907	31
~~K-01-47-08~~	~~146~~	~~284~~	~~0.51~~	~~0.11691~~	~~0.00128~~	~~5.32695~~	~~0.05428~~	~~0.33052~~	~~0.00395~~	~~1910~~	~~10~~	~~1873~~	~~9~~	~~1841~~	~~19~~
~~K-01-47-09~~	~~123~~	~~226~~	~~0.55~~	~~0.11503~~	~~0.00167~~	~~5.02291~~	~~0.04637~~	~~0.3167~~	~~0.00356~~	~~1880~~	~~27~~	~~1823~~	~~8~~	~~1774~~	~~17~~
~~K-01-47-10~~	~~298~~	~~558~~	~~0.54~~	~~0.11591~~	~~0.00134~~	~~5.32049~~	~~0.03158~~	~~0.3329~~	~~0.0033~~	~~1894~~	~~21~~	~~1872~~	~~5~~	~~1852~~	~~16~~
~~K-01-47-11~~	~~434~~	~~1151~~	~~0.38~~	~~0.11159~~	~~0.0007~~	~~3.82187~~	~~0.02272~~	~~0.24844~~	~~0.00252~~	~~1825~~	~~10~~	~~1597~~	~~5~~	~~1430~~	~~13~~
K-01-47-12	88.7	170	0.52	0.11265	0.00106	5.1522	0.04532	0.33178	0.00374	1843	9	1845	7	1847	18
K-01-47-13	169	258	0.65	0.11165	0.00087	5.04463	0.03713	0.32774	0.00349	1826	10	1827	6	1827	17
K-01-47-14	132	160	0.83	0.11291	0.00103	5.14294	0.04411	0.33039	0.00369	1847	9	1843	7	1840	18
K-01-47-15	128	352	0.36	0.14171	0.00237	8.12897	0.12731	0.4161	0.00658	2248	12	2245	14	2243	30
~~K-01-47-16~~	~~95.9~~	~~402~~	~~0.24~~	~~0.1145~~	~~0.00078~~	~~4.86582~~	~~0.03142~~	~~0.30824~~	~~0.00319~~	~~1872~~	~~10~~	~~1796~~	~~5~~	~~1732~~	~~16~~
~~K-01-47-17~~	~~80.3~~	~~304~~	~~0.26~~	~~0.11406~~	~~0.00142~~	~~4.83641~~	~~0.03388~~	~~0.30753~~	~~0.00316~~	~~1865~~	~~23~~	~~1791~~	~~6~~	~~1729~~	~~16~~
K-01-47-18	42.0	68.9	0.61	0.11459	0.00172	5.3123	0.07372	0.33627	0.00467	1873	11	1871	12	1869	23
K-01-47-19	67.7	160	0.42	0.14609	0.00178	8.63342	0.09908	0.42864	0.00565	2301	10	2300	10	2300	25
K-01-47-20	154	477	0.32	0.11622	0.00079	5.51661	0.03564	0.34429	0.00357	1899	10	1903	6	1907	17
K-01-47-21	73.0	117	0.62	0.11236	0.00115	5.09348	0.04878	0.32879	0.00382	1838	10	1835	8	1833	19
K-01-47-22	70.4	182	0.39	0.11379	0.00098	5.1919	0.04212	0.33092	0.00364	1861	9	1851	7	1843	18
K-01-47-23	49.3	94.3	0.52	0.11284	0.00124	5.21944	0.05367	0.33549	0.00401	1846	10	1856	9	1865	19
K-01-47-24	37.3	54.7	0.68	0.11303	0.00219	5.17516	0.09268	0.33208	0.0054	1849	14	1849	15	1848	26
K-01-47-25	36.7	56.4	0.65	0.11017	0.00155	5.0395	0.06579	0.33176	0.00443	1802	11	1826	11	1847	21
K-01-47-26	359	483	0.74	0.11461	0.00076	5.26581	0.03311	0.33323	0.00343	1874	10	1863	5	1854	17
~~K-01-47-27~~	~~98.4~~	~~207~~	~~0.48~~	~~0.11224~~	~~0.00164~~	~~4.70749~~	~~0.04386~~	~~0.30419~~	~~0.00343~~	~~1836~~	~~27~~	~~1769~~	~~8~~	~~1712~~	~~17~~
~~K-01-47-28~~	~~229~~	~~589~~	~~0.39~~	~~0.17429~~	~~0.00108~~	~~11.33329~~	~~0.0681~~	~~0.47161~~	~~0.00488~~	~~2599~~	~~10~~	~~2551~~	~~6~~	~~2491~~	~~21~~
K-01-47-29	90.4	291	0.31	0.11662	0.00087	5.45825	0.03857	0.33944	0.0036	1905	10	1894	6	1884	17
~~K-01-47-30~~	~~128~~	~~642~~	~~0.20~~	~~0.11681~~	~~0.00087~~	~~5.32564~~	~~0.03767~~	~~0.33064~~	~~0.0035~~	~~1908~~	~~10~~	~~1873~~	~~6~~	~~1841~~	~~17~~
~~K-01-47-31~~	~~65.0~~	~~124~~	~~0.52~~	~~0.11323~~	~~0.00116~~	~~5.07968~~	~~0.0487~~	~~0.32535~~	~~0.00379~~	~~1852~~	~~10~~	~~1833~~	~~8~~	~~1816~~	~~18~~
~~K-01-47-32~~	~~59.7~~	~~195~~	~~0.31~~	~~0.11223~~	~~0.00196~~	~~4.28213~~	~~0.05155~~	~~0.27673~~	~~0.00349~~	~~1836~~	~~32~~	~~1690~~	~~10~~	~~1575~~	~~18~~
~~K-01-47-33~~	~~92.1~~	~~558~~	~~0.16~~	~~0.11646~~	~~0.00076~~	~~5.10691~~	~~0.03168~~	~~0.31802~~	~~0.00327~~	~~1903~~	~~10~~	~~1837~~	~~5~~	~~1780~~	~~16~~
K-01-47-34	352	495	0.71	0.1165	0.00085	5.52146	0.03823	0.34371	0.00362	1903	10	1904	6	1904	17
~~K-01-47-35~~	~~120~~	~~547~~	~~0.22~~	~~0.11819~~	~~0.00117~~	~~5.4674~~	~~0.05038~~	~~0.33547~~	~~0.00387~~	~~1929~~	~~9~~	~~1895~~	~~8~~	~~1865~~	~~19~~
K-01-47-36	153	146	1.05	0.16428	0.00155	10.73676	0.09673	0.47396	0.00565	2500	9	2501	8	2501	25

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$^{207}Pb/^{206}Pb$	(±%)	$^{207}Pb/^{235}U$	(±%)	$^{206}Pb/^{238}U$	(±%)	$^{207}Pb/^{206}Pb$ 年龄(Ma)	(±%)	$^{207}Pb/^{235}U$ 年龄(Ma)	(±%)	$^{206}Pb/^{238}U$ 年龄(Ma)	(±%)
K-01-47-37	108	268	0.40	0.11186	0.00117	5.07234	0.04944	0.32883	0.00385	1830	10	1831	8	1833	19
K-01-47-38	95.0	540	0.18	0.11406	0.00077	5.26924	0.03375	0.33499	0.00347	1865	10	1864	5	1863	17
K-01-47-39	79.5	371	0.21	0.11618	0.00124	5.47776	0.05465	0.34191	0.00406	1898	10	1897	9	1896	20
K-01-47-40	80.3	119	0.67	0.11045	0.00243	4.92828	0.09967	0.32355	0.0057	1807	16	1807	17	1807	28
K-01-47-41	98.2	190	0.52	0.11712	0.00142	5.58289	0.06283	0.34567	0.00434	1913	10	1913	10	1914	21
~~K-01-47-42~~	~~130~~	~~323~~	~~0.40~~	~~0.11089~~	~~0.00165~~	~~4.84274~~	~~0.04617~~	~~0.31673~~	~~0.0036~~	~~1814~~	~~28~~	~~1792~~	~~8~~	~~1774~~	~~18~~
14-HW-1 黄海群石英片岩															
14-HW-1-1	28.9	34.1	0.85	0.11441	0.00235	5.58372	0.11124	0.354	0.0076	1871	17	1914	17	1954	36
14-HW-1-2	43.5	44.0	0.85	0.11132	0.00261	5.40359	0.12274	0.3521	0.00785	1821	19	1885	19	1945	37
14-HW-1-3	65.8	135	0.99	0.08123	0.00171	2.32356	0.04677	0.20749	0.00428	1227	18	1220	14	1215	23
~~14-HW-1-4~~	~~96.5~~	~~136~~	~~0.49~~	~~0.11536~~	~~0.00187~~	~~5.59112~~	~~0.08726~~	~~0.35157~~	~~0.00711~~	~~1886~~	~~17~~	~~1915~~	~~13~~	~~1942~~	~~34~~
~~14-HW-1-5~~	~~76.4~~	~~104~~	~~0.71~~	~~0.11591~~	~~0.00198~~	~~5.59228~~	~~0.0922~~	~~0.34997~~	~~0.00716~~	~~1894~~	~~17~~	~~1915~~	~~14~~	~~1934~~	~~34~~
14-HW-1-6	150	234	0.74	0.08177	0.00162	2.39723	0.04545	0.21265	0.00434	1240	18	1242	14	1243	23
14-HW-1-7	52.5	69.2	0.64	0.08342	0.00159	2.51147	0.04584	0.21839	0.00443	1279	18	1275	13	1273	23
14-HW-1-8	69.3	128	0.76	0.14982	0.00204	9.0142	0.11871	0.43643	0.00867	2344	17	2339	12	2335	39
14-HW-1-9	35.0	42.5	0.54	0.11515	0.0029	5.35755	0.1305	0.33749	0.00772	1882	20	1878	21	1875	37
14-HW-1-10	152	322	0.82	0.11554	0.00149	5.28983	0.06523	0.33211	0.00645	1888	18	1867	11	1849	31
14-HW-1-11	36.8	85.2	0.47	0.08467	0.00227	2.50049	0.0641	0.21421	0.0047	1308	22	1272	19	1251	25
14-HW-1-12	33.6	50.5	0.43	0.13266	0.00387	7.1723	0.20462	0.39218	0.00996	2133	22	2133	25	2133	46
14-HW-1-13	72.7	121	0.67	0.11529	0.00202	5.40627	0.09128	0.34017	0.00699	1884	17	1886	14	1887	34
14-HW-1-14	90.9	160	0.60	0.11439	0.00176	5.51712	0.08182	0.34986	0.007	1870	17	1903	13	1934	33
14-HW-1-15	335	458	0.57	0.08339	0.00129	2.42493	0.03557	0.21094	0.00413	1278	18	1250	11	1234	22
14-HW-1-16	214	281	0.73	0.11519	0.00157	5.38172	0.07023	0.33893	0.00663	1883	18	1882	11	1882	32
14-HW-1-17	110	178	0.76	0.1642	0.00212	10.78715	0.13473	0.47657	0.0094	2499	17	2505	12	2512	41
14-HW-1-18	132	212	0.62	0.11639	0.00166	5.47322	0.07493	0.34113	0.00673	1902	17	1896	12	1892	32
14-HW-1-19	45.8	44.7	0.62	0.12873	0.00274	6.77005	0.13989	0.38151	0.00841	2081	17	2082	18	2083	39
14-HW-1-20	66.9	364	1.02	0.13441	0.00151	7.44959	0.07965	0.40208	0.00769	2156	19	2167	10	2179	35
14-HW-1-21	119	205	0.18	0.11508	0.00166	5.46371	0.07568	0.34443	0.00681	1881	17	1895	12	1908	33
14-HW-1-22	112	243	0.58	0.11836	0.00156	5.60648	0.07067	0.34362	0.0067	1932	18	1917	11	1904	32
14-HW-1-23	37.5	54.6	0.46	0.1813	0.00515	12.38331	0.23933	0.49537	0.0103	2665	48	2634	18	2594	44
14-HW-1-24	224	200	0.69	0.08663	0.00404	2.56149	0.10529	0.21444	0.00472	1352	92	1290	30	1252	25
14-HW-1-25	39.4	47.6	1.12	0.11621	0.00216	5.22913	0.09374	0.32644	0.00679	1899	17	1857	15	1821	33
~~14-HW-1-26~~	~~4183~~	~~1261~~	~~0.83~~	~~0.13224~~	~~0.00207~~	~~3.04009~~	~~0.04435~~	~~0.16678~~	~~0.00332~~	~~2128~~	~~17~~	~~1418~~	~~11~~	~~994~~	~~18~~

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$ 年龄(Ma)	(±%)	$\frac{^{207}Pb}{^{235}U}$ 年龄(Ma)	(±%)	$\frac{^{206}Pb}{^{238}U}$ 年龄(Ma)	(±%)
14-HW-1-27	86.7	112	3.32	0.08078	0.00297	2.32201	0.08199	0.20852	0.00514	1216	34	1219	25	1221	27
14-HW-1-28	81.5	160	0.77	0.11556	0.00184	5.42593	0.08294	0.34064	0.00685	1889	17	1889	13	1890	33
14-HW-1-29	63.5	86.2	0.51	0.11353	0.0024	5.32492	0.10889	0.34026	0.00734	1857	17	1873	17	1888	35
14-HW-1-30	190	232	0.74	0.16261	0.00198	10.5335	0.12359	0.46994	0.00915	2483	18	2483	11	2483	40
14-HW-1-31	478	732	0.82	0.08516	0.00183	2.67792	0.055	0.22813	0.00475	1319	18	1322	15	1325	25
14-HW-1-32	24.8	44.6	0.65	0.1154	0.00303	5.3998	0.13738	0.33948	0.00792	1886	20	1885	22	1884	38
14-HW-1-33	21.0	99.8	0.56	0.1511	0.00221	9.31552	0.13198	0.44727	0.00902	2358	17	2370	13	2383	40
14-HW-1-34	85.8	114	0.21	0.11648	0.00191	5.54524	0.08754	0.34539	0.00699	1903	17	1908	14	1913	33
14-HW-1-35	31.8	39.0	0.76	0.11614	0.00376	5.48475	0.17238	0.34263	0.00884	1898	26	1898	27	1899	42
14-HW-1-36	117	153	0.82	0.11444	0.00236	5.32635	0.10629	0.33767	0.00725	1871	17	1873	17	1875	35
~~14-HW-1-37~~	~~284~~	~~787~~	~~0.77~~	~~0.14263~~	~~0.00151~~	~~7.00662~~	~~0.07023~~	~~0.35641~~	~~0.00676~~	~~2259~~	~~19~~	~~2112~~	~~9~~	~~1965~~	~~32~~
14-HW-1-38	164	773	0.36	0.11511	0.00146	5.16125	0.0624	0.32531	0.00629	1882	18	1846	10	1816	31
14-HW-1-39	126	167	0.21	0.11627	0.0023	5.28355	0.10065	0.3297	0.00698	1900	17	1866	16	1837	34
14-HW-1-40	547	706	0.76	0.08087	0.00113	2.31638	0.03079	0.20781	0.00402	1218	19	1217	9	1217	21
14-HW-1-41	93.7	248	0.78	0.14549	0.0017	8.28971	0.09239	0.41339	0.00795	2294	18	2263	10	2230	36
14-HW-1-42	194	344	0.38	0.11616	0.00149	5.37507	0.06573	0.33573	0.0065	1898	18	1881	10	1866	31
14-HW-1-43	753	1336	0.56	0.08144	0.00113	2.35369	0.03105	0.20969	0.00405	1232	19	1229	9	1227	22
14-HW-1-44	101	385	0.56	0.11616	0.00144	5.46025	0.06446	0.34105	0.00657	1898	18	1894	10	1892	32
14-HW-1-45	19.0	18.3	0.26	0.07899	0.00422	2.09989	0.10743	0.19288	0.00575	1172	56	1149	35	1137	31
14-HW-1-46	95.1	167	1.04	0.11504	0.00174	5.30632	0.07699	0.33466	0.00666	1881	17	1870	12	1861	32
14-HW-1-47	37.8	76.5	0.57	0.11338	0.00208	5.37654	0.09495	0.34405	0.00713	1854	17	1881	15	1906	34
14-HW-1-48	29.8	38.8	0.49	0.11309	0.00391	5.17271	0.17347	0.33188	0.00878	1850	28	1848	29	1847	42
14-HW-1-49	247	305	0.77	0.16563	0.00198	10.91022	0.12512	0.47795	0.00926	2514	18	2516	11	2518	40
14-HW-1-50	81.8	124	0.81	0.11473	0.00157	5.21717	0.06828	0.32995	0.00645	1876	18	1855	11	1838	31
14-HW-1-51	229	277	0.66	0.11431	0.0022	5.28222	0.09802	0.3353	0.00704	1869	17	1866	16	1864	34
14-HW-1-52	127	193	0.83	0.11393	0.00203	5.26646	0.09012	0.3354	0.0069	1863	17	1863	15	1865	33
14-HW-1-53	98.4	119	0.66	0.11409	0.00203	5.28119	0.09066	0.33588	0.00691	1866	17	1866	15	1867	33
14-HW-1-54	255	326	0.82	0.1151	0.00149	5.37697	0.06658	0.33896	0.00657	1881	18	1881	11	1882	32
14-HW-1-55	122	147	0.78	0.11679	0.00208	5.57456	0.09556	0.34632	0.00714	1908	17	1912	15	1917	34
~~14-HW-1-56~~	~~289~~	~~220~~	~~0.83~~	~~0.13609~~	~~0.00199~~	~~6.06166~~	~~0.08449~~	~~0.3232~~	~~0.00642~~	~~2178~~	~~17~~	~~1985~~	~~12~~	~~1805~~	~~31~~
14-HW-1-57	193	528	1.32	0.15485	0.00171	9.73121	0.10192	0.456	0.00869	2400	19	2410	10	2422	38
14-HW-1-58	45.1	60.9	0.36	0.11398	0.00249	5.26961	0.11132	0.33548	0.00729	1864	18	1864	18	1865	35
14-HW-1-59	176	235	0.74	0.11719	0.00172	5.59299	0.07883	0.34629	0.00686	1914	17	1915	12	1917	33

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	同位素比值						年龄(Ma)					
				$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)
14-HW-1-60	46.3	135	0.75	0.11258	0.00151	5.24805	0.06738	0.33825	0.00658	1841	18	1860	11	1878	32
14-HW-1-61	21.5	30.1	0.34	0.11439	0.00279	5.30285	0.12502	0.33639	0.00761	1870	19	1869	20	1869	37
14-HW-1-62	48.2	154	0.71	0.14676	0.00194	8.98569	0.11441	0.44426	0.00873	2309	17	2337	12	2370	39
14-HW-1-63	43.2	53.8	0.31	0.11522	0.00485	5.39139	0.2204	0.33954	0.01017	1883	35	1883	35	1884	49
14-HW-1-64	64.8	180	0.80	0.11522	0.00179	5.23375	0.07815	0.32961	0.00658	1883	17	1858	13	1836	32
PK-12 黄海群变砂岩															
PK12-01	~~73.2~~	~~135~~	~~0.54~~	0.08191	0.00117	2.33591	0.03059	0.20682	0.0026	1243	12	1223	9	1212	14
~~PK12-02~~	~~270~~	~~333~~	~~0.81~~	~~0.04728~~	~~0.00363~~	~~0.06891~~	~~0.00486~~	~~0.01057~~	~~0.00034~~	~~63~~	~~96~~	~~68~~	~~5~~	~~68~~	~~2~~
PK12-03	25.2	83.4	0.30	0.15318	0.00143	9.7379	0.08707	0.46107	0.00547	2382	10	2410	8	2444	24
~~PK12-04~~	~~227~~	~~564~~	~~0.40~~	~~0.05578~~	~~0.00146~~	~~0.49518~~	~~0.01183~~	~~0.06438~~	~~0.00098~~	~~444~~	~~28~~	~~408~~	~~8~~	~~402~~	~~6~~
~~PK12-05~~	~~96.7~~	~~192~~	~~0.50~~	~~0.09206~~	~~0.00497~~	~~0.13283~~	~~0.00606~~	~~0.01047~~	~~0.0003~~	~~1469~~	~~105~~	~~127~~	~~5~~	~~67~~	~~2~~
~~PK12-06~~	~~8483~~	~~3626~~	~~2.34~~	~~0.22736~~	~~0.01468~~	~~1.3081~~	~~0.06052~~	~~0.04173~~	~~0.00188~~	~~3034~~	~~106~~	~~849~~	~~27~~	~~264~~	~~12~~
PK12-07	~~57.3~~	~~320~~	~~0.18~~	0.11242	0.00078	5.20331	0.03459	0.33569	0.00353	1839	10	1853	6	1866	17
~~PK12-08~~	~~59.7~~	~~112~~	~~0.53~~	~~0.05269~~	~~0.00241~~	~~0.36075~~	~~0.01511~~	~~0.04966~~	~~0.0011~~	~~315~~	~~56~~	~~313~~	~~11~~	~~312~~	~~7~~
PK12-09	~~123~~	~~233~~	~~0.53~~	0.17054	0.00116	11.52011	0.07646	0.48994	0.00526	2563	10	2566	6	2570	23
~~PK12-10~~	~~24.1~~	~~182~~	~~0.13~~	~~0.04723~~	~~0.00511~~	~~0.06195~~	~~0.00615~~	~~0.00951~~	~~0.00043~~	~~61~~	~~137~~	~~61~~	~~6~~	~~61~~	~~3~~
PK12-11	572	1812	~~0.32~~	~~0.10158~~	~~0.00058~~	~~2.58026~~	~~0.0142~~	~~0.18423~~	~~0.00186~~	~~1653~~	~~11~~	~~1295~~	~~4~~	~~1090~~	~~10~~
PK12-12	147	588	~~0.25~~	0.14887	0.0011	8.92419	0.06313	0.43477	0.00472	2333	10	2330	6	2327	21
~~PK12-13~~	~~369~~	~~420~~	~~0.88~~	~~0.08525~~	~~0.00134~~	~~2.20191~~	~~0.02382~~	~~0.18733~~	~~0.00215~~	~~1321~~	~~31~~	~~1182~~	~~8~~	~~1107~~	~~12~~
~~PK12-14~~	~~115~~	~~154~~	~~0.75~~	~~0.05581~~	~~0.00159~~	~~0.43064~~	~~0.01124~~	~~0.05596~~	~~0.0009~~	~~445~~	~~31~~	~~364~~	~~8~~	~~351~~	~~5~~
PK12-15	~~185~~	~~172~~	~~1.08~~	0.16094	0.00112	10.42072	0.07	0.46959	0.00504	2466	10	2473	6	2482	22
PK12-16	227	294	0.77	0.10718	0.00083	4.57328	0.03362	0.30947	0.00332	1752	10	1744	6	1738	16
~~PK12-17~~	~~82.5~~	~~494~~	~~0.17~~	~~0.08079~~	~~0.00103~~	~~1.9967~~	~~0.01497~~	~~0.17924~~	~~0.00185~~	~~1216~~	~~26~~	~~1114~~	~~5~~	~~1063~~	~~10~~
~~PK12-18~~	~~63.3~~	~~113~~	~~0.56~~	~~0.09867~~	~~0.00186~~	~~2.71053~~	~~0.03696~~	~~0.19924~~	~~0.00259~~	~~1599~~	~~36~~	~~1331~~	~~10~~	~~1171~~	~~14~~
~~PK12-19~~	~~146~~	~~62.6~~	~~2.34~~	~~0.13386~~	~~0.00346~~	~~6.04647~~	~~0.14204~~	~~0.32762~~	~~0.00684~~	~~2149~~	~~18~~	~~1983~~	~~20~~	~~1827~~	~~33~~
PK12-20	36.3	65.1	~~0.56~~	0.08163	0.00177	2.36651	0.04703	0.21027	0.00329	1237	18	1233	14	1230	18
~~PK12-21~~	~~68~~	~~605~~	~~0.11~~	~~0.09086~~	~~0.0008~~	~~2.08923~~	~~0.01714~~	~~0.16677~~	~~0.00181~~	~~1444~~	~~10~~	~~1145~~	~~6~~	~~994~~	~~10~~
~~PK12-22~~	~~350~~	~~605~~	~~0.58~~	~~0.06096~~	~~0.00138~~	~~0.60568~~	~~0.01117~~	~~0.07206~~	~~0.00095~~	~~638~~	~~50~~	~~481~~	~~7~~	~~449~~	~~6~~
~~PK12-23~~	~~17.8~~	~~21.7~~	~~0.82~~	~~0.11342~~	~~0.00403~~	~~4.44411~~	~~0.12339~~	~~0.28418~~	~~0.00631~~	~~1855~~	~~66~~	~~1721~~	~~23~~	~~1612~~	~~32~~
~~PK12-24~~	~~38.1~~	~~658~~	~~0.06~~	~~0.05645~~	~~0.00094~~	~~0.5552~~	~~0.00855~~	~~0.07133~~	~~0.00088~~	~~470~~	~~16~~	~~448~~	~~6~~	~~444~~	~~5~~
~~PK12-25~~	~~96.0~~	~~201~~	~~0.48~~	~~0.12191~~	~~0.00148~~	~~5.62569~~	~~0.06331~~	~~0.33468~~	~~0.00423~~	~~1984~~	~~10~~	~~1920~~	~~10~~	~~1861~~	~~20~~
~~PK12-26~~	~~1706~~	~~2751~~	~~0.62~~	~~0.05303~~	~~0.00129~~	~~0.07124~~	~~0.00158~~	~~0.00974~~	~~0.00014~~	~~330~~	~~26~~	~~70~~	~~1~~	~~62.5~~	~~0.9~~
PK12-27	171	301	0.57	0.12569	0.00085	6.52239	0.04251	0.37637	0.00395	2039	10	2049	6	2059	19

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$ 年龄(Ma)	(±%)	$\frac{^{207}Pb}{^{235}U}$ 年龄(Ma)	(±%)	$\frac{^{206}Pb}{^{238}U}$ 年龄(Ma)	(±%)
~~PK12-28~~	~~62.3~~	~~111~~	~~0.56~~	~~0.16857~~	~~0.00263~~	~~10.05835~~	~~0.09729~~	~~0.43276~~	~~0.00529~~	~~2543~~	~~27~~	~~2440~~	~~9~~	~~2318~~	~~24~~
~~PK12-29~~	~~262~~	~~470~~	~~0.56~~	~~0.05402~~	~~0.00125~~	~~0.32231~~	~~0.00685~~	~~0.04327~~	~~0.00061~~	~~372~~	~~24~~	~~284~~	~~5~~	~~273~~	~~4~~
PK12-30	140	401	0.35	0.12085	0.00078	5.92564	0.03711	0.35564	0.00369	1969	10	1965	5	1961	18
12-CK-1 直岘群五峰组砂岩															
~~12-CK1-01~~	~~159~~	~~274~~	~~0.58~~	~~0.15343~~	~~0.00144~~	~~8.57183~~	~~0.07662~~	~~0.40516~~	~~0.00491~~	~~2385~~	~~10~~	~~2294~~	~~8~~	~~2193~~	~~23~~
12-CK1-02	139	154	0.90	0.1169	0.00099	5.46197	0.04411	0.33885	0.00386	1909	10	1895	7	1881	19
12-CK1-03	100	76.7	1.30	0.11717	0.00126	5.64262	0.05708	0.34926	0.0043	1913	10	1923	9	1931	21
12-CK1-04	123	250	0.49	0.11317	0.00084	5.04639	0.03625	0.32338	0.00357	1851	10	1827	6	1806	17
12-CK1-05	120	247	0.49	0.11345	0.00082	5.24878	0.03694	0.33551	0.00368	1855	10	1861	6	1865	18
12-CK1-06	63.6	299	0.21	0.11425	0.00083	5.28505	0.03739	0.33545	0.00369	1868	10	1866	6	1865	18
~~12-CK1-07~~	~~289~~	~~253~~	~~1.14~~	~~0.16294~~	~~0.00138~~	~~8.77275~~	~~0.07061~~	~~0.39043~~	~~0.00456~~	~~2486~~	~~10~~	~~2315~~	~~7~~	~~2125~~	~~21~~
12-CK1-08	100	147	0.68	0.1117	0.00109	5.01463	0.0464	0.32555	0.00385	1827	10	1822	8	1817	19
12-CK1-09	54.8	114	0.48	0.11334	0.00107	5.17642	0.04634	0.3312	0.00388	1854	10	1849	8	1844	19
12-CK1-10	~~51.6~~	~~275~~	0.19	0.11987	0.00084	5.85051	0.03985	0.35393	0.00386	1954	10	1954	6	1953	18
~~12-CK1-11~~	~~153~~	~~388~~	~~0.39~~	~~0.14301~~	~~0.00202~~	~~5.01881~~	~~0.04175~~	~~0.25452~~	~~0.00291~~	~~2264~~	~~25~~	~~1822~~	~~7~~	~~1462~~	~~15~~
12-CK1-12	139	127	1.09	0.11812	0.00104	5.69371	0.04772	0.34953	0.00402	1928	10	1930	7	1932	19
~~12-CK1-13~~	~~79.0~~	~~173~~	~~0.46~~	~~0.11301~~	~~0.00159~~	~~3.87462~~	~~0.0329~~	~~0.24865~~	~~0.00279~~	~~1848~~	~~26~~	~~1608~~	~~7~~	~~1432~~	~~14~~
12-CK1-14	236	302	0.78	0.11457	0.00163	5.20407	0.04493	0.32945	0.00373	1873	26	1853	7	1836	18
12-CK1-15	32.3	49.2	0.66	0.1649	0.00186	10.811	0.11655	0.47538	0.00631	2507	10	2507	10	2507	28
~~12-CK1-16~~	~~292~~	~~1251~~	~~0.23~~	~~0.1096~~	~~0.00154~~	~~1.18688~~	~~0.01013~~	~~0.07854~~	~~0.00087~~	~~1793~~	~~26~~	~~795~~	~~5~~	~~487~~	~~5~~
~~12-CK1-17~~	~~85.4~~	~~266~~	~~0.32~~	~~0.1359~~	~~0.00099~~	~~7.32592~~	~~0.05188~~	~~0.39088~~	~~0.00432~~	~~2176~~	~~10~~	~~2152~~	~~6~~	~~2127~~	~~20~~
~~12-CK1-18~~	~~299~~	~~557~~	~~0.54~~	~~0.13397~~	~~0.00177~~	~~2.82441~~	~~0.02111~~	~~0.15291~~	~~0.00167~~	~~2151~~	~~24~~	~~1362~~	~~6~~	~~917~~	~~9~~
~~12-CK1-19~~	~~85.3~~	~~165~~	~~0.52~~	~~0.11631~~	~~0.00248~~	~~5.20504~~	~~0.10184~~	~~0.32448~~	~~0.0057~~	~~1900~~	~~16~~	~~1853~~	~~17~~	~~1812~~	~~28~~
~~12-CK1-20~~	~~165~~	~~198~~	~~0.83~~	~~0.14657~~	~~0.00216~~	~~4.76602~~	~~0.04253~~	~~0.23583~~	~~0.00276~~	~~2306~~	~~26~~	~~1779~~	~~7~~	~~1365~~	~~14~~
~~12-CK1-21~~	~~299~~	~~619~~	~~0.48~~	~~0.15723~~	~~0.00184~~	~~8.01175~~	~~0.04528~~	~~0.36956~~	~~0.0038~~	~~2426~~	~~20~~	~~2232~~	~~5~~	~~2027~~	~~18~~
~~12-CK1-22~~	~~326~~	~~1338~~	~~0.24~~	~~0.1007~~	~~0.00128~~	~~1.002~~	~~0.00725~~	~~0.07217~~	~~0.00076~~	~~1637~~	~~24~~	~~705~~	~~4~~	~~449~~	~~5~~
12-CK1-23	39.0	263	0.15	0.11566	0.00097	5.44054	0.04346	0.34107	0.00385	1890	10	1891	7	1892	19
12-CK1-24	201	144	1.39	0.11765	0.001	5.68281	0.04631	0.35022	0.00398	1921	10	1929	7	1936	19
~~12-CK1-25~~	~~152~~	~~354~~	~~0.43~~	~~0.14974~~	~~0.00212~~	~~5.49752~~	~~0.04602~~	~~0.26627~~	~~0.00305~~	~~2343~~	~~25~~	~~1900~~	~~7~~	~~1522~~	~~16~~
~~12-CK1-26~~	~~160~~	~~216~~	~~0.74~~	~~0.13596~~	~~0.00177~~	~~6.93284~~	~~0.04986~~	~~0.36984~~	~~0.004~~	~~2176~~	~~23~~	~~2103~~	~~6~~	~~2029~~	~~19~~
~~12-CK1-27~~	~~92.6~~	~~562~~	~~0.16~~	~~0.20826~~	~~0.00266~~	~~5.40307~~	~~0.0359~~	~~0.18816~~	~~0.00205~~	~~2892~~	~~21~~	~~1885~~	~~6~~	~~1111~~	~~11~~
~~12-CK1-28~~	~~110~~	~~248~~	~~0.44~~	~~0.14517~~	~~0.00224~~	~~6.30877~~	~~0.06042~~	~~0.31518~~	~~0.00381~~	~~2290~~	~~27~~	~~2020~~	~~8~~	~~1766~~	~~19~~
~~12-CK1-29~~	~~177~~	~~474~~	~~0.37~~	~~0.14899~~	~~0.0018~~	~~4.62279~~	~~0.02844~~	~~0.22503~~	~~0.00235~~	~~2334~~	~~21~~	~~1753~~	~~5~~	~~1308~~	~~12~~

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$ 年龄(Ma)	(±%)	$\frac{^{207}Pb}{^{235}U}$ 年龄(Ma)	(±%)	$\frac{^{206}Pb}{^{238}U}$ 年龄(Ma)	(±%)
~~12-CK1-30~~	~~370~~	~~707~~	~~0.52~~	~~0.09864~~	~~0.00128~~	~~2.11614~~	~~0.01576~~	~~0.1556~~	~~0.00165~~	~~1598~~	~~25~~	~~1154~~	~~5~~	~~932~~	~~9~~
~~12-CK1-31~~	~~275~~	~~545~~	~~0.50~~	~~0.14667~~	~~0.00206~~	~~3.39528~~	~~0.02811~~	~~0.16789~~	~~0.0019~~	~~2308~~	~~25~~	~~1503~~	~~6~~	~~1000~~	~~10~~
~~12-CK1-32~~	~~41.3~~	~~974~~	~~0.04~~	~~0.13159~~	~~0.00161~~	~~3.52611~~	~~0.02239~~	~~0.19434~~	~~0.00203~~	~~2119~~	~~22~~	~~1533~~	~~5~~	~~1145~~	~~11~~
15-JY-6 直岘群长寿山组砂岩															
15-JY-6-1	126	348	0.36	0.08934	0.00113	3.17388	0.03777	0.25837	0.00491	1411	19	1451	9	1481	25
~~15-JY-6-2~~	~~328~~	~~210~~	~~1.57~~	~~0.09897~~	~~0.00697~~	~~3.78296~~	~~0.24983~~	~~0.27722~~	~~0.00681~~	~~1605~~	~~135~~	~~1589~~	~~53~~	~~1577~~	~~34~~
~~15-JY-6-3~~	~~100~~	~~187~~	~~0.53~~	~~0.0871~~	~~0.00131~~	~~3.04296~~	~~0.04344~~	~~0.25408~~	~~0.00493~~	~~1363~~	~~18~~	~~1418~~	~~11~~	~~1459~~	~~25~~
15-JY-6-4	127	196	0.65	0.09436	0.00137	3.52348	0.0484	0.27157	0.00526	1515	18	1532	11	1549	27
15-JY-6-5	54.5	196	0.28	0.10256	0.00137	4.4661	0.05665	0.31667	0.00609	1671	18	1725	11	1773	30
15-JY-6-6	86	217	0.40	0.10336	0.00136	4.44481	0.05524	0.31272	0.006	1685	18	1721	10	1754	29
15-JY-6-7	321	332	0.97	0.15052	0.00165	9.43014	0.09762	0.45559	0.00862	2352	19	2381	10	2420	38
~~15-JY-6-8~~	~~760~~	~~1608~~	~~0.47~~	~~0.07991~~	~~0.00263~~	~~1.74985~~	~~0.04632~~	~~0.15881~~	~~0.00311~~	~~1195~~	~~67~~	~~1027~~	~~17~~	~~950~~	~~17~~
15-JY-6-9	60.3	94.1	0.64	0.10398	0.00177	4.30836	0.06994	0.30129	0.00604	1696	17	1695	13	1698	30
15-JY-6-10	55.6	152	0.37	0.089	0.00143	3.1394	0.04793	0.25648	0.00502	1404	17	1442	12	1472	26
15-JY-6-11	67.0	84.9	0.79	0.09271	0.00186	3.33602	0.06378	0.26163	0.00537	1482	17	1490	15	1498	27
15-JY-6-12	66.7	213	0.31	0.10494	0.00139	4.46711	0.05598	0.30952	0.00594	1713	18	1725	10	1738	29
15-JY-6-13	163	156	1.04	0.08994	0.00142	3.23849	0.04852	0.26179	0.00512	1424	17	1466	12	1499	26
15-JY-6-14	41.0	49.9	0.82	0.10309	0.00212	4.34338	0.08565	0.30631	0.00642	1680	17	1702	16	1723	32
~~15-JY-6-15~~	~~885~~	~~1853~~	~~0.48~~	~~0.07593~~	~~0.00254~~	~~1.39562~~	~~0.03789~~	~~0.13331~~	~~0.00261~~	~~1093~~	~~69~~	~~887~~	~~16~~	~~807~~	~~15~~
~~15-JY-6-16~~	~~687~~	~~520~~	~~1.32~~	~~0.08106~~	~~0.00103~~	~~2.11818~~	~~0.02527~~	~~0.18998~~	~~0.00359~~	~~1223~~	~~19~~	~~1155~~	~~8~~	~~1121~~	~~19~~
15-JY-6-17	646	582	1.11	0.09332	0.00106	3.60573	0.03827	0.2809	0.00527	1494	20	1551	8	1596	27
~~15-JY-6-18~~	~~66.0~~	~~110~~	~~0.60~~	~~0.08578~~	~~0.00155~~	~~3.01602~~	~~0.05185~~	~~0.2556~~	~~0.0051~~	~~1333~~	~~17~~	~~1412~~	~~13~~	~~1467~~	~~26~~
15-JY-6-19	89.3	179	0.50	0.09661	0.00143	3.77179	0.05317	0.28381	0.00552	1560	18	1587	11	1611	28
15-JY-6-20	331	266	1.25	0.07809	0.00104	1.97189	0.02476	0.18357	0.00348	1149	19	1106	8	1086	19
15-JY-6-21	116	199	0.58	0.07872	0.00132	2.18186	0.03457	0.20148	0.00393	1165	18	1175	11	1183	21
~~15-JY-6-22~~	~~218~~	~~139~~	~~1.56~~	~~0.07546~~	~~0.00153~~	~~2.18632~~	~~0.04228~~	~~0.21059~~	~~0.00424~~	~~1081~~	~~18~~	~~1177~~	~~13~~	~~1232~~	~~23~~
15-JY-6-23	48.5	21.3	2.28	0.07856	0.00364	2.03861	0.09055	0.18863	0.00505	1161	48	1128	30	1114	27
15-JY-6-24	13.1	63.6	0.21	0.08968	0.00151	3.12964	0.05022	0.25365	0.00501	1419	17	1440	12	1457	26
15-JY-6-25	91.1	114	0.80	0.09792	0.00167	3.73108	0.06043	0.27694	0.00551	1585	17	1578	13	1576	28
15-JY-6-26	501	657	0.76	0.08172	0.00095	2.53225	0.0276	0.22522	0.00422	1239	20	1281	8	1309	22
15-JY-6-27	189	135	1.41	0.09247	0.0015	3.11125	0.04787	0.24454	0.0048	1477	17	1435	12	1410	25
15-JY-6-28	238	931	0.26	0.09982	0.00106	3.96579	0.03912	0.28876	0.00539	1621	20	1627	8	1635	27
15-JY-6-29	237	507	0.47	0.076	0.00098	2.05022	0.02473	0.19605	0.0037	1095	20	1132	8	1154	20

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	同位素比值						年龄(Ma)					
				$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)
15-JY-6-30	68.7	108	0.63	0.07517	0.00141	1.97998	0.03526	0.19143	0.00379	1073	18	1109	12	1129	21
15-JY-6-31	34.9	91.8	0.38	0.11349	0.00191	5.21849	0.08403	0.33417	0.00673	1856	17	1856	14	1859	33
~~15-JY-6-32~~	~~83.3~~	~~96.3~~	~~0.87~~	~~0.09375~~	~~0.00175~~	~~3.66471~~	~~0.06542~~	~~0.28408~~	~~0.00574~~	~~1503~~	~~17~~	~~1564~~	~~14~~	~~1612~~	~~29~~
15-JY-6-33	68.6	135	0.51	0.09658	0.00327	3.53409	0.09628	0.26538	0.00532	1559	65	1535	22	1517	27
~~15-JY-6-34~~	~~66.7~~	~~81.7~~	~~0.82~~	~~0.09714~~	~~0.00197~~	~~3.43272~~	~~0.06631~~	~~0.25678~~	~~0.00529~~	~~1570~~	~~17~~	~~1512~~	~~15~~	~~1473~~	~~27~~
15-JY-6-35	142	205	0.69	0.07742	0.00132	2.07558	0.03351	0.19481	0.0038	1132	18	1141	11	1147	21
15-JY-6-36	172	216	0.80	0.09483	0.00134	3.60461	0.04816	0.2762	0.00531	1525	18	1551	11	1572	27
15-JY-6-37	57.3	119	0.48	0.09837	0.0017	3.60973	0.05928	0.26663	0.00531	1593	17	1552	13	1524	27
15-JY-6-38	93.2	161	0.58	0.07759	0.00146	2.07668	0.03719	0.19448	0.00386	1136	18	1141	12	1146	21
15-JY-6-39	57.3	97.8	0.59	0.09581	0.00154	3.56733	0.05449	0.27053	0.00531	1544	17	1542	12	1543	27
15-JY-6-40	448	551	0.81	0.0979	0.00114	3.82615	0.04193	0.28397	0.00534	1585	19	1598	9	1611	27
15-JY-6-41	131	181	0.73	0.09414	0.00137	3.54688	0.04903	0.27372	0.00528	1511	18	1538	11	1560	27
15-JY-6-42	62.9	146	0.43	0.10453	0.00155	4.45006	0.06286	0.3093	0.00603	1706	17	1722	12	1737	30
15-JY-6-43	79.9	120	0.67	0.09672	0.00166	3.66408	0.06007	0.27522	0.00547	1562	17	1564	13	1567	28
~~15-JY-6-44~~	~~68.1~~	~~1360~~	~~0.05~~	~~0.07549~~	~~0.00164~~	~~1.64991~~	~~0.01956~~	~~0.15851~~	~~0.0029~~	~~1082~~	~~45~~	~~990~~	~~7~~	~~948~~	~~16~~
15-JY-6-45	188	268	0.70	0.10425	0.00135	4.47305	0.05458	0.31171	0.00594	1701	18	1726	10	1749	29
15-JY-6-46	192	209	0.92	0.09749	0.0014	3.57897	0.04848	0.26668	0.00514	1577	18	1545	11	1524	26
15-JY-6-47	49.3	281	0.18	0.09864	0.00128	3.89891	0.04774	0.28716	0.00546	1599	18	1613	10	1627	27
15-JY-6-48	54.4	74.6	0.73	0.07631	0.00121	2.05839	0.03093	0.19594	0.00378	1103	18	1135	10	1153	20
15-JY-6-49	122	186	0.65	0.07915	0.0014	2.08902	0.03502	0.19173	0.00376	1176	17	1145	12	1131	20
~~15-JY-6-50~~	~~158~~	~~278~~	~~0.57~~	~~0.09272~~	~~0.00146~~	~~2.97244~~	~~0.04426~~	~~0.23287~~	~~0.00453~~	~~1482~~	~~17~~	~~1401~~	~~11~~	~~1350~~	~~24~~
15-JY-6-51	69.3	113	0.61	0.0938	0.00169	3.4051	0.05859	0.26368	0.00527	1504	17	1506	14	1509	27
15-JY-6-52	120	137	0.88	0.0948	0.00154	3.57122	0.0553	0.27363	0.00537	1524	17	1543	12	1559	27
15-JY-6-53	316	375	0.84	0.09425	0.00118	3.54717	0.04168	0.27337	0.00517	1513	19	1538	9	1558	26
15-JY-6-54	154	346	0.45	0.10239	0.00126	4.19351	0.04854	0.29747	0.00562	1668	19	1673	9	1679	28
15-JY-6-55	98.0	107	0.92	0.09526	0.00176	3.50234	0.06177	0.26703	0.00537	1533	17	1528	14	1526	27
15-JY-6-56	129	214	0.60	0.0943	0.00135	3.55497	0.04833	0.27381	0.00527	1514	18	1540	11	1560	27
15-JY-6-57	126	244	0.52	0.10412	0.00138	4.37681	0.05464	0.3053	0.00583	1699	18	1708	10	1718	29
15-JY-6-58	133	539	0.25	0.10858	0.00123	4.7102	0.04985	0.31505	0.0059	1776	19	1769	9	1766	29
15-JY-6-59	87.0	175	0.50	0.09055	0.00142	3.22501	0.048	0.25866	0.00503	1437	17	1463	12	1483	26
15-JY-6-60	84.4	127	0.66	0.09858	0.00161	3.78014	0.05881	0.27848	0.00548	1597	17	1589	12	1584	28
15-JY-6-61	135	204	0.66	0.09733	0.00142	3.78858	0.05222	0.28267	0.00545	1574	17	1590	11	1605	27
15-JY-6-62	180	470	0.38	0.07816	0.00105	2.07904	0.02631	0.19315	0.00365	1151	19	1142	9	1138	20

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	同位素比值						年龄(Ma)					
				$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)
15-JY-6-63	99.4	122	0.82	0.09132	0.00162	3.27071	0.05521	0.26008	0.00517	1453	17	1474	13	1490	26
15-JY-6-64	125	235	0.53	0.11186	0.00146	4.92263	0.06088	0.31956	0.0061	1830	18	1806	10	1788	30
~~15-JY-6-65~~	~~119~~	~~135~~	~~0.88~~	~~0.11622~~	~~0.00173~~	~~4.94747~~	~~0.06978~~	~~0.3091~~	~~0.00603~~	~~1899~~	~~17~~	~~1810~~	~~12~~	~~1736~~	~~30~~
15-JY-6-66	107	190	0.56	0.08979	0.0014	3.05755	0.04509	0.24724	0.00479	1421	17	1422	11	1424	25
15-JY-6-67	59.8	87.2	0.69	0.09371	0.00189	3.3377	0.06411	0.25862	0.00528	1502	17	1490	15	1483	27
~~15-JY-6-68~~	~~129~~	~~253~~	~~0.51~~	~~0.09653~~	~~0.00137~~	~~3.37685~~	~~0.04529~~	~~0.25399~~	~~0.00487~~	~~1558~~	~~18~~	~~1499~~	~~11~~	~~1459~~	~~25~~
15-JY-6-69	71.5	450	0.16	0.11221	0.00144	4.96729	0.06017	0.3214	0.00612	1836	18	1814	10	1797	30
15-JY-6-70	85.6	124	0.69	0.0956	0.00166	3.53672	0.05849	0.26859	0.00533	1540	17	1535	13	1534	27
15-JY-6-71	38.5	81.5	0.47	0.09433	0.00195	3.25439	0.06424	0.25049	0.00515	1515	17	1470	15	1441	27
15-JY-6-72	127	180	0.70	0.09726	0.00165	3.72138	0.06005	0.27778	0.00549	1572	17	1576	13	1580	28
15-JY-6-73	93.4	94.4	0.99	0.09645	0.00183	3.47775	0.06279	0.26177	0.00528	1557	17	1522	14	1499	27
15-JY-6-74	126	272	0.46	0.1047	0.00135	4.47636	0.05441	0.31039	0.00589	1709	18	1727	10	1743	29
15-JY-6-75	468	441	1.06	0.10299	0.00125	4.09559	0.0466	0.28868	0.00543	1679	19	1653	9	1635	27
15-JY-6-76	92.2	164	0.56	0.19496	0.00245	14.046	0.16977	0.52301	0.01017	2784	17	2753	11	2712	43
15-JY-6-77	140	175	0.80	0.09937	0.00147	3.76489	0.05257	0.27505	0.00531	1612	17	1585	11	1566	27
15-JY-6-78	59.0	106	0.56	0.09142	0.00171	3.26366	0.05838	0.25914	0.00519	1455	17	1472	14	1485	27
15-JY-6-79	161	312	0.51	0.09678	0.00126	3.59842	0.04416	0.26989	0.00511	1563	18	1549	10	1540	26
15-JY-6-80	258	356	0.72	0.09944	0.00129	3.78262	0.0463	0.27609	0.00523	1614	18	1589	10	1572	26
15-JY-6-81	115	254	0.45	0.09987	0.00138	3.76419	0.04898	0.27358	0.00522	1622	18	1585	10	1559	26
~~15-JY-6-82~~	~~323~~	~~326~~	~~0.99~~	~~0.07664~~	~~0.00113~~	~~2.21121~~	~~0.03069~~	~~0.2094~~	~~0.00399~~	~~1112~~	~~18~~	~~1185~~	~~10~~	~~1226~~	~~21~~
15-JY-6-83	146	203	0.72	0.078	0.00132	2.14279	0.03431	0.1994	0.00387	1147	17	1163	11	1172	21
15-JY-6-84	265	286	0.93	0.09718	0.00134	3.73844	0.04862	0.27921	0.00533	1571	18	1580	10	1587	27
15-JY-6-85	193	376	0.51	0.09753	0.00124	3.66144	0.04387	0.27248	0.00515	1577	18	1563	10	1553	26
15-JY-6-86	80.1	199	0.40	0.10604	0.00149	4.43274	0.05877	0.30339	0.00582	1732	17	1718	11	1708	29
15-JY-6-87	111	202	0.55	0.10625	0.00147	4.46204	0.05844	0.3048	0.00584	1736	17	1724	11	1715	29
~~15-JY-6-88~~	~~179~~	~~183~~	~~0.98~~	~~0.08386~~	~~0.00144~~	~~2.34775~~	~~0.03824~~	~~0.20319~~	~~0.00396~~	~~1289~~	~~17~~	~~1227~~	~~12~~	~~1192~~	~~21~~
15-JY-6-89	211	313	0.67	0.15825	0.00177	9.71937	0.10222	0.44574	0.00837	2437	18	2409	10	2376	37
15-JY-11 直岘群长寿山组砂岩															
15-JY-11-1	106	207	0.51	0.10103	0.00143	3.94696	0.05255	0.28353	0.00542	1643	17	1623	11	1609	27
15-JY-11-2	205	277	0.74	0.07697	0.00115	2.03119	0.02853	0.19153	0.00364	1120	18	1126	10	1130	20
15-JY-11-3	69.9	264	0.26	0.08854	0.00124	3.11213	0.04106	0.25508	0.00485	1394	18	1436	10	1465	25
15-JY-11-4	144	236	0.61	0.09319	0.00131	3.26364	0.04337	0.25416	0.00484	1492	18	1472	10	1460	25
15-JY-11-5	82.6	178	0.46	0.10848	0.00153	4.69859	0.06251	0.31434	0.00604	1774	17	1767	11	1762	30

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	同位素比值						年龄(Ma)					
				$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)
15-JY-11-6	88.6	104	0.86	0.09745	0.00174	3.67562	0.06246	0.27371	0.00545	1576	17	1566	14	1560	28
15-JY-11-7	114	46.9	2.44	0.0801	0.00238	2.35456	0.06702	0.21333	0.0047	1199	26	1229	20	1247	25
15-JY-11-8	78.8	240	0.33	0.07978	0.00127	2.28825	0.03456	0.20815	0.004	1192	17	1209	11	1219	21
15-JY-11-9	66.9	194	0.34	0.08195	0.00142	2.40547	0.03949	0.21302	0.00415	1244	17	1244	12	1245	22
15-JY-11-10	83.3	114	0.73	0.09756	0.00165	3.57703	0.05754	0.26607	0.00524	1578	17	1544	13	1521	27
~~15-JY-11-11~~	~~132~~	~~101~~	~~1.31~~	~~0.11478~~	~~0.00181~~	~~5.06381~~	~~0.07604~~	~~0.32014~~	~~0.0063~~	~~1876~~	~~17~~	~~1830~~	~~13~~	~~1790~~	~~31~~
~~15-JY-11-12~~	~~112~~	~~135~~	~~0.83~~	~~0.10803~~	~~0.00173~~	~~4.281~~	~~0.06519~~	~~0.28757~~	~~0.00565~~	~~1766~~	~~17~~	~~1690~~	~~13~~	~~1629~~	~~28~~
15-JY-11-13	160	167	0.96	0.0783	0.00142	2.12596	0.03655	0.19704	0.00386	1154	17	1157	12	1159	21
15-JY-11-14	94.7	212	0.45	0.10493	0.00143	4.32427	0.05563	0.29904	0.00571	1713	18	1698	11	1687	28
15-JY-11-15	129	249	0.52	0.08361	0.0012	2.61556	0.03539	0.227	0.00432	1283	18	1305	10	1319	23
15-JY-11-16	73.7	115	0.64	0.09841	0.00163	3.769	0.05921	0.27791	0.00546	1594	17	1586	13	1581	28
15-JY-11-17	219	279	0.78	0.0772	0.00108	1.99294	0.02632	0.18734	0.00355	1126	19	1113	9	1107	19
15-JY-11-18	42.6	112	0.38	0.07876	0.00168	2.13327	0.04329	0.19654	0.00396	1166	18	1160	14	1157	21
~~15-JY-11-19~~	~~146~~	~~184~~	~~0.79~~	~~0.08308~~	~~0.00161~~	~~2.26028~~	~~0.04153~~	~~0.19741~~	~~0.00393~~	~~1271~~	~~17~~	~~1200~~	~~13~~	~~1161~~	~~21~~
~~15-JY-11-20~~	~~154~~	~~224~~	~~0.69~~	~~0.09915~~	~~0.0015~~	~~3.71185~~	~~0.05306~~	~~0.27164~~	~~0.00526~~	~~1608~~	~~17~~	~~1574~~	~~11~~	~~1549~~	~~27~~
15-JY-11-21	87.4	127	0.69	0.09185	0.00163	3.27513	0.05526	0.25875	0.00513	1464	17	1475	13	1483	26
~~15-JY-11-22~~	~~42.1~~	~~274~~	~~0.15~~	~~0.10864~~	~~0.00142~~	~~4.5607~~	~~0.05602~~	~~0.30461~~	~~0.00579~~	~~1777~~	~~18~~	~~1742~~	~~10~~	~~1714~~	~~29~~
15-JY-11-23	73.0	123	0.59	0.1081	0.00166	4.68735	0.06825	0.31465	0.00614	1768	17	1765	12	1764	30
15-JY-11-24	100	141	0.71	0.10784	0.00155	4.5682	0.06229	0.30739	0.00593	1763	17	1743	11	1728	29
15-JY-11-25	146	102	1.44	0.09654	0.0018	3.67647	0.06534	0.27633	0.00556	1558	17	1566	14	1573	28
15-JY-11-26	196	201	0.98	0.08142	0.00134	2.33122	0.03646	0.20774	0.00403	1232	17	1222	11	1217	22
~~15-JY-11-27~~	~~264~~	~~734~~	~~0.36~~	~~0.10746~~	~~0.00129~~	~~3.4049~~	~~0.03828~~	~~0.22991~~	~~0.00432~~	~~1757~~	~~19~~	~~1506~~	~~9~~	~~1334~~	~~23~~
15-JY-11-28	55.7	109	0.51	0.11183	0.00181	5.01971	0.07749	0.3257	0.00645	1829	17	1823	13	1818	31
15-JY-11-29	95.7	232	0.41	0.10088	0.0014	4.0172	0.05254	0.28894	0.00553	1640	18	1638	11	1636	28
15-JY-11-30	73.8	81.7	0.90	0.11371	0.00197	5.13492	0.08515	0.32766	0.0066	1860	16	1842	14	1827	32
15-JY-11-31	93.2	138	0.68	0.07586	0.0016	1.90949	0.03845	0.18263	0.00367	1091	18	1084	13	1081	20
15-JY-11-32	45.1	57.1	0.79	0.09077	0.00196	3.11817	0.0642	0.24924	0.00515	1442	18	1437	16	1435	27
15-JY-11-33	209	399	0.52	0.08716	0.00116	2.87418	0.03599	0.23927	0.00453	1364	19	1375	9	1383	24
~~15-JY-11-34~~	~~117~~	~~310~~	~~0.38~~	~~0.09076~~	~~0.00125~~	~~3.00029~~	~~0.03902~~	~~0.23984~~	~~0.00457~~	~~1442~~	~~18~~	~~1408~~	~~10~~	~~1386~~	~~24~~
~~15-JY-11-35~~	~~26.7~~	~~100~~	~~0.27~~	~~0.07812~~	~~0.00178~~	~~1.97393~~	~~0.04294~~	~~0.18334~~	~~0.00375~~	~~1150~~	~~19~~	~~1107~~	~~15~~	~~1085~~	~~20~~
15-JY-11-36	51.2	226	0.23	0.07521	0.00134	1.86238	0.03146	0.17967	0.00351	1074	18	1068	11	1065	19
15-JY-11-37	164	160	1.02	0.08823	0.00151	2.91284	0.04734	0.23953	0.0047	1387	17	1385	12	1384	24
15-JY-11-38	110	330	0.33	0.09334	0.0019	3.32441	0.06444	0.2584	0.00529	1495	17	1487	15	1482	27

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	同位素比值						年龄(Ma)					
				$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)
15-JY-11-39	157	220	0.71	0.09727	0.00139	3.63052	0.04922	0.27081	0.0052	1572	18	1556	11	1545	26
15-JY-11-40	106	342	0.31	0.08995	0.0012	3.02815	0.03818	0.24425	0.00464	1424	18	1415	10	1409	24
15-JY-11-41	91.4	133	0.68	0.0896	0.00159	3.07549	0.05195	0.24904	0.00493	1417	17	1427	13	1434	25
15-JY-11-42	150	187	0.80	0.08098	0.00142	2.24424	0.03721	0.20107	0.00394	1221	17	1195	12	1181	21
15-JY-11-43	188	159	1.19	0.07711	0.00149	2.0009	0.03688	0.18826	0.00374	1124	18	1116	12	1112	20
15-JY-11-44	44.7	160	0.28	0.09454	0.00151	3.46743	0.05262	0.26609	0.0052	1519	17	1520	12	1521	26
15-JY-11-45	53.0	152	0.35	0.07844	0.00154	2.05782	0.0385	0.19032	0.00379	1158	18	1135	13	1123	21
15-JY-11-46	112	281	0.40	0.0907	0.00129	3.02848	0.04058	0.24224	0.00464	1440	18	1415	10	1398	24
15-JY-11-47	45.2	23.1	1.96	0.07652	0.00584	1.99679	0.14667	0.18931	0.00691	1109	89	1114	50	1118	37
15-JY-11-48	223	280	0.80	0.1007	0.00134	3.98805	0.05001	0.28733	0.00548	1637	18	1632	10	1628	27
~~15-JY-11-49~~	~~161~~	~~184~~	~~0.88~~	~~0.09152~~	~~0.00148~~	~~2.9978~~	~~0.04604~~	~~0.23762~~	~~0.00464~~	~~1457~~	~~17~~	~~1407~~	~~12~~	~~1374~~	~~24~~
15-JY-11-50	47.1	146	0.32	0.07598	0.00284	1.94061	0.06944	0.1853	0.00449	1095	36	1095	24	1096	24
15-JY-11-51	82.5	284	0.29	0.09017	0.00128	3.02835	0.04064	0.24365	0.00467	1429	18	1415	10	1406	24
15-JY-11-52	137	200	0.68	0.10209	0.00145	4.06883	0.05481	0.28913	0.00557	1662	18	1648	11	1637	28
15-JY-11-53	73.5	64.3	1.14	0.10816	0.00373	4.70473	0.15692	0.31555	0.00817	1769	28	1768	28	1768	40
15-JY-11-54	294	396	0.74	0.0762	0.00115	1.94948	0.0278	0.1856	0.00355	1100	18	1098	10	1097	19
15-JY-11-55	39.9	122	0.33	0.08101	0.00164	2.29332	0.04424	0.20536	0.00413	1222	18	1210	14	1204	22
15-JY-11-56	94.9	117	0.81	0.07805	0.00293	2.08291	0.07474	0.19359	0.00472	1148	36	1143	25	1141	25
~~15-JY-11-57~~	~~96.5~~	~~96.2~~	~~1.00~~	~~0.08983~~	~~0.00195~~	~~2.90679~~	~~0.06039~~	~~0.23473~~	~~0.00486~~	~~1422~~	~~18~~	~~1384~~	~~16~~	~~1359~~	~~25~~
15-JY-11-58	59.5	88.7	0.67	0.08085	0.00202	2.32321	0.05542	0.20846	0.0044	1218	21	1219	17	1221	23
15-JY-11-59	116	104	1.12	0.07542	0.00155	1.84821	0.03603	0.17776	0.00356	1080	18	1063	13	1055	19
~~15-JY-11-60~~	~~431~~	~~233~~	~~1.85~~	~~0.08183~~	~~0.00151~~	~~2.24871~~	~~0.03954~~	~~0.19936~~	~~0.00395~~	~~1241~~	~~17~~	~~1196~~	~~12~~	~~1172~~	~~21~~
15-JY-11-61	68.3	104	0.66	0.07802	0.00159	2.10927	0.04097	0.19611	0.00394	1147	18	1152	13	1154	21
15-JY-11-62	126	130	0.97	0.10201	0.00252	3.96822	0.09419	0.28219	0.00621	1661	20	1628	19	1602	31
15-JY-11-63	127	222	0.57	0.08448	0.00124	2.58137	0.03599	0.22165	0.00426	1304	18	1295	10	1291	22
15-JY-11-64	152	153	0.99	0.08151	0.00243	2.36941	0.06757	0.21085	0.00475	1234	26	1233	20	1233	25
15-JY-11-65	280	306	0.92	0.09889	0.00129	3.86199	0.04761	0.28329	0.0054	1603	18	1606	10	1608	27
15-JY-11-66	76.7	138	0.56	0.07489	0.00276	1.89549	0.0669	0.18358	0.0044	1066	35	1080	23	1087	24
15-JY-11-67	115	143	0.80	0.09448	0.00153	3.35558	0.05163	0.25761	0.00505	1518	17	1494	12	1478	26
15-JY-11-68	197	266	0.74	0.08716	0.00129	2.95011	0.04133	0.24552	0.00473	1364	18	1395	11	1415	24
~~15-JY-11-69~~	~~98.3~~	~~164~~	~~0.60~~	~~0.08745~~	~~0.00218~~	~~2.55947~~	~~0.06085~~	~~0.21229~~	~~0.00455~~	~~1370~~	~~20~~	~~1289~~	~~17~~	~~1241~~	~~24~~
~~15-JY-11-70~~	~~234~~	~~479~~	~~0.49~~	~~0.09161~~	~~0.00114~~	~~3.06398~~	~~0.03597~~	~~0.24261~~	~~0.00459~~	~~1459~~	~~19~~	~~1424~~	~~9~~	~~1400~~	~~24~~
15-JY-11-71	67.1	88.2	0.76	0.08905	0.00186	3.04669	0.06092	0.24815	0.0051	1405	18	1419	15	1429	26

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$ 年龄(Ma)	(±%)	$\frac{^{207}Pb}{^{235}U}$ 年龄(Ma)	(±%)	$\frac{^{206}Pb}{^{238}U}$ 年龄(Ma)	(±%)
15-JY-11-72	237	221	1.07	0.11422	0.00148	5.11453	0.06266	0.3248	0.00622	1868	18	1839	10	1813	30
~~15-JY-11-73~~	~~81.5~~	~~170~~	~~0.48~~	~~0.08684~~	~~0.00187~~	~~2.58423~~	~~0.05314~~	~~0.21585~~	~~0.00445~~	~~1357~~	~~18~~	~~1296~~	~~15~~	~~1260~~	~~24~~
~~15-JY-11-74~~	~~42.7~~	~~66.7~~	~~0.64~~	~~0.0992~~	~~0.00204~~	~~4.12077~~	~~0.08132~~	~~0.30129~~	~~0.00627~~	~~1609~~	~~17~~	~~1658~~	~~16~~	~~1698~~	~~31~~
15-JY-11-75	274	920	0.30	0.08153	0.00096	2.31561	0.02553	0.206	0.00387	1234	20	1217	8	1207	21
15-JY-11-76	81.0	60.8	1.33	0.09546	0.0021	3.67039	0.07743	0.27889	0.00587	1537	18	1565	17	1586	30
15-JY-11-77	76.1	80.8	0.94	0.09888	0.00192	3.74437	0.0694	0.27466	0.00561	1603	17	1581	15	1564	28
15-JY-11-78	111	143	0.78	0.07981	0.00151	2.30292	0.04153	0.20929	0.00416	1192	17	1213	13	1225	22
~~15-JY-11-79~~	~~151~~	~~228~~	~~0.66~~	~~0.14265~~	~~0.00585~~	~~3.8635~~	~~0.13124~~	~~0.19643~~	~~0.0045~~	~~2260~~	~~72~~	~~1606~~	~~27~~	~~1156~~	~~24~~
15-JY-11-80	188	644	0.29	0.08509	0.00109	2.66403	0.03229	0.22708	0.00431	1318	19	1319	9	1319	23
~~15-JY-11-81~~	~~104~~	~~87~~	~~1.19~~	~~0.1064~~	~~0.00176~~	~~4.34208~~	~~0.06871~~	~~0.29597~~	~~0.00589~~	~~1739~~	~~17~~	~~1701~~	~~13~~	~~1671~~	~~29~~
15-JY-11-82	70.4	205	0.34	0.07631	0.0016	1.95783	0.03911	0.18608	0.00376	1103	18	1101	13	1100	20
15-JY-11-83	251	226	1.11	0.0744	0.00236	1.81545	0.05497	0.17696	0.00399	1052	29	1051	20	1050	22
15-JY-11-84	23	138	0.17	0.11158	0.00161	5.05917	0.06949	0.32885	0.00641	1825	17	1829	12	1833	31
15-JY-11-85	104	104	1.00	0.09349	0.00162	3.34762	0.05546	0.25969	0.00517	1498	17	1492	13	1488	26
14-UR-7 黄州群砂岩															
14-UR-7-1	86.7	225	0.39	0.08076	0.00135	2.22795	0.03528	0.20009	0.00391	1216	18	1190	11	1176	21
14-UR-7-2	38.0	78.3	0.48	0.13841	0.00222	7.77899	0.12045	0.4076	0.00826	2207	16	2206	14	2204	38
14-UR-7-3	70.2	75.7	0.93	0.16796	0.00251	11.07775	0.16115	0.47834	0.00969	2537	16	2530	14	2520	42
14-UR-7-4	22.2	34.4	0.65	0.1127	0.00277	4.99903	0.11876	0.32171	0.00717	1843	19	1819	20	1798	35
14-UR-7-5	64.2	172	0.37	0.18076	0.00219	12.74113	0.14785	0.51121	0.00988	2660	17	2661	11	2662	42
14-UR-7-6	46.3	81.0	0.57	0.11572	0.00211	5.2638	0.09231	0.32989	0.00677	1891	17	1863	15	1838	33
14-UR-7-7	55.2	83.4	0.66	0.18809	0.00258	13.4942	0.1801	0.52033	0.01039	2726	17	2715	13	2701	44
14-UR-7-8	61.7	101	0.61	0.1657	0.0023	10.49856	0.14087	0.45952	0.00913	2515	17	2480	12	2437	40
14-UR-7-9	17.9	20.8	0.86	0.11048	0.00309	4.70377	0.12686	0.30879	0.0072	1807	22	1768	23	1735	35
14-UR-7-10	62.1	67.0	0.93	0.11326	0.00225	4.89844	0.09324	0.31367	0.00656	1852	17	1802	16	1759	32
14-UR-7-11	54.2	101	0.54	0.11636	0.00196	5.39611	0.08697	0.33634	0.00678	1901	17	1884	14	1869	33
14-UR-7-12	47.5	82.7	0.57	0.1113	0.00206	4.71154	0.08366	0.307	0.0063	1821	17	1769	15	1726	31
14-UR-7-13	77.6	110	0.70	0.11798	0.00189	5.63014	0.08629	0.34611	0.00692	1926	17	1921	13	1916	33
14-UR-7-14	39.4	42.6	0.92	0.16706	0.00299	10.96704	0.19271	0.47611	0.01021	2528	16	2520	16	2510	45
14-UR-7-15	70.9	295	0.24	0.11605	0.00146	5.37675	0.0641	0.33602	0.00644	1896	18	1881	10	1867	31
14-UR-7-16	88.3	108	0.82	0.11514	0.00192	5.0601	0.08085	0.31873	0.00641	1882	17	1829	14	1784	31
14-UR-7-17	619	1066	0.58	0.09623	0.00142	1.15843	0.01597	0.08731	0.00168	1552	17	781	8	540	10
14-UR-7-18	54.2	64.9	0.83	0.11029	0.00227	4.81791	0.09536	0.31681	0.00668	1804	17	1788	17	1774	33

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	同位素比值						年龄(Ma)					
				$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)
14-UR-7-19	46.5	82.0	0.57	0.11485	0.00295	5.21652	0.1294	0.3294	0.00756	1878	20	1855	21	1835	37
14-UR-7-20	111	250	0.44	0.08711	0.00132	2.82751	0.0408	0.23541	0.00458	1363	18	1363	11	1363	24
14-UR-7-21	76.5	205	0.37	0.1193	0.00207	5.73719	0.0957	0.34877	0.00712	1946	17	1937	14	1929	34
14-UR-7-22	112	154	0.72	0.0989	0.00157	3.84499	0.0583	0.28195	0.00556	1603	17	1602	12	1601	28
14-UR-7-23	149	109	1.37	0.11947	0.00286	5.6722	0.13123	0.34434	0.00776	1948	19	1927	20	1908	37
14-UR-7-24	77.6	108	0.72	0.11544	0.00187	5.26188	0.08188	0.33057	0.00663	1887	17	1863	13	1841	32
14-UR-7-25	57.6	67.5	0.85	0.11559	0.00222	5.3346	0.09886	0.3347	0.00699	1889	17	1874	16	1861	34
14-UR-7-26	45.5	48.8	0.93	0.1691	0.00321	10.62302	0.19741	0.45561	0.00998	2549	16	2491	17	2420	44
14-UR-7-27	52.3	68.3	0.77	0.16979	0.00263	11.20387	0.16964	0.47855	0.00984	2556	16	2540	14	2521	43
14-UR-7-28	35.0	71.6	0.49	0.16999	0.0026	11.03376	0.16439	0.47073	0.00964	2558	16	2526	14	2487	42
14-UR-7-29	48.9	106	0.46	0.11442	0.00191	5.14871	0.08235	0.32634	0.00658	1871	17	1844	14	1821	32
14-UR-7-30	79	428	0.18	0.08922	0.00122	3.00661	0.03883	0.2444	0.0047	1409	19	1409	10	1410	24
14-UR-7-31	126	311	0.41	0.09405	0.00181	3.42459	0.06313	0.26406	0.0054	1509	17	1510	14	1511	28
14-UR-7-32	70.9	131	0.54	0.16636	0.0022	10.91188	0.13911	0.47568	0.00939	2521	17	2516	12	2508	41
14-UR-7-33	81.6	166	0.49	0.16167	0.00204	10.13338	0.12245	0.45456	0.00886	2473	17	2447	11	2415	39
14-UR-7-34	168	212	0.79	0.07733	0.00136	2.03941	0.03417	0.19126	0.00377	1130	18	1129	11	1128	20
14-UR-7-35	132	206	0.64	0.10275	0.00203	4.0896	0.07733	0.28865	0.00599	1674	17	1652	15	1635	30
14-UR-7-36	37.3	81.9	0.46	0.11431	0.00223	5.12899	0.09639	0.32539	0.00682	1869	17	1841	16	1816	33
14-UR-7-37	61.5	75.6	0.81	0.0918	0.00209	3.07832	0.06719	0.24319	0.00514	1463	19	1427	17	1403	27
14-UR-7-38	51.7	72.3	0.72	0.16315	0.00253	10.37877	0.15694	0.46136	0.00947	2489	16	2469	14	2446	42
14-UR-7-39	49.7	61.4	0.81	0.172	0.00273	11.1445	0.17252	0.46991	0.00974	2577	16	2535	14	2483	43
14-UR-7-40	51.6	106	0.49	0.16882	0.00227	11.21347	0.14632	0.48171	0.00957	2546	17	2541	12	2535	42
14-UR-7-41	34.0	66.1	0.51	0.15159	0.0025	8.91905	0.14266	0.42672	0.00883	2364	16	2330	15	2291	40
14-UR-7-42	28.1	35.6	0.79	0.1447	0.00308	8.29301	0.17245	0.41565	0.00931	2284	17	2264	19	2241	42
14-UR-7-43	29.2	38.5	0.76	0.16435	0.0031	10.87802	0.2018	0.48002	0.01052	2501	17	2513	17	2527	46
14-UR-7-44	113	130	0.87	0.16632	0.00219	11.38305	0.14555	0.49635	0.00981	2521	17	2555	12	2598	42
14-UR-7-45	27.0	47.2	0.57	0.16239	0.00281	10.13944	0.1717	0.45282	0.0096	2481	16	2448	16	2408	43
14-UR-7-46	76.8	213	0.36	0.10517	0.00147	4.44854	0.05937	0.30677	0.00598	1717	18	1721	11	1725	29
14-UR-7-47	75.8	153	0.50	0.16594	0.00217	10.93041	0.1382	0.47771	0.00942	2517	17	2517	12	2517	41
14-UR-7-48	174	187	0.93	0.12646	0.00169	6.51687	0.08337	0.37374	0.0073	2049	18	2048	11	2047	34
14-UR-7-49	64.4	55.9	1.15	0.16401	0.00296	10.68859	0.18946	0.47263	0.01019	2497	16	2496	16	2495	45
14-UR-7-50	100	94.1	1.06	0.16456	0.00227	10.76899	0.14385	0.47461	0.00947	2503	17	2503	12	2504	41
14-UR-7-51	70.9	79.3	0.90	0.11462	0.00318	5.33998	0.14341	0.33788	0.00806	1874	22	1875	23	1876	39
14-UR-7-52	44.9	118	0.38	0.13596	0.00235	7.52303	0.12616	0.40129	0.00835	2176	17	2176	15	2175	38

续表 1

Continued Table 1

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	$\frac{^{207}Pb}{^{206}Pb}$	(±%)	$\frac{^{207}Pb}{^{235}U}$	(±%)	$\frac{^{206}Pb}{^{238}U}$	(±%)	$\frac{^{207}Pb}{^{206}Pb}$ 年龄(Ma)	(±%)	$\frac{^{207}Pb}{^{235}U}$ 年龄(Ma)	(±%)	$\frac{^{206}Pb}{^{238}U}$ 年龄(Ma)	(±%)
14-UR-7-53	81.8	358	0.23	0.07572	0.00136	1.92259	0.0328	0.18414	0.00365	1088	18	1089	11	1090	20
14-UR-7-54	102	124	0.83	0.14287	0.00198	8.14922	0.10861	0.41368	0.00819	2262	17	2248	12	2232	37
14-UR-7-55	47.9	122	0.39	0.11402	0.0018	5.1485	0.07789	0.32748	0.00655	1864	17	1844	13	1826	32
14-UR-7-56	78.1	95.6	0.82	0.16809	0.0023	10.9925	0.146	0.47429	0.00947	2539	17	2522	12	2502	41
14-UR-7-57	30.3	39.7	0.76	0.11174	0.00347	5.01832	0.15088	0.3257	0.00813	1828	25	1822	25	1818	40
14-UR-7-58	111	163	0.68	0.11359	0.00164	5.21428	0.07213	0.33291	0.00656	1858	17	1855	12	1852	32
14-UR-7-59	77.9	155	0.50	0.11733	0.00169	5.57241	0.07668	0.34443	0.0068	1916	17	1912	12	1908	33
14-UR-7-60	72.4	127	0.57	0.0986	0.00167	3.74845	0.06079	0.27572	0.00554	1598	17	1582	13	1570	28
14-UR-7-61	169	274	0.62	0.18674	0.00216	13.47087	0.1497	0.52318	0.01012	2714	18	2713	11	2713	43
14-UR-7-62	82.0	147	0.56	0.10847	0.00164	4.74198	0.06877	0.31706	0.00629	1774	17	1775	12	1775	31
14-UR-7-63	79.1	145	0.55	0.11203	0.00185	5.08637	0.08071	0.32928	0.00666	1833	17	1834	13	1835	32
14-UR-7-64	39.0	58.8	0.66	0.11357	0.00369	5.14144	0.16153	0.32835	0.00842	1857	26	1843	27	1830	41
14-UR-7-65	129	179	0.72	0.12713	0.00168	6.6815	0.08456	0.38118	0.00745	2059	18	2070	11	2082	35
14-UR-7-66	30.6	101	0.30	0.11496	0.00192	5.55099	0.08926	0.3502	0.00712	1879	17	1909	14	1936	34
14-UR-7-67	28.4	52.7	0.54	0.16599	0.00265	11.06904	0.173	0.48363	0.01008	2518	17	2529	15	2543	44
14-UR-7-68	103	144	0.71	0.10087	0.00211	4.02823	0.08096	0.28964	0.00612	1640	18	1640	16	1640	31
14-UR-7-69	131	98.0	1.33	0.1117	0.00187	5.13394	0.08252	0.33333	0.00676	1827	17	1842	14	1855	33
14-UR-7-70	86.5	276	0.31	0.15443	0.00303	9.58918	0.18451	0.45033	0.00996	2396	17	2396	18	2397	44
14-UR-7-71	65.5	77	0.86	0.07986	0.00199	2.22096	0.05301	0.2017	0.00432	1194	21	1188	17	1184	23
14-UR-7-72	190	101	1.88	0.15597	0.00216	10.02931	0.13493	0.46637	0.00933	2412	17	2437	12	2468	41
14-UR-7-73	70.3	83.4	0.84	0.11582	0.00225	5.47847	0.10281	0.34305	0.00726	1893	17	1897	16	1901	35
14-UR-7-74	37.6	68.0	0.55	0.11057	0.00285	4.92691	0.12279	0.32318	0.00744	1809	20	1807	21	1805	36
14-UR-7-75	41.5	60.3	0.69	0.16848	0.00286	11.21434	0.18729	0.48274	0.01028	2543	16	2541	16	2539	45
14-UR-7-76	79.5	98.8	0.80	0.14826	0.00223	8.8965	0.13003	0.43521	0.00884	2326	17	2327	13	2329	40
14-UR-7-77	33.5	95.1	0.35	0.07487	0.0019	1.87032	0.04543	0.18117	0.00385	1065	22	1071	16	1073	21
14-UR-7-78	85.0	95.7	0.89	0.11394	0.00187	5.22796	0.08246	0.33277	0.00674	1863	17	1857	13	1852	33
14-UR-7-79	70.6	82.6	0.86	0.08791	0.00188	2.89556	0.05941	0.23889	0.00498	1381	18	1381	15	1381	26
14-UR-7-80	48.8	79.7	0.61	0.13131	0.00212	6.97779	0.10896	0.38542	0.00788	2116	17	2109	14	2102	37
14-UR-7-81	91.1	164	0.56	0.09701	0.00151	3.79244	0.05669	0.28354	0.00563	1567	18	1591	12	1609	28
14-UR-7-82	49.3	103	0.48	0.12044	0.003	5.94235	0.14375	0.35786	0.00829	1963	19	1967	21	1972	39
14-UR-7-83	50.9	184	0.28	0.24131	0.00281	20.79044	0.23684	0.62489	0.01228	3129	17	3129	11	3129	49
14-UR-7-84	14.4	35.8	0.40	0.07582	0.00574	1.91658	0.13922	0.18333	0.00674	1090	88	1087	48	1085	37
14-UR-7-85	30.1	44.3	0.68	0.10916	0.0025	4.7468	0.10499	0.3154	0.00694	1785	18	1776	19	1767	34

注:表中划删除线的数据是作年龄谱图(图 5)时舍去谐和度相对较差的数据

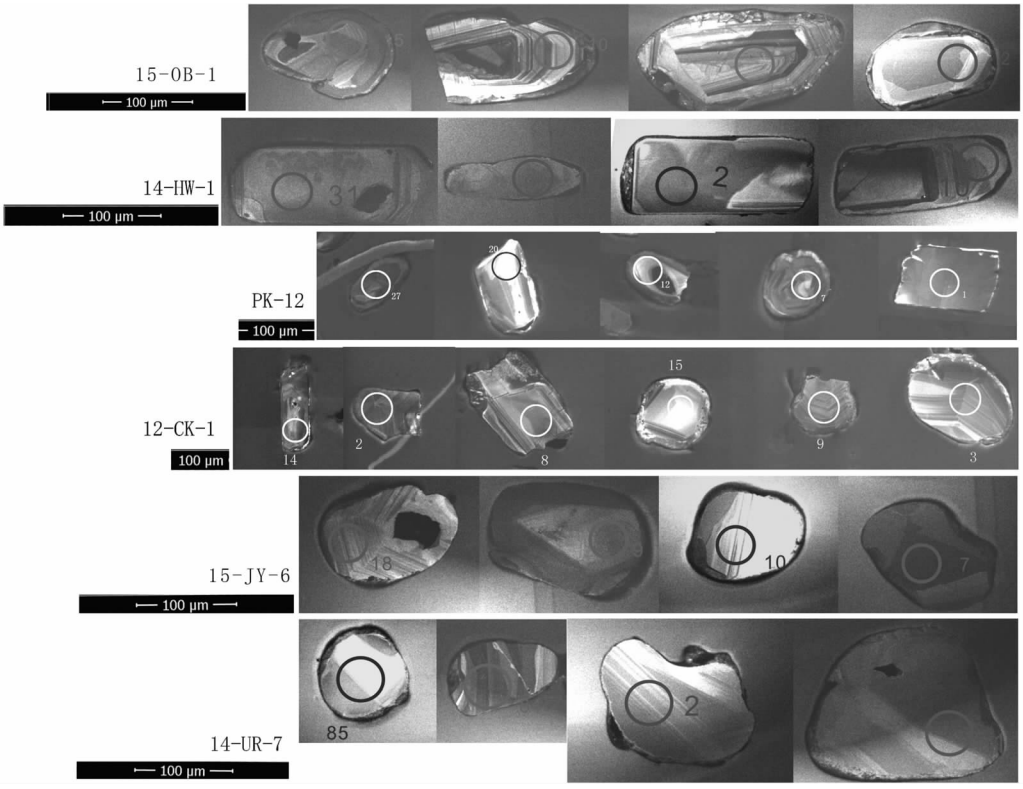

图 4 部分锆石阴极发光图像

15-OB-1：甑山群变质石英砂岩（浅粒岩）；14-HW-1：黄海群变质石英砂岩（石英片岩）；PK-12：黄海群浅变质砂岩（石英片岩）；12-CK-1：直岘群长峰组砂岩；15-JY-06：直岘群长寿山组砂岩；14-UR-7：黄州群砂岩

Fig. 4 Representative cathodoluminescent (CL) images of zircon grains

石具有长英质岩浆岩锆石特点，主要表现为岩浆韵律环带发育（图 4）。年龄谱存在明显的 2420Ma 的峰值（图 5）。开城东部甑山群样品（K-01-47）碎屑锆石年龄峰值为为 1900 ~ 1800Ma（图 5），28 个 $^{207}Pb/^{206}Pb$ 年龄接近的点给出了 1859 ± 9Ma 加权平均年龄（n = 28；MSWD = 4.0）。这一年龄与前人揭示的甑山群变质时代一致（Kim *et al.*，2006，2008；Han *et al.*，2011；赵磊等，2016）。合并甑山群 2 件样品（15-OB-1、K-01-47），可以看出，~2500Ma 和 ~1850Ma 是两个最为明显的峰值，前者可能代表平南盆地的基底岩石年龄，而后者代表变质年龄（Kim *et al.*，2006，2008；朴贤旭等，2016a）。

黄海群样品（14-HW-1）碎屑锆石多具有高级变质岩变质锆石特征，环带不发育，浑圆状（图 4），尤其是古元古代年龄锆石，少部分锆石（中元古代年龄锆石）发育环带，具有岩浆锆石特征。合并 2 件样品，可以看出，~1850Ma 和 ~1250Ma 的年龄峰值明显，并有少量 ~2500Ma 年龄记录（图 5），其中 ~1250Ma 的年龄和黄海群下部酸性火山岩以及邻区瓮津花岗岩年龄一致（朴贤旭等，2016b）。

祥原超群直岘群长峰组样品 12-CK-1 碎屑锆石多发于岩浆环带（图 4），但年龄大多不谐和，少数谐和年龄中，除了 1 个 ~2500Ma 的年龄，其他多集中在 ~1850Ma。长寿山组 2 件样品（15-JY-6、15-JY-11）碎屑锆石年龄显示明显的 1100 ~ 1200Ma 和 1400 ~ 1600Ma 年龄峰值，尤其是后者，另外，还有很少的 ~1850Ma 或者更老的年龄。将朴贤旭等（2016a）长寿山组碎屑锆石年龄放在一起，可以明显看出 ~1200Ma 和 1400 ~ 1600Ma 以及次要的 ~1850Ma 峰值（图 5）。

黄州群样品（14-UR-7）碎屑锆石有明显岩浆条带（环带），锆石多磨圆较好（图 4），年龄峰值为 ~1850Ma 和 ~2500Ma，另外，也有 1100 ~ 1200Ma 和 1400 ~ 1600Ma 次要年龄峰（图 5）。

5 讨论

5.1 对沉积时限和沉积物源区的启示

甑山群两件样品碎屑锆石中，店古隆起的样品（15-OB-1：变质砂岩）出现 ca. 2500 ~ 2100Ma 的年龄峰（图 5），该样品变质程度较低（角闪岩相：Paek *et al.* 1993），可能多记录碎屑年龄而未记录变质年龄，代表物源信息，并且限定沉积岩最大沉积时限为 ~2100Ma。另外，3650Ma 的碎屑锆石是目前为止朝鲜发现的最古老碎屑锆石。开城东部样品 K-01-47（夕线榴片麻岩）锆石年龄峰值为 ~1850Ma（$^{207}Pb/^{206}Pb$ 加权平均年龄为 1859 ± 9Ma），代表变质时代。该样品几乎没有记录碎屑锆石年龄信息，可能与样品变质程度高（麻粒岩相）

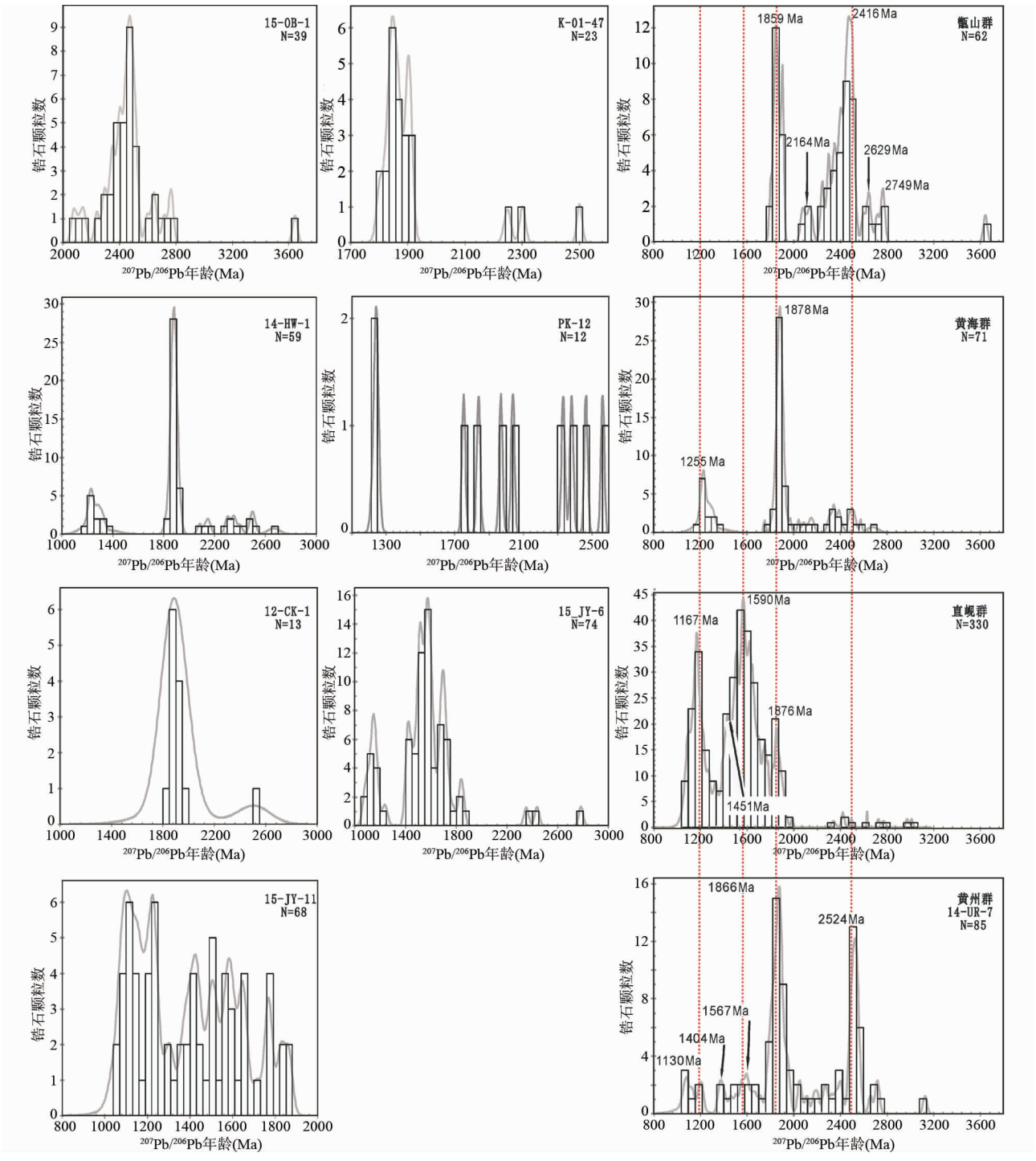

图 5 平南盆地样品碎屑锆石年龄谱图

15-OB-1:甑山群变质石英砂岩(浅粒岩);K-01-47:甑山群夕线榴片麻岩;14-HW-1:黄海群变质石英砂岩(石英片岩);PK-12:黄海群浅变质砂岩(石英片岩);12-CK-1:直岘群长峰组砂岩;15-JY-6 和 15-JY-11:直岘群长寿山组砂岩;14-UR-7:黄州群砂岩

Fig. 5 Spectrum of U-Pb ages of the detrital zircons from the samples in the Pyongnam basin

或者原岩为泥质岩有关。

黄海群浅变质石英砂岩中碎屑锆石年龄谱有三个大的特点,1) ~2500Ma 年龄少, 以 ~1850Ma 峰值为主,而且,根据锆石形态和 CL 照片特征,判断沉积物源可能包括岩浆岩和变质岩(参见彭澎等,2016);2) 未见 1600 ~ 1400Ma 的峰值,考虑到华北古陆该时期正好处于蓟县群盖层稳定发育阶段(翟明国等, 2014),缺少这一峰值是华北古陆本身的特点;3) 可见 ~1250Ma 的年龄值,这与黄海群下部酸性火山岩

以及邻区瓮津花岗岩年龄一致(朴贤郁等,2016),这些年龄可能来自翁津花岗岩或同期岩浆岩,但这与上部层位火山岩~1250Ma 的年龄矛盾(朴贤郁等,2016b)。

直岘群砂岩锆石年龄谱的研究最为系统,Hu *et al.* (2012)和朴贤旭等(2016a)通过对第二个组五峰组和第三个组长寿山组碎屑锆石的分析提出直岘群形成晚于~1000Ma。本次工作,我们对第一组长峰组(1 件样品)和第三组长寿山组(2 件样品)砂岩碎屑锆石年龄谱进行了分析(图 5),得知:1)长峰组有明显的~1850Ma 前后的年龄峰值,说明沉积物源可能来自基底变质岩系;但长寿山组~1850Ma 的年龄不明显,说明长寿山组主要物源可能不是基底变质岩系。2)长寿山组具有明显的 ca. 1000~1200Ma 和 ca. 1400~1600Ma 的碎屑锆石年龄峰值,而长峰组没有,这说明物源有大量中元古代的物质;前人的工作表明,直岘群第二个组五峰组砂岩碎屑锆石也有这两个峰值(Hu *et al.*,2012;朴贤旭等,2016a),但华北并不发育这些时代的岩浆岩;另外,黄海群未见 ca. 1400~1600Ma 的峰值,这更加说明中元古代的年龄可能不是华北古陆物质。根据直岘群 ca. 1200~1000Ma 的碎屑锆石,结合前人对侵入其上部层位~900Ma 岩床年龄(Peng *et al.*, 2011a),我们推测,直岘群沉积于 ca. 1000~900Ma。

黄州群中和组砂岩碎屑锆石显示明显的~1850Ma 和~2500Ma 年龄峰值;另外,还有次要的 ca. 1000~1200Ma 及 1400~1600Ma 年龄。这些年龄数量较少,而且锆石磨圆度好(图 4),我们推测这些锆石可以来自黄海群-直岘群沉积岩的再沉积。

5.2 对平南盆地和华北古陆古元古代-古生代地质演化的启示

综合分析,可以得出:1)甑山群作为平南盆地的基底岩系,其物源区为中朝古陆晚太古代-古元古代岩石,同时在 1.85 亿年经历变质作用;2)平南盆地沉积始于黄海群,从中元古代-古生代断续接收沉积,其物源有中朝古陆年龄的印记:均不同程度的记录~2500Ma 和~1800Ma 的年龄峰值(图 5);3)黄海群未记录 1400~1600Ma 碎屑锆石年龄,但直岘群这一峰值是非常明显的,然而,中朝古陆上并未发育这一峰值的岩浆活动,这可能说明,这些沉积物来源于中朝古陆之外的古陆;4)从黄海群-黄州群,均有 ca. 1000~1200Ma 的年龄信息,考虑到华北只有少量这一时代的岩浆活动,华北古陆能否作为主源区值得怀疑。朴贤旭等(2016b)提出瓮津花岗岩可以作为沉积物物源。不过这些岩浆活动出露面积非常小,是否可以作为物源尚不清楚。

胡波等(2013)研究的山东半岛新元古界土门群,Luo *et al.* (2006)研究辽东大连盆地榆树砣子群,陆松年等(2012)研究胶东新元古界蓬莱群等时,都注意到了 1600~1400Ma 和 1200~1000Ma 的峰值。这些相似性,说明平南盆地与这些盆地可能经历了相似的演化。陆松年等(2012)认为华北古陆曾经可能与劳伦大陆格林威尔造山带、西伯利亚东南缘相连。这一模型能够解释 ca. 1200~1000Ma 碎屑锆石的来源。研究者根据平南盆地~900Ma 岩床群及相关地层的对比,提出华北古陆东缘存在一个徐淮-大连-平南裂谷系(简称徐淮裂谷系)(Peng *et al.*,2011a),并根据岩墙群的对比,提出华北古陆东缘在中元古代-新元古代早期可能和圣弗朗西斯科(São Francisco)克拉通相连(Peng *et al.*,2011b)。这一模型最近得到了古地磁工作的支持(Cederberg *et al.*, 2016)。圣弗朗西斯科及周缘 1400~1600Ma 以及 1000~1200Ma 均有广泛的岩浆活动(Söllner and Trouw, 1997; Valladares *et al.*,2004;Danderfer *et al.*,2009;Heilbron *et al.*, 2010;Babinski *et al.*,2012)。如果华北古陆东缘中新元古代曾经与圣弗朗西斯科相邻,本文得到的平南盆地碎屑锆石年龄谱可以得到很好的解释。按照 Peng *et al.* (2011b)以及 Cederberg *et al.* (2016)古地理重建模型,平南盆地可能与 Macaúbas 盆地接近。Macaúbas 盆地是一个新元古代盆地,其沉积序列由陆内裂谷(碎屑岩系)演化到内海盆地(碳酸岩系),其碎屑锆石 U-Pb 年龄峰值与直岘群砂岩相似:它们都具有明显的 1000~1200Ma 及 1400~1600Ma 的峰值(Uhlein *et al.*,1999;Kuchenbecker *et al.*,2015)。

6 结论

本文选取了平南盆地变质基底(古元古界甑山群)以及浅变质沉积岩系(中元古界黄海群、新元古界直岘群和下古生界黄州群)进行碎屑锆石年龄谱分析,得出如下结论:

(1)甑山群物源主体是基底岩石,其沉积时代为 ca. 2100~1900Ma,变质时代为~1850Ma;另外,甑山群变质砂岩中 3650Ma 碎屑锆石是目前发现的朝鲜半岛最古老锆石。

(2)黄海群物源包括古元古代基底岩浆岩和变质岩,也涉及中元古代(~1250Ma)物源,其沉积时代为 ca. 1250~1000Ma。

(3)直岘群下部长峰组沉积物源主体为基底岩系,其上(五峰组-长寿山组)地层中有大量 ca. 1000~1200Ma 和 ca. 1400~1600Ma 中元古代物质,直岘群的沉积时代为 ca. 1000~900Ma。

(4)黄州群沉积物源以晚太古代-古元古代基底岩系为主,可能也有部分为中新元古代沉积岩系(黄海群-直岘群)的再沉积。

(5)平南盆地黄海群-直岘群中有大量 1000~1200Ma 及 1400~1600Ma 的物质,这些物质很可能来自中朝古陆之外的地块;我们之前提出的华北古陆东缘与圣弗朗西斯科相邻的模型能够很好的解释这一数据特征。

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