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河西走廊平山湖盆地早白垩世构造变形期次及其碎屑锆石U-Pb年龄约束

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提要:河西走廊北部的平山湖盆地,被围限于龙首山、北大山和合黎山之间,是一个在早白垩世受南北两侧逆冲断层共同控制形成并发展的盆地。笔者通过研究盆地内下白垩统沉积特征、构造变形、生长地层以及碎屑锆石U-Pb年代学特征,划分了平山湖盆地在早白垩世的构造演化期次,并恢复其形成演化过程。盆地内发育一套由下向上总体变细的下白垩统庙沟群沉积序列,盆地内构造变形以NE-SW向挤压和近E-W向伸展为主,庙沟群上岩组的碎屑锆石最小年龄为(129.3±1.8)Ma,可能代表了地层沉积和同期地堑发育的最早时间。由此得出,在早白垩世早期发育挤压构造盆地,同构造生长地层为挤压盆地的形成与构造演化提供了时代约束;在早白垩世晚期发育伸展断陷盆地,由挤压到伸展的转换时间晚于129.3 Ma。

关 键 词:平山湖盆地;早白垩世;沉积特征;构造变形;生长地层;形成演化;深地探测工程

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The Early Cretaceous tectonic deformation stages and detrital zircon U-Pb ages of Pingshanhu Basin in Hexi Corridor

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Abstract: Pingshanhu basin, located in the north of Hexi Corridor, is bounded by the Longshou Mountain in the south, the Beida Mountain in the north, and Heli Mountain in the west. The deposition and evolution of Pingshanhu basin were controlled by overthrust fault in the Early Cretaceous. In this paper, the authors deepened the study of the Early Cretaceous Miaogou Group, mainly about the geometry of the basin, the tectonic stress field and detrital zircon. The authors made a detail discussion on the

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tectonic evolution of Pingshanhu Basin. In Pingshanhu Basin, Miaogou Group exhibits an upward−fining sedimentary sequence. The tectonic deformation is dominated by NE−SW trending compression and E−W trending extension. The latest zircon age is (129.3±1.8) Ma, which may represent the earlieset time of the upper rock formation and the formation age of graben. On the basis of the sedimentary facies of Early Cretaceous Miaogou Group, the tectonic style, tectonic stress field and zircon ages of clastic rocks, the authors hold that Pingshanhu Basin was a compressional basin in the early Early Cretaceous. The growth strata restricted the compressional structure ages. It was an extensional rifted basin in late Early Cretaceous. The conversion time was posterior to 129.3 Ma.

Key words: Pingshanhu Basin; Early Cretaceous; sedimentary characteristics; tectonic deformation; growth strata; tectonic evolution; deep exploration engineering

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1 引 言

平山湖盆地位于河西走廊北部,总体围限于龙首山、北大山与合黎山之间,盆地在早白垩世受南北两侧的龙首山断裂和北大山南缘断裂共同控制(图1),南北宽约 30 km,东西长约 40 km,是甘肃省河西地区发现的煤炭资源前景较好的区块之一(李雄,2010;琚惠姣等,2016),对其进行沉积与构造演化研究具有重要意义。

在侏罗纪末期,冈底斯地块与北方大陆的碰撞和拼接,使青藏高原东北部边界处的祁连山区域发生隆升,并且在祁连山北侧发育了一系列的具有前陆盆地性质的早白垩世走廊盆地(刘金辉等,2005;曹珂,2013;陈军等,2013;梅冥相,2014a, b;陈宣华等,2019),而平山湖盆地就位于这一系列走廊盆地中的潮水盆地西部,潮水盆地西部下白垩统庙沟群中曾发现一批铀矿床、铀矿点(陈祖伊,1988—1989;王正其等,2004;陈静等,2015;陈江源等,2017;杨昆等,2017),但在白垩纪末期与古近纪之间的喜马拉雅地块与北方大陆的碰撞、拼接,使得祁连山地区进一步隆升,盆地抬升为陆,造成盆地内部上白垩统普遍缺失(梅冥相,2014a, b;郭荣涛,2015),平山湖盆地早白垩世沉积与构造演化对研究祁连山地区构造隆升以及盆地找矿工作有具有重要意义。本文通过对平山湖盆地开展1∶2000实测地层剖面调查与野外综合地质填图,结合沉积学、构造应力场以及碎屑锆石U−Pb年代学分析,划分了平山湖盆地早白垩世构造演化期次,恢复了盆地早白垩世构造演化历史,为本区开展盆山耦合过程研究及区域找矿工作等提供参考。

2 地质背景

平山湖盆地是一个由南北两条逆冲断裂控制形成的中新生代盆地(图1),由于逆冲断裂的控制,盆地内构造变形强烈、构造样式丰富。基底地层绝大部分位于盆地的南北两侧,在平山湖盆地北侧出露有早中震旦纪地层,在盆地南部和东部可见中上石炭统及华力西中期花岗闪长岩、斜长花岗岩等,其中,中、上石炭统含煤泥质岩、粉砂岩、炭质板岩出露较为广泛,并呈条带状沿 NW−SE 向分布,内部发育有强烈褶皱和断层,与白垩系呈断层或不整合接触。沉积盖层在盆地内出露下白垩统庙沟群以及第四纪沉积,庙沟群可以分为两个岩性组:下岩组、上岩组。下岩组由紫红色巨厚层、厚层砾岩和砂砾岩组成,砾石成分复杂、磨圆度较差且分选性差,花岗质、砂质砾石混杂堆积,局部夹紫红色、黄褐色含砾粗砂岩、粉砂岩等,产介形类 *Cypridea* sp.,轮藻 *Tolypella stipitata*、*Stellatochara mundula*、*Euaclistochara mundula* 等化石(宋杰己,1993);上岩组主要为一套黄褐色中厚层中细粒砂岩、杂色粉砂岩、粉砂质泥岩、灰色泥灰岩等,局部夹有泥质、钙质结核和石膏,在砂岩中发育有交错层理等原生构造。

2.1 盆地构造样式

平山湖盆地构造样式丰富,通过野外综合观

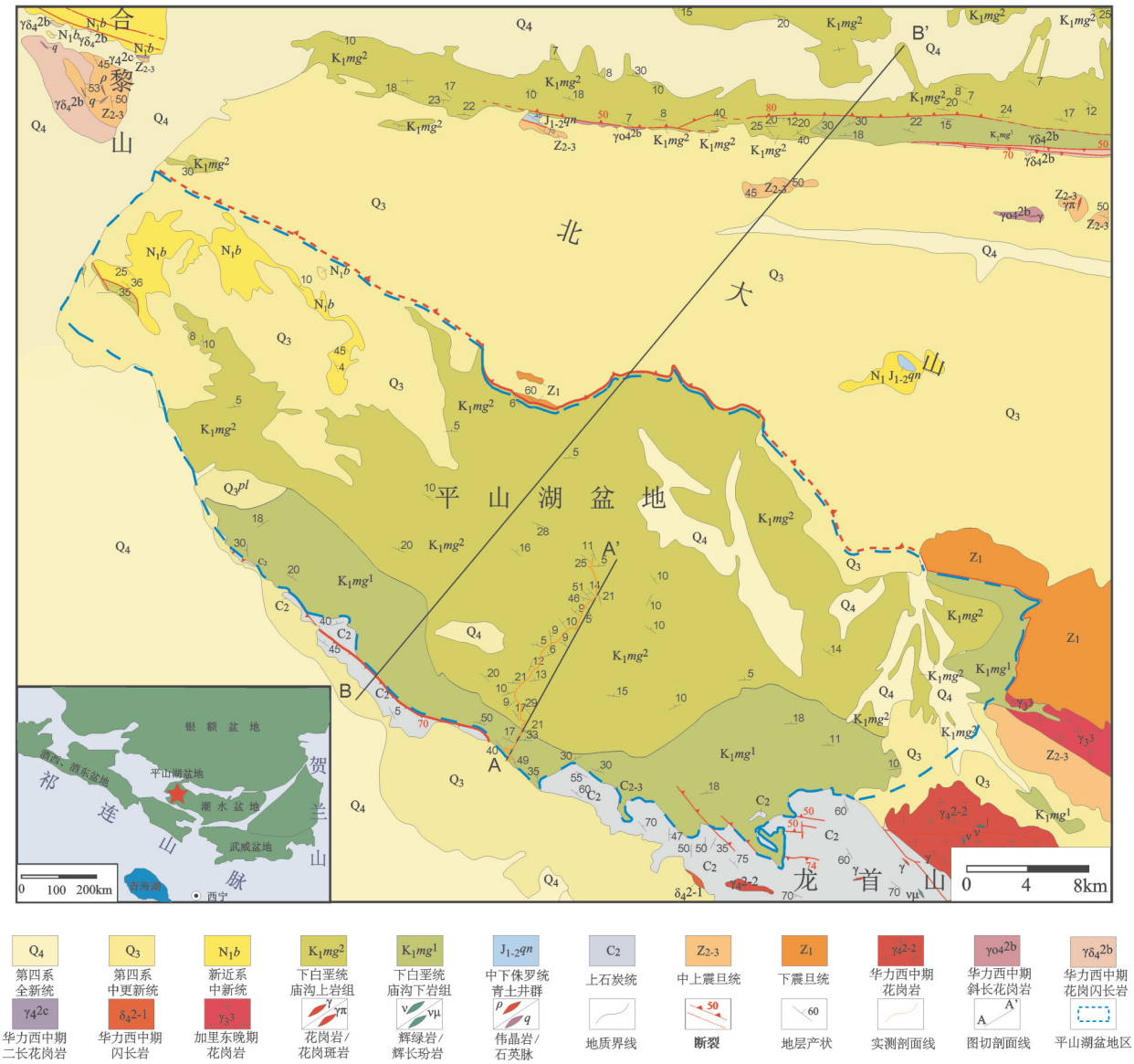

图1　平山湖盆地区域地质图[1-2]

(线A—A', B—B'为图切剖面线;黄色折线为实测剖面线;蓝色虚线框内为平山湖盆地边界)

Fig. 1　Regional geological map of Pingshanhu Basin[1-2]

(Line A—A' and B—B' are secant section lines, the yellow broken line is the measured section line, and the blue dotted line is the boundary of basin)

察,发现平山湖盆地南侧和北侧以挤压构造为主,中部和南部也发育有一系列伸展(地堑)正断层。

根据实测剖面调查并综合已有区域地质资料,在平山湖盆地内部作了2条比例尺分别为1:20万和1:5万的构造剖面(图2, 图3),由图可看出,盆地受北侧北大山南缘逆冲断裂及其分支断裂与南侧龙首山逆冲断裂的控制,盆地内部断层及褶皱构造发育。受龙首山断裂NE-SW向挤压,在盆地南部形成了仁宗口背斜,同时,平山湖盆地形成于北大山南缘逆冲断裂的前缘,具有前陆盆地的性质。

2.2　盆内挤压和伸展构造应力场

在构造演化的一定阶段,区域构造应力场相对统一,主应力方向相对一致。通过对盆地内构造应力场的分析可以恢复平山湖区域内地壳变动历史,了解盆地形成的动力学背景。平山湖盆地的形成受龙首山逆冲断裂和北大山南缘逆冲断裂的控制,盆地内发育的褶皱具有纵弯褶皱特征。在纵弯褶皱中,主应力σ_1方向与轴面垂直,枢纽相当于σ_2,σ_3

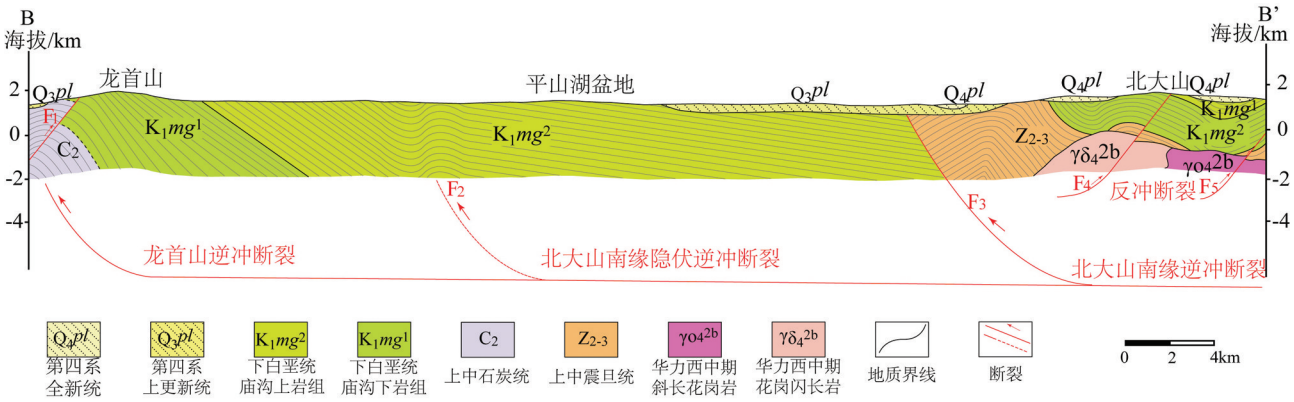

图2 平山湖盆地1:20万构造剖面(深部断裂据张进等,2007)

Fig. 2 1:200,000 structural sections of Pingshanhu basin(The deep faults are modified from Zhang et al., 2007)

则包含在轴面内并与枢纽垂直。通过分析平山湖盆地内正断层的应力方向可以判断盆地伸展的方向。正断层主应力方向为:最大主应力直立,中间和最小主应力水平。中间主应力和断层走向相同,断层上盘沿着断层面向下运动。在此基础上,对盆地内褶皱和正断层产状的极射赤平投影产状进行统计(表1,表2)。

赤平投影中,两翼产状的交点就是褶皱枢纽的产状,那么垂直于枢纽线的走向的方向可以大致认为是褶皱形成的挤压方向。由平山湖盆地内的褶皱两翼产状和枢纽产状极射赤平投影的极密点(图4)可以看出,几乎所有的枢纽走向的垂向都为NE-SW方向。因此可以认为,平山湖盆地先期形成于大致为NE-SW向的构造应力场中。

赤平投影中,最小主应力(σ_3)的方向就可以认为是正断层的运动方向即平山湖盆地伸展的方向。对平山湖盆地内发育的正断层的产状进行赤平投影分析可以看出(图4),最小主应力(σ_3)的方向近似为E-W方向,也就是平山湖盆地的伸展方向。

2.3 盆内生长地层

生长地层自其被定义以来,国内外的地质学家在世界范围内发现了不少生长地层典型发育地区(Vergés, 2002; Nigro, 2004),例如安第斯地区(Zapata et al., 1996)、伊朗西南部波斯湾地区(Fereshth Ghaseminia, 2016)、天山(陈杰等, 2001a, b;郭召杰等,2006)、龙门山(Li et al.,2016)等地,作为一种同沉积变形构造,其既反映了地层的构造变形,同时记录了沉积历史信息,是构造地质学和沉积地质学的重要研究内容之一。

平山湖盆地内发育了多处生长地层,其中最具代表性的是仁宗口背斜北翼处的生长地层和平易背斜南翼的生长地层(图5)。仁宗口背斜位于龙首

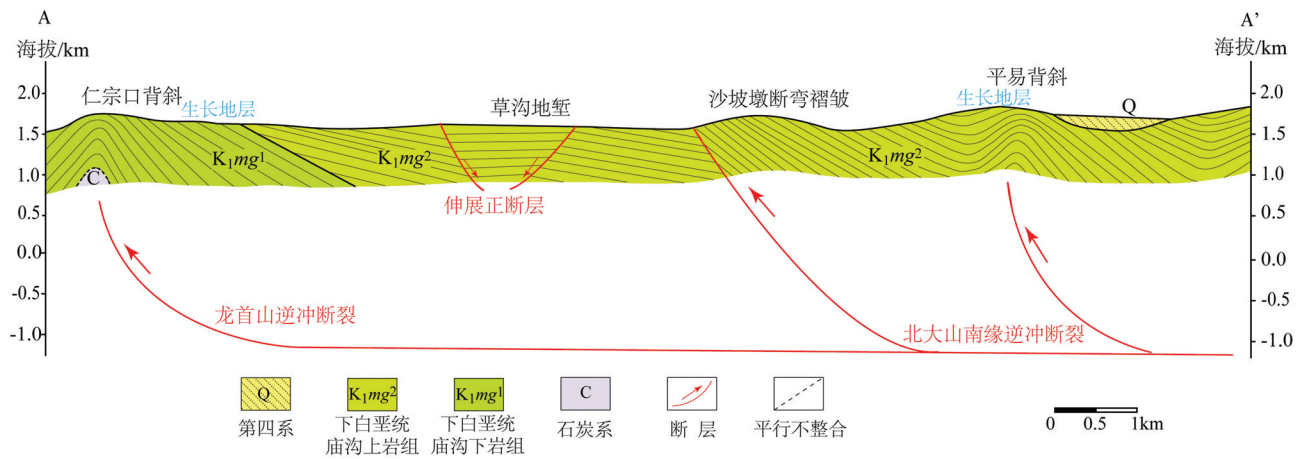

图3 平山湖盆地1:5万构造剖面(深部断裂据张进等,2007)

Fig. 3 1:50,000 structural sections of Pingshanhu basin(The deep fault are modified from Zhang et al., 2007)

表1　平山湖盆地的褶皱产状赤平投影统计

Table 1　The stereographic projection of attitudes of the folds in Pingshanhu basin

褶皱名称	两翼产状极密点				枢纽极密点		枢纽走向垂向/°
	倾向/°	倾角/°	倾向/°	倾角/°	倾向/°	倾角/°	
仁宗口背斜	31	16	210	28	300	3	30/210
燕蛙墩向斜	63	23	127	6	123	9	33/213
燕蛙墩背斜	128	6	210	8	153	5	63/243
古三墩背斜	109	25	295	14	22	2	112/292
平易背斜	43	49	194	45	121	11	31/211
平易向斜	61	31	203	50	127	13	37/217
平易北背斜	26	23	288	26	338	19	68/248
红大坂背斜	24	5	211	33	306	3	36/216

表2　平山湖盆地的正断层产状赤平投影统计

Table 2　The stereographic projection of the normal faults in Pingshanhu basin

正断层编号	倾向/°	倾角/°	最小主应力方向/°
1	265	49	265
2	116	67	116
3	321	69	321
4	291	53	291
5	296	52	296
6	235	62	235
7	86	58	86
8	104	57	104

山逆冲推覆的前缘,其形成受下部逆冲断裂的控制。背斜北翼地层的倾角由22°逐渐变化为12°,倾角逐渐变缓。其沉积物粒度自下而上呈现出由粗到细的变化,说明这套地层为一套典型的发育在山前坳陷的磨拉石建造,符合同褶皱生长地层的特点。庙沟群下岩组下部的砾岩为前生长地层,其砾岩上部的含砾砂岩、粗砂岩为生长地层。此处生长地层代表了平山湖盆地南部的仁宗口背斜构造是盆地演化早期的挤压构造。平易背斜位于北大山南缘断裂的前缘地带,其南翼地层倾角呈现出由49°到35°逐渐变化的特点。其沉积物粒度自下而上也呈现出由粗到细的变化,为同沉积褶皱生长地层。庙沟组上岩组上部的灰色、土黄色粉砂岩、泥岩为前生长地层,砂泥岩上部的灰黑色炭质板岩、泥岩为生长地层,为平山湖盆地晚期的挤压构造。

3　碎屑锆石U-Pb年代学

3.1　样品来源与实验条件

碎屑锆石U-Pb同位素测年的样品采集于平山湖盆地庙沟群下岩组和上岩组中。砂岩样品分别为CQL2016-L1-25、CQL2016-L1-42、CQL2016-L1-88、CQL2016-L1-154、CQL2016-L1-183。CQL2016-L1-25样品采集于下岩组仁宗口背斜处;CQL2016-L1-42样品采集于下岩组和上岩组的分界处上岩组一侧;CQL2016-L1-88样品采集于上岩组的地堑构造中;CQL2016-L1-154样品采集于平易背斜处;CQL2016-L1-183样品采集于剖面结束处红大坂背斜处(图4)。

碎屑锆石U-Pb同位素测年的样品粉碎和挑选工作在河北省区域地质矿产研究所完成。在室内先将岩石样品粉碎至80~120目,之后用水清洗颗粒表面,再用磁选方法分离出锆石,最后在双目镜下进行观察、记录,选出晶型较好的锆石颗粒。锆石制靶的工作在北京锆年领航科技有限公司的电子探针室完成。将锆石在显微镜下进行反射光、透射光拍照,在扫描电镜下进行阴极发光拍照。LA-MC-ICP-MS碎屑锆石U-Pb测年在中国地质科学院矿产资源研究所的等离子质谱实验室里完成。分析仪器为Finnigan Neptune型MC-ICP-MS以及配套的Newwave UP213激光剥蚀系统。激光剥蚀系统以氦气为载体,频率为10 Hz,束斑直径为30 μm,能量密度为6~8 J/cm^2。激光剥蚀系统采用单点剥蚀的方式,碎屑锆石U-Pb同位素定年以锆石标准GJ-1为外标,U、Th含量以锆石PLE1为外标。用ICPMSDataCal程序处理数据,用Isoplot4.15程序进行绘制锆石年龄谐和图。由于年龄小于1000 Ma的锆石中放射性成因的Pb含量低,分析易产生较大的误差,因而采用$^{206}Pb/^{238}U$年龄。而年龄大于1000 Ma的锆石中含有放射性成因Pb较多,故采用$^{207}Pb/^{206}Pb$年龄(数据见电子版附表1)。

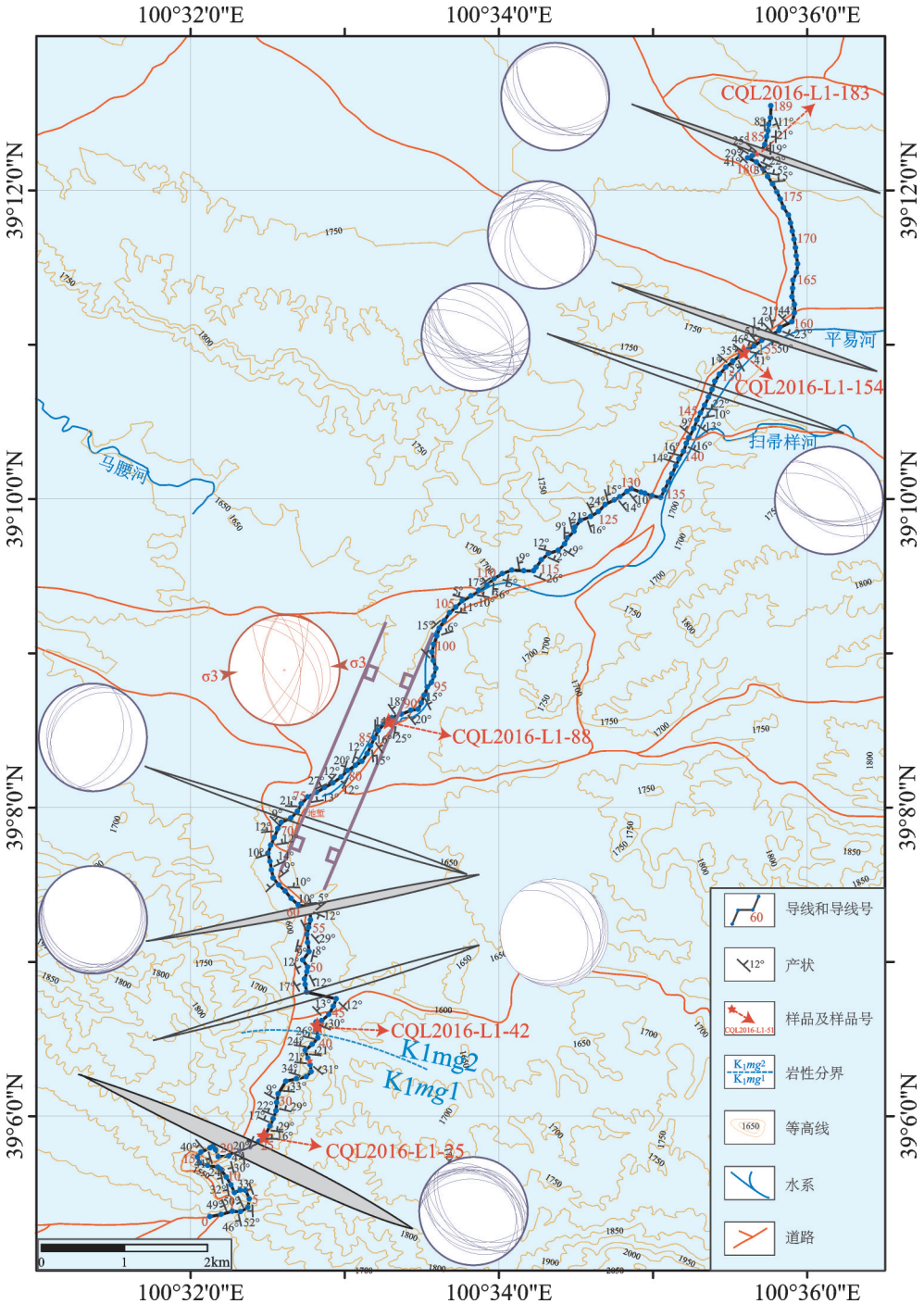

图4 平山湖盆地挤压和伸展构造应力场

（黑色折线为剖面线；赤平投影为褶皱两翼产状和正断层赤平投影；灰色阴影为褶皱枢纽；紫色区域为伸展区；红五角星为代表性样品点）

Fig. 4 The compresses and stretches tectonic stress field in Pinshanhu basin

(The black broken line is section line, the stereographic projections are for folds and normal faults, the gray shadow is fold hub, the purple area is the extension area, and the red five-pointed stars are location of samples)

3.2 样品分析结果

3.2.1 样品CQL2016-L1-25

样品CQL2016-L1-25共测试样品点80个，得到有效数据63组。分选出的锆石大多都为柱状和粒状，锆石粒径在80~150 μm。Th/U比值介于0.12~1.81。49颗锆石的Th/U大于0.4，且大多具有良好的岩浆振荡环带，因此样品CQL2016-L1-25的锆石以岩浆锆石为主（图6a）。样品里的碎屑锆石年

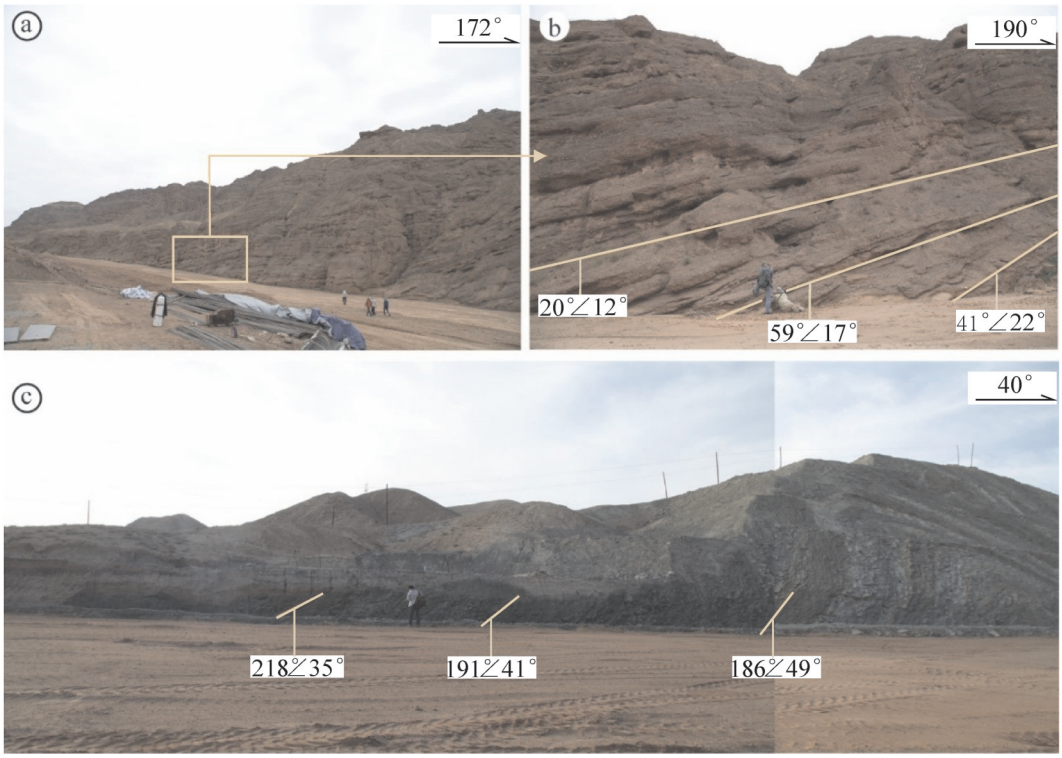

图5　平山湖盆地内发育的生长地层

(a, b—仁宗口背斜北翼生长地层;c—平易背斜南翼生长地层)

Fig. 5　The growth strata in Pingshanhu basin

(a, b-The growth strata on the north wing slope of Renzongkou anticline; c-The growth strata on the south wing slope of Pingyi anticline)

龄介于283.2~3214 Ma,最年轻年龄为283.2 Ma(图7a)。年龄峰值集中在400~600 Ma、800~1000 Ma和2400~2600 Ma,3组相对年龄峰值分别为(466.3±5.1) Ma、(955.9±4.6) Ma和(2505±6.1) Ma。

3.2.2 样品CQL2016-L1-42

样品CQL2016-L1-42共测试样品点80个,得到有效数据75组。分选出的锆石大多都为柱状和粒状,锆石粒径在100~150 μm。忽略个别测试点,Th/U比值介于0.03~25.11。61颗锆石的Th/U比值大于0.4,且大多具有良好的岩浆振荡环带,因此样品CQL2016-L1-42的锆石以岩浆锆石为主(图6b)。样品里的碎屑锆石年龄介于408.9~3116.4 Ma,最年轻年龄为408.9 Ma(图7b)。年龄峰值集中在800~1000 Ma和2400~2600 Ma两组,相对年龄峰值分别为(976.5±2.7) Ma和(2483.0±12.0) Ma。

3.2.3 样品CQL2016-L1-88

样品CQL2016-L1-88共测试样品点80个,得到有效数据49组。分选出的锆石大多都为柱状和粒状,锆石粒径在50~100 μm。Th/U比值介于0.12~1.55。40颗锆石的Th/U比值大于0.4,且大多具有良好的岩浆振荡环带,因此样品CQL2016-L1-88的锆石以岩浆锆石为主(图6c)。样品里的碎屑锆石年龄介于129.3~2686.1 Ma,最年轻年龄为129.3 Ma(图7c)。年龄峰值集中在200~300 Ma和400~500 Ma,相对年龄峰值分别为(275.1±1.0) Ma和(450.3±2.2) Ma。

3.2.4 样品CQL2016-L1-154

样品CQL2016-L1-154共测试样品点75个,得到有效数据60组。分选出的锆石大多都为柱状和粒状,锆石粒径在80~150 μm。Th/U比值介于0.08~3.73。43颗锆石的Th/U大于0.4,且大多具有良好的岩浆振荡环带,因此样品CQL2016-L1-154的锆石以岩浆锆石为主(图6d)。样品里的碎屑锆石年龄介于209.0~2077.8 Ma,最年轻年龄为209.0 Ma(图7d)。年龄峰值集中在200~400 Ma和1800~2000 Ma两组,相对年龄峰值分别为(302.7±3.9) Ma和(1826±19) Ma。

3.2.5 样品CQL2016-L1-183

样品CQL2016-L1-183共测试样品点75个,得到有效数据71组。分选出的锆石大多都为柱状和

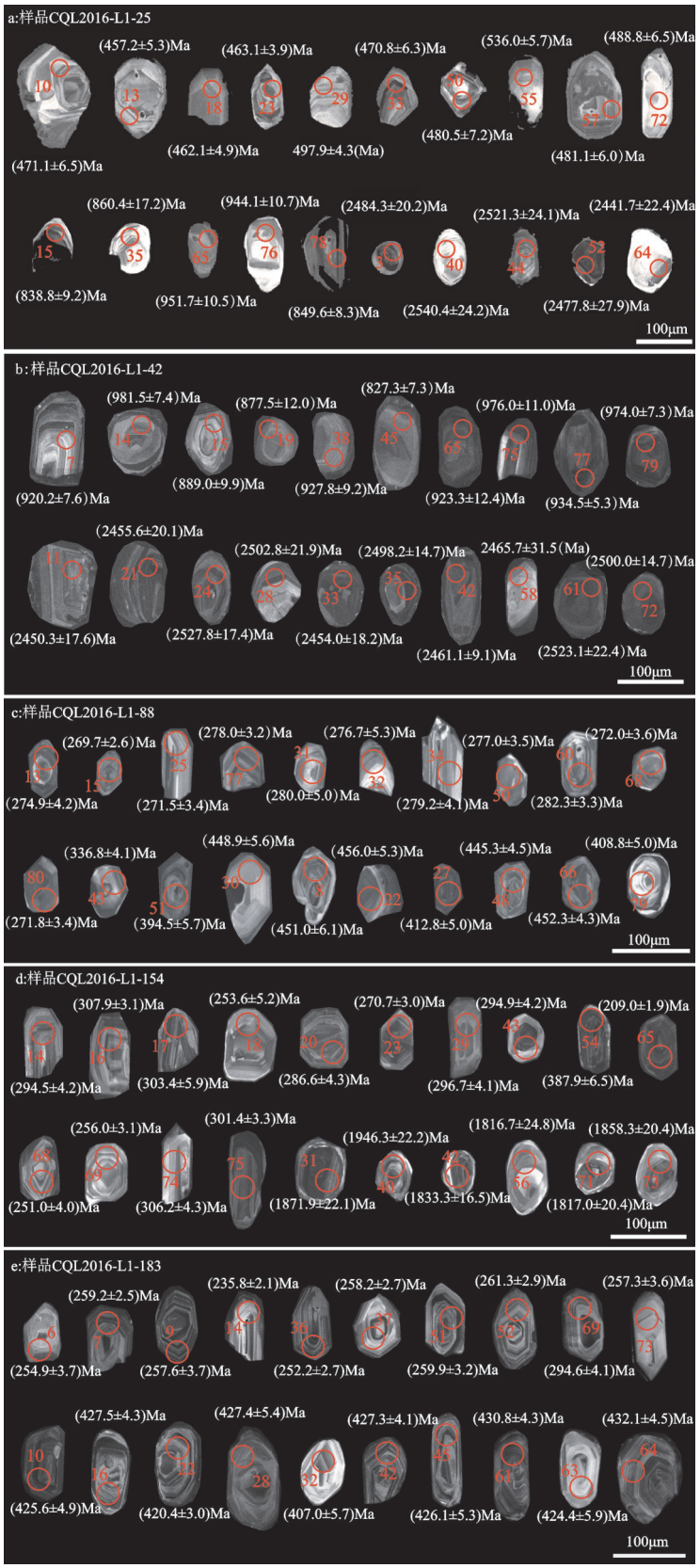

图6 平山湖盆地样品碎屑锆石阴极发光图

Fig. 6 Cathodoluminescence images of detrital zircon samples from Pingshanhu basin

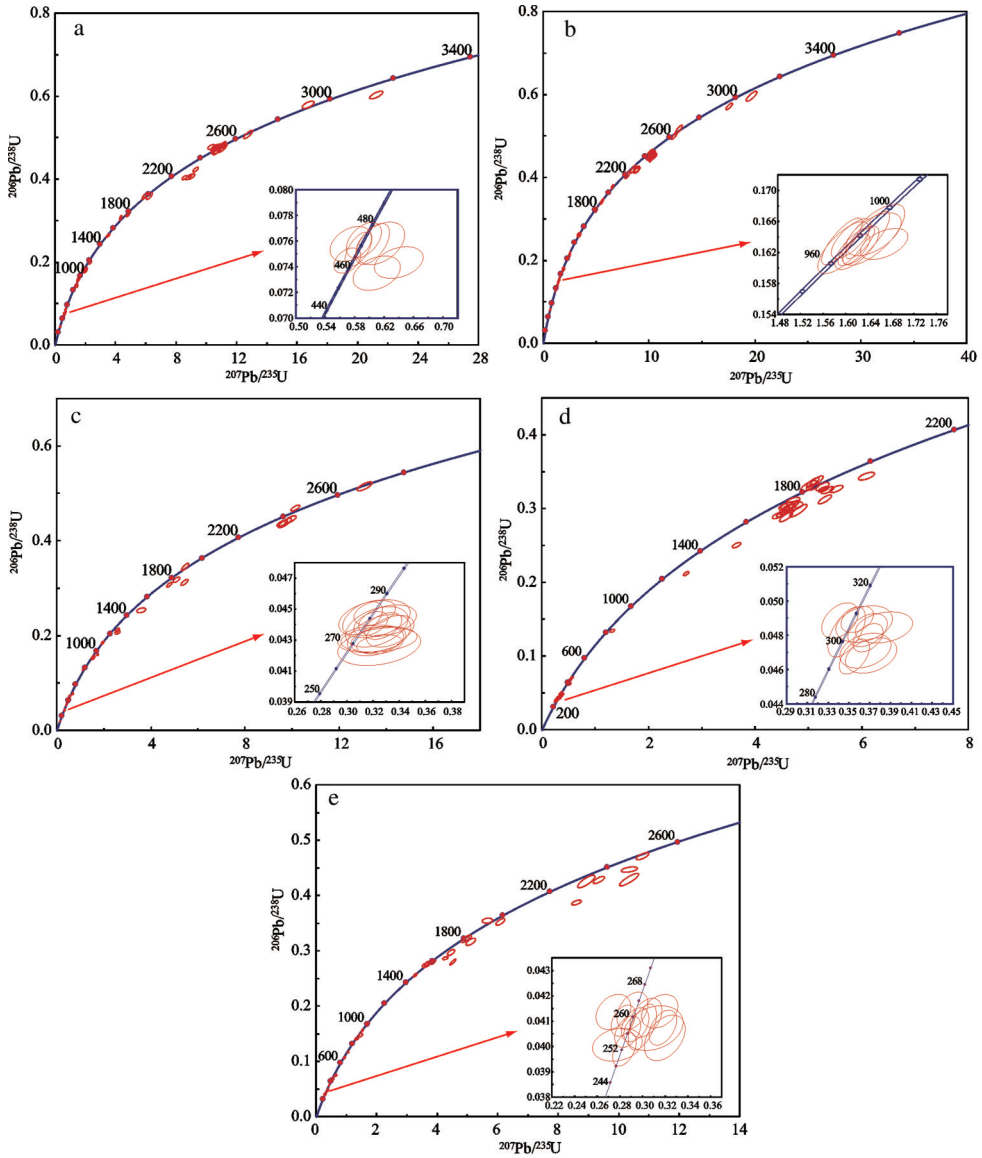

图7 平山湖盆地样品碎屑锆石U-Pb年龄谐和图

Fig. 7 Concordia diagram of the clastic zircons U-Pb data of the samples from Pingshanhu basin

粒状,锆石粒径在100~150 μm。Th/U比值介于0.03~2.17。61颗锆石的Th/U大于0.4,且大多具有良好的岩浆振荡环带,因此样品CQL2016-L1-183的锆石以岩浆锆石为主(图6e)。样品里的碎屑锆石年龄介于235.8~2622.2 Ma,最年轻年龄为235.8 Ma(图7e)。年龄峰值集中在200~300 Ma和400~500 Ma两组,相对年龄峰值分别为(257.7±1.6) Ma和(427.2±2.6) Ma。

3.3 碎屑锆石年龄及其物源分析

物源分析在盆地的演化与相邻造山带的研究中扮演着桥梁的作用,可以作为古陆或侵蚀区存在的证据,并且可以恢复古陆地形起伏特征和古河流体系(彭楠等,2013)。平山湖盆地北部以北大山断裂与阿拉善地块相邻,南部为祁连造山带。因此,盆地东北侧的北大山地区或邻近的阿拉善地块与南部的祁连造山带可能为平山湖盆地沉积的潜在物源区。

3.3.1 古元古代—新元古代

平山湖盆地中的古元古代碎屑锆石主要出现在样品CQL2016-L1-25和CQL2016-L1-42中,即庙沟群下岩组和上、下岩组的分界处的沉积岩层中,还有部分在样品CQL2016-L1-154中。年龄峰

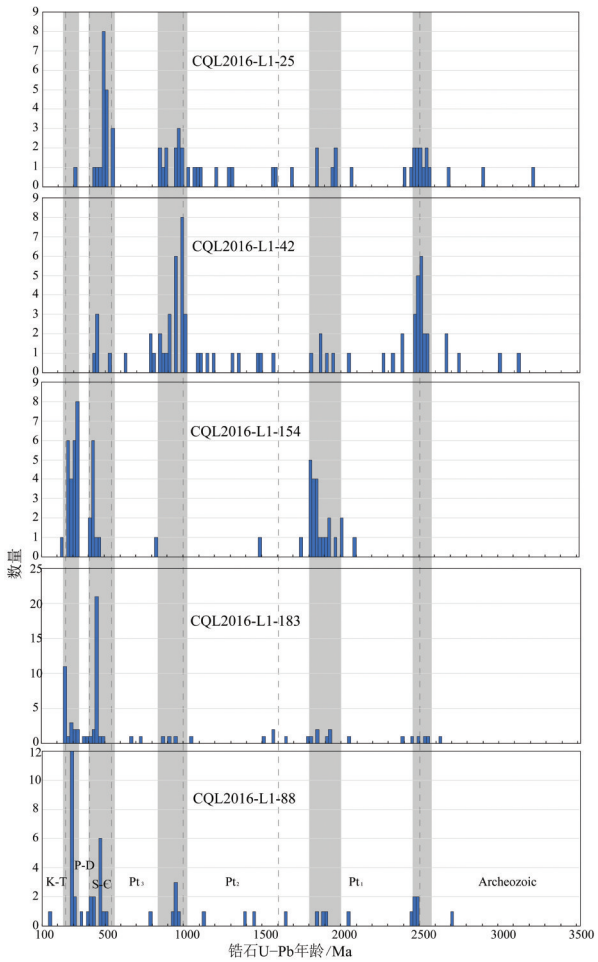

图8 平山湖盆地样品碎屑锆石U-Pb年龄谱图

Fig. 8 Histogram plot of the clastic zircons U-Pb data of the samples from Pingshanhu basin

值主要集中在1800~2000 Ma和2400~2600 Ma的年龄区间。平山湖盆地中的新元古代碎屑锆石主要出现在样品CQL2016-L1-25和CQL2016-L1-42中,即庙沟群下岩组和上、下岩组的分界处的沉积岩层中,年龄峰值主要集中在800~1000 Ma的年龄区间(图8)。阿拉善地块东部区域存在着古元古代的岩浆构造热事件(耿元生等,2007,2010a)。阿拉善西部地区在新元古代早期也存在岩浆事件(耿元生等,2010b)。花岗岩在阿拉善南缘龙首山地区也有分布(段俊等,2015)。因此,庙沟群下岩组沉积地层中的部分碎屑锆石应该来自于其北部的阿拉善地块(北大山)。

3.3.2 早古生代

平山湖盆地中的早古生代碎屑锆石主要出现在样品CQL2016-L1-88和CQL2016-L1-183中,即庙沟群上岩组的沉积岩层中。还有部分在样品CQL2016-L1-25中。其年龄峰值主要集中在400~600 Ma的年龄区间(图8)。早古生代,北祁连洋向南俯冲,形成了两期有关的花岗质作用,第一次岩浆作用在512~501 Ma,第二次岩浆作用在477 Ma(吴才来,2010)。而后向北俯冲消减、增生,在490~440 Ma形成了以中-基性火山岩为主的北祁连洋岛弧。而到了S—D时期,中祁连地块与北部的阿拉善地块碰撞拼贴,形成了同碰撞期的花岗闪长岩、二长花岗岩和二云母花岗岩等(彭楠等,2013)。加里东运动时期,南部祁连造山带向北挤压,造成了多次中酸性岩浆活动,在龙首山中东部地区形成了一系列的花岗岩带(祁程等,2017)。因此,庙沟群上岩组沉积地层中的部分碎屑锆石应该来自于其南部的祁连造山带(龙首山)。

3.3.3 晚古生代晚期

平山湖盆地中的晚古生代碎屑锆石主要出现在样品CQL2016-L1-88、CQL2016-L1-154和CQL2016-L1-183中,即庙沟群上岩组的沉积岩层中。其年龄峰值主要集中在200~300 Ma的年龄区间(图8)。阿拉善地块在晚古生代期间受到古亚洲洋关闭的强烈影响,发育很多岩浆岩和火山岩(Li et al., 2014)。阿拉善地块南缘的北大山地区至少存在3期构造岩浆事件,即晚石炭世—早二叠世、早二叠世—晚二叠世、二叠纪末,可能主要与古亚洲洋关闭、俯冲或俯冲之后的伸展作用相关(焦建刚等,2017)。因此,庙沟群上岩组沉积地层中的部分碎屑锆石应该来自于其北部的阿拉善地块(北大山)。

4 讨 论

4.1 平山湖盆地早白垩世构造先后期次的判定——来自沉积学分析、构造特征以及碎屑锆石年代学的证据

由于受到南北两侧逆冲断裂的控制,平山湖盆地在早白垩世期间形成了两期构造。一期是盆地广泛存在的大规模的挤压构造,另一期是发育于盆地中部的伸展(地堑)构造。通过沉积学分析、构造应力场特征、生长地层的发现以及碎屑锆石U-Pb年代学分析可以判断盆地内挤压以及伸展构造发育的先后期次。

通过沉积特征分析可知,平山湖盆地内下白垩统庙沟群地层由下到上是一个总体变细的沉积序列。其岩性由砾岩、含砾砂岩逐渐过渡为粉砂岩、泥岩和泥灰岩。地层沉积相经历了由冲积扇相到河流相再到湖泊相的转变。反映了一套水进的沉积体系,其沉积时潮水基准面是逐渐上升的。由此说明,平山湖盆地早白垩世期间盆地经历了由山前快速沉积转变成稳定沉积的整个过程。因此从侧面证明了平山湖盆地在早白垩世早期经历了大规模的挤压,造成盆地平山湖盆地周边龙首山地区快速隆升,进而盆地内部接受沉积的过程。

由盆地内构造赤平投影可知,平山湖盆地褶皱枢纽走向的垂向大致为NE-SW方向,则平山湖盆地遭受龙首山逆冲断裂和北大山南缘逆冲断裂挤压方向为NE-SW向。并且盆地南部部分褶皱受挤压方向为近似NW-SE向,可以认为是龙首山逆冲断裂具有NW-SE向走滑的性质。在平山湖盆地内发育的正断层的赤平投影中,其最小主应力(σ_3)的方向近似为E-W方向,则平山湖盆地的伸展方向近似为E-W方向。在伸展作用形成的地堑和半地堑组合中,其地层产状平缓,未遭受挤压变形,认为伸展构造发育于挤压构造之后。综上所述,平山湖盆地先期受到龙首山逆冲断裂和北大山南缘逆冲断裂NE-SW向挤压,形成了一系列的挤压褶皱。其中龙首山断裂还带有NW-SE向走滑的性质。而后期则发生了近E-W向的伸展,形成了草沟地堑、半地堑组合和庙沟群下岩组的一系列正断层构造。

平山湖盆地内挤压构造发育的先后顺序可以通过生长地层来判定。在仁宗口背斜北翼同褶皱生长地层中,庙沟群下岩组下部的砾岩为前生长地层,其砾岩上部的含砾砂岩、粗砂岩为生长地层。此处生长地层的发现,代表了平山湖盆地南部的仁宗口背斜构造是盆地演化早期的挤压构造。在平易背斜南翼为同沉积褶皱生长地层中,庙沟组上岩组上部的灰色、土黄色粉砂岩、泥岩为前生长地层,砂泥岩上部的灰黑色炭质板岩、泥岩为生长地层。平易背斜南翼生长地层的发现代表了平易背斜及其相邻褶皱为平山湖盆地晚期的挤压构造。

根据锆石年龄分析,庙沟群下岩组的碎屑锆石年龄较早,主要为古元古代—新元古代和早古生代的锆石;上岩组的碎屑锆石年龄较晚,为新元古代和早古生代—晚古生代的锆石。而从物源分析得知,平山湖盆地下白垩统庙沟群下岩组沉积阶段的物源区可能为其北部的阿拉善地块(北大山),上岩组沉积阶段物源区为其南部的祁连造山带(龙首山)以及北部的阿拉善地块(北大山)。则说明在平山湖盆地形成之前,其北部的北大山南缘断裂发生了大规模的逆冲事件,造成了古元古代—新元古代岩层出露地表遭受剥蚀。从而造成了年龄较早的锆石沉积在下部地层中。此外,庙沟群上岩组地堑系样品CQL2016-L1-88中测得的最年轻年龄为(129.3±1.8) Ma,代表了上岩组沉积的年龄和同时期地堑的发育在其之后。

4.2 平山湖盆地早白垩世构造演化期次划分

根据平山湖盆地内地层及沉积相分析、构造特征以及构造应力场分析,可以初步认为平山湖盆地是一个在挤压构造基础上发育的断陷盆地,在早白垩世经历了由挤压到伸展的转换。其中早白垩世庙沟群下岩组和上岩组中段发育的生长地层为盆地构造演化阶段的划分提供了时限上的证据。平山湖盆地早白垩世构造演化可分为4个阶段:早白垩世早期北大山南缘断裂NE-SW向逆冲阶段、早白垩世中期NE-SW向挤压伴随局部NW-SE向挤压阶段、早白垩世中晚期NE-SW向挤压阶段和早白垩世后期近E-W向伸展阶段。

4.2.1 早期北大山南缘断裂NE-SW向逆冲阶段

早白垩世早期,在平山湖盆地形成之前,其北部的北大山南缘断裂发生了大规模的NE-SW逆冲事件,北大山开始凸起,造成了古元古代—新元古代岩层出露地表从而遭受剥蚀(图9a)。早期北大山南缘断裂NE-SW向逆冲为平山湖盆地的形成提供了物源区,奠定了平山湖挤压盆地形成的基础。

4.2.2 中期龙首山断裂NE-SW向逆冲伴随NW-SE向走滑阶段

早白垩世中期,受到龙首山逆冲断裂的NE-SW向挤压,平山湖南部地区形成一系列的NE-SW向挤压褶皱。其中在平山湖南部仁宗口地区形成一背斜褶皱,在背斜的北翼发育有同褶皱沉积的生长地层(图9b)。仁宗口背斜北翼同褶皱沉积生长地层的发育表明此期挤压构造发育在早白垩世早期庙沟群下岩组地层沉积时期。

此外,龙首山逆冲断裂附近局部地区还发育有

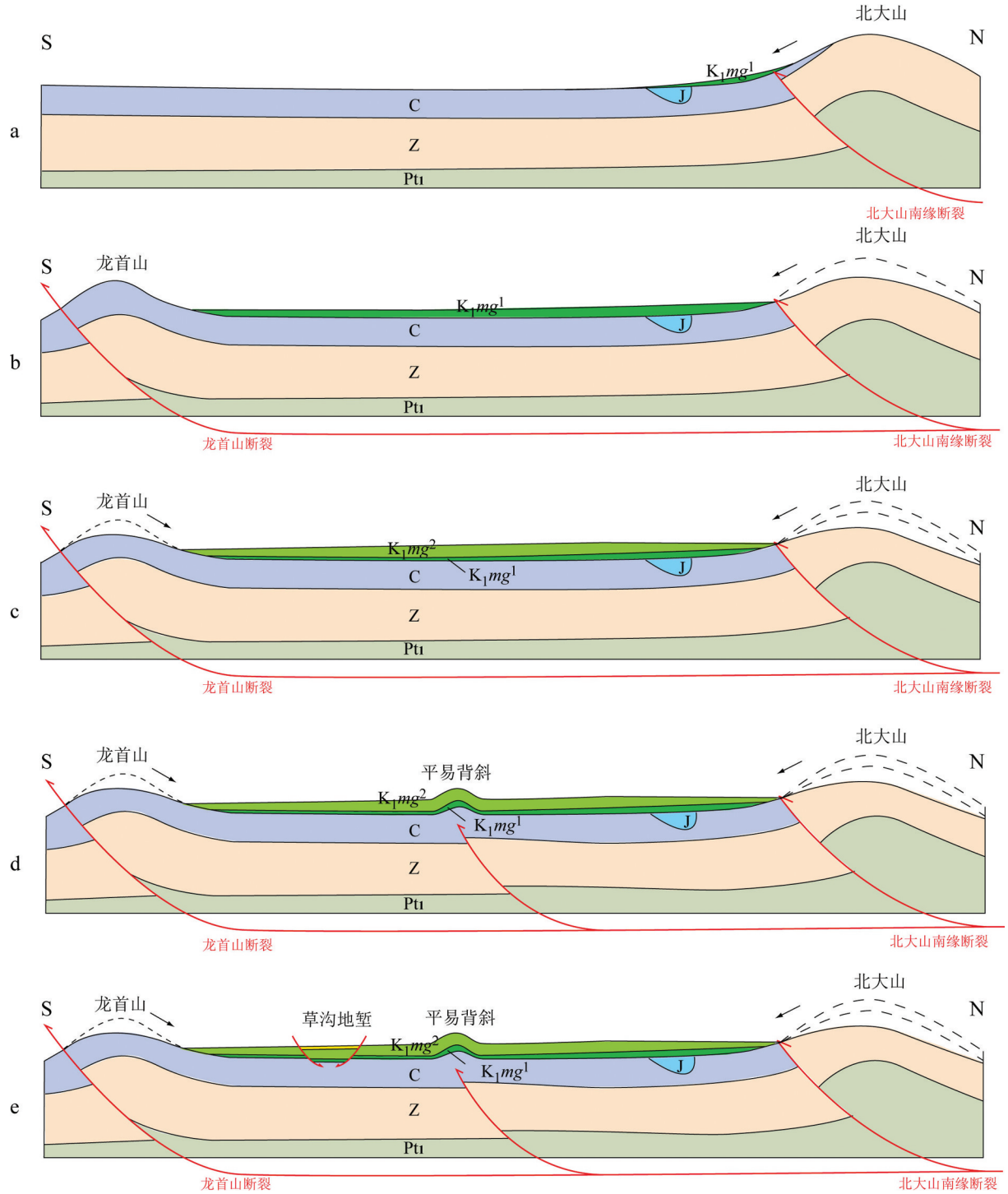

图9 平山湖盆地构造演化模式

Fig. 9 The tectonic evolutionary model of Pingshanhu basin

NW−SE向挤压的褶皱。表明龙首山逆冲断裂伴随有NW−SE向走滑的性质,在断裂附近形成NW−SE向的挤压隆起。早期龙首山逆冲断裂NE−SW向挤压,在仁宗口背斜北侧形成一背驼式盆地,表明平山湖盆地开始形成。

4.2.3 中晚期北大山南缘断裂NE−SW向逆冲阶段

早白垩世中晚期,受到北大山南缘逆冲断裂的NE−SW向挤压,在平山湖地区中部形成一系列的

NE-SW向挤压褶皱。如沙坡墩断弯褶皱、平易背斜褶皱等。在平易背斜的南翼发育有同褶皱沉积的生长地层(图9d)。其地层为早白垩世上岩组粉砂岩、粉砂质泥岩、炭质页岩等。平易背斜南翼同褶皱生长地层的发育表明此期挤压构造发育在早白垩世中晚期上岩组地层沉积时期。

4.2.4 后期近E-W向伸展阶段

早白垩世后期,在平山湖地区中部发育有伸展性质的地堑、半地堑组合。同时在南部也发育有显著的正断层作用(图9e)。地堑组合构造内地层产状平缓,没有受到挤压破坏。表明伸展构造发育于挤压构造之后。结合地质资料表明,早白垩世晚期在酒泉盆地等一系列盆地中在NW-SE方向上表现为长时间的伸展作用 (王崇孝等,2005;郭庆银等,2006;王晓丰等,2008)。在平山湖盆地内发育的这期显著的伸展作用可能与此有关。早白垩世后期的近E-W向的伸展表明平山湖盆地开始了从挤压到伸展的转换。

5 结　论

通过平山湖盆地早白垩世地层沉积特征、构造应力场分析与沉积地层的碎屑锆石U-Pb年代学分析,得到以下几点认识:

(1)平山湖盆地早白垩世早期构造样式以挤压变形及其相关褶皱为主,挤压构造应力场为NE-SW向;早白垩世晚期发育有一期显著的伸展构造,伸展构造应力场为近E-W向。

(2)平山湖盆地为龙首山断裂(逆冲断层)作用下形成的龙首山背驼式盆地,具有类前陆盆地的性质。

(3)平山湖盆地下白垩统庙沟群下岩组沉积阶段的物源区可能为北部的阿拉善地块(北大山),上岩组沉积阶段物源区为南部的祁连造山带(龙首山)以及北部的阿拉善地块(北大山)。庙沟群上岩组地堑系样品中测得的最年轻年龄为(129.3±1.8) Ma,代表了上岩组沉积的年龄和同时期地堑的发育的最早时期。

(4)平山湖盆地是早白垩世早期发育的挤压构造盆地,同构造生长地层为挤压盆地的形成与构造演化提供了时代约束;晚期发育伸展断陷盆地,由挤压到伸展的转换时间大致在129.3 Ma之后。平山湖盆地早白垩世构造演化可分为四个阶段:早期北大山南缘断裂NE-SW向逆冲阶段、中期龙首山断裂 NE-SW向逆冲伴随局部NW-SE向走滑阶段、中晚期北大山南缘断裂NE-SW向逆冲阶段和后期近E-W向伸展阶段。

注释

❶甘肃省地质局. 1973. 张掖幅J-47-11 1:20万地质图.

❷甘肃省地质局. 1973. 平川幅J-47-5 1:20万地质图.

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附表1 平山湖盆地样品CQL2017-L1-25碎屑锆石U-Pb同位素测年数据表

Table1 Zircon U-Pb age data from sample CQL2017-L1-25 in Pingshanhu basin

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
1	77.7	109.6	430.3	0.084062	0.001282	2.080358	0.036892	0.181289	0.003441	0.254619	1294.4	29.6	1142.4	12.2	1074.0	18.8	93
2	91.2	546.6	736.2	0.107653	0.002570	1.547073	0.036882	0.104011	0.001139	0.742476	1761.1	43.4	949.3	14.7	637.9	6.7	60
3	132.7	202.9	216.9	0.162746	0.002039	10.615954	0.186440	0.472631	0.007266	0.935615	2484.3	20.2	2490.1	16.3	2495.1	31.8	99
4	43.5	420.7	518.7	0.062528	0.001543	0.603012	0.018612	0.069971	0.001645	0.811050	700.0	51.8	479.1	11.8	436.0	9.9	90
5	92.1	1129.5	905.8	0.129036	0.005154	1.379302	0.033877	0.087954	0.004206	1.246960	2084.9	70.4	880.1	14.5	543.4	24.9	52
6	47.8	253.9	618.1	0.098373	0.002550	0.876175	0.022709	0.064610	0.000699	0.410787	1594.4	49.2	638.9	12.3	403.6	4.2	54
7	123.7	133.5	432.6	0.095738	0.001184	3.474973	0.047026	0.263368	0.002590	0.308491	1542.6	22.7	1521.6	10.7	1507.0	13.2	99
8	52.2	26.8	98.5	0.165556	0.002361	10.719073	0.197451	0.469728	0.006701	0.271582	2513.3	18.4	2499.1	17.1	2482.4	29.4	99
9	135.1	167.5	422.6	0.129435	0.002976	5.084156	0.189639	0.276849	0.005748	0.396309	2090.4	40.7	1833.5	31.7	1575.5	29.0	84
10	10.9	93.8	122.1	0.059088	0.002074	0.614991	0.021805	0.075816	0.001091	0.768796	568.6	77.8	486.7	13.7	471.1	6.5	96
11	354.6	260.5	636.1	0.157163	0.002085	10.349439	0.148365	0.477420	0.003489	0.409550	2425.6	22.5	2466.5	13.3	2516.0	15.2	98
12	18.8	165.9	242.3	0.054183	0.001504	0.496204	0.015155	0.066524	0.001016	0.684589	388.9	58.3	409.1	10.3	415.2	6.1	98
13	11.9	122.4	127.7	0.060853	0.002369	0.610026	0.021235	0.073495	0.000884	0.957864	635.2	85.2	483.6	13.4	457.2	5.3	94
14	55.3	54.1	134.0	0.119825	0.001804	5.942112	0.095590	0.359926	0.003323	0.404137	1953.4	26.4	1967.4	14.0	1981.8	15.7	99
15	95.2	91.0	659.3	0.066591	0.000984	1.276509	0.022703	0.138960	0.001617	0.138078	833.3	30.4	835.3	10.1	838.8	9.2	99
16	21.6	71.5	114.2	0.069503	0.001750	1.549828	0.040177	0.161971	0.002082	0.626032	922.2	51.9	950.4	16.0	967.7	11.6	98
17	384.0	727.1	1222.0	0.250817	0.003106	8.969302	0.222684	0.257711	0.004723	0.594980	3189.8	19.8	2334.9	22.7	1478.1	24.2	55
18	23.0	154.1	270.3	0.062670	0.002165	0.640005	0.021973	0.074321	0.000814	0.569923	698.2	74.1	502.3	13.6	462.1	4.9	91
19	24.0	192.8	233.7	0.060327	0.001631	0.716011	0.019418	0.086605	0.001293	0.824680	616.7	52.8	548.3	11.5	535.4	7.7	97
20	39.1	705.0	748.5	0.086242	0.003864	0.455190	0.018545	0.038866	0.000361	0.941867	1343.5	86.6	380.9	12.9	245.8	2.2	56
21	101.0	109.8	624.4	0.069514	0.001090	1.485846	0.025621	0.154983	0.001478	0.175869	922.2	32.6	924.6	10.5	928.8	8.2	99

续附表1

测试点	含量/10^{-6}			同位素比值							表面年龄						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
22	23.2	182.8	261.8	0.056641	0.001461	0.592638	0.015703	0.076055	0.000923	0.698387	476.0	89.8	472.6	10.0	472.5	5.5	99
23	29.9	301.7	317.5	0.055515	0.001155	0.569983	0.012212	0.074481	0.000653	0.950144	431.5	46.3	458.0	7.9	463.1	3.9	98
24	40.3	103.4	200.4	0.079890	0.001435	1.960285	0.046693	0.178241	0.003162	0.515902	1194.4	35.5	1102.0	16.0	1057.4	17.3	95
25	102.8	175.4	155.9	0.167259	0.002105	11.075284	0.173551	0.480238	0.005532	1.125539	2531.5	21.3	2529.5	14.6	2528.3	24.1	99
26	106.2	234.8	505.4	0.075797	0.000997	1.938402	0.030390	0.185346	0.001753	0.464564	1100.0	25.9	1094.4	10.5	1096.1	9.5	99
27	132.1	84.0	218.8	0.182600	0.002002	12.783679	0.195246	0.507948	0.006468	0.383793	2676.9	18.2	2663.8	14.4	2647.9	27.7	99
28	133.5	763.3	827.8	0.093290	0.001276	1.655794	0.024705	0.129301	0.001697	0.922012	1494.4	-6.5	991.8	9.4	783.9	9.7	76
29	16.9	250.3	138.5	0.064087	0.001652	0.709476	0.018547	0.080304	0.000716	1.806677	746.3	49.1	544.4	11.0	497.9	4.3	91
30	15.6	103.8	173.3	0.061371	0.001989	0.656920	0.021637	0.078282	0.001285	0.599026	653.7	65.7	512.7	13.3	485.9	7.7	94
31	97.5	206.8	475.8	0.075355	0.001037	1.912784	0.032120	0.183844	0.001878	0.434631	1079.6	27.8	1085.6	11.2	1087.9	10.2	99
32	43.1	334.2	475.7	0.056335	0.001047	0.585063	0.011960	0.075360	0.000890	0.702561	464.9	36.1	467.7	7.7	468.4	5.3	99
33	20.7	186.8	223.6	0.058081	0.001432	0.604322	0.015128	0.075771	0.001053	0.835485	531.5	53.7	480.0	9.6	470.8	6.3	98
34	203.2	411.1	1319.6	0.109081	0.001481	2.022870	0.026443	0.135735	0.002231	0.311570	1784.3	25.2	1123.2	8.9	820.5	12.7	68
35	19.7	48.8	123.9	0.072766	0.002411	1.420201	0.046747	0.142784	0.003050	0.394051	1009.3	67.1	897.4	19.6	860.4	17.2	95
36	49.3	118.0	240.6	0.074352	0.001303	1.875854	0.045877	0.182732	0.003143	0.490571	1050.9	35.2	1072.6	16.2	1081.9	17.1	99
37	57.8	675.9	593.8	0.068846	0.001371	0.679912	0.013625	0.071728	0.000808	1.138306	894.4	73.2	526.7	8.2	446.6	4.9	83
38	66.6	100.1	434.5	0.068032	0.000975	1.344605	0.021077	0.143204	0.001246	0.230461	877.8	29.6	865.2	9.1	862.8	7.0	99
39	54.3	228.2	267.5	0.069591	0.001204	1.550738	0.028017	0.161648	0.001671	0.853362	916.7	36.0	950.8	11.2	965.9	9.3	98
40	73.6	86.4	121.4	0.168280	0.002468	11.053506	0.213725	0.475877	0.006944	0.712103	2540.4	24.2	2527.6	18.0	2509.3	30.3	99

续附表1

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
41	25.5	265.5	223.5	0.057378	0.001756	0.687721	0.022233	0.087057	0.001378	1.188134	505.6	66.7	531.4	13.4	538.1	8.2	98
42	350.8	938.1	1441.1	0.166667	0.001980	4.607105	0.108526	0.200465	0.004492	0.650953	2524.4	19.3	1750.6	19.7	1177.8	24.1	60
43	93.5	194.8	202.8	0.119558	0.001649	5.915813	0.105354	0.358672	0.004834	0.960515	1950.0	24.4	1963.6	15.5	1975.9	22.9	99
44	97.1	174.2	170.0	0.166325	0.002382	10.891006	0.250446	0.475965	0.009971	1.025032	2521.3	24.1	2513.9	21.4	2509.7	43.5	99
45	153.5	1358.3	858.0	0.105766	0.001690	1.800771	0.024698	0.123943	0.001276	1.583137	1727.5	34.3	1045.7	9.0	753.2	7.3	67
46	460.6	582.8	536.3	0.254738	0.002842	21.229517	0.287839	0.603277	0.005968	1.086624	3214.5	16.8	3149.1	13.1	3043.0	24.0	96
47	18.5	98.4	172.9	0.071089	0.005175	0.913988	0.070066	0.093558	0.002376	0.569048	961.1	149.2	659.2	37.2	576.5	14.0	86
48	150.7	486.5	1235.8	0.123532	0.001741	1.704668	0.022578	0.100146	0.000968	0.393670	2009.3	24.5	1010.3	8.5	615.3	5.7	51
49	54.4	474.6	412.3	0.075239	0.002558	1.016772	0.022960	0.099997	0.001913	1.151242	1075.9	68.5	712.3	11.6	614.4	11.2	85
50	22.5	179.8	246.6	0.056944	0.001549	0.606709	0.017723	0.077387	0.001198	0.729366	500.0	61.1	481.5	11.2	480.5	7.2	99
51	26.9	203.5	143.2	0.063623	0.002524	1.204066	0.044363	0.137616	0.001745	1.420514	727.8	84.1	802.5	20.4	831.2	9.9	96
52	467.7	709.5	740.4	0.161074	0.002150	10.563760	0.160549	0.474942	0.005070	0.958227	2477.8	27.9	2485.5	14.1	2505.2	22.2	99
53	230.8	313.1	622.0	0.111420	0.001482	4.874333	0.077390	0.316920	0.003807	0.503377	1833.3	24.1	1797.8	13.4	1774.7	18.6	98
54	6.8	43.3	49.0	0.079799	0.004156	1.187029	0.064817	0.107376	0.001745	0.882427	1192.3	102.3	794.6	30.1	657.5	10.2	81
55	15.4	143.1	136.7	0.058228	0.001692	0.696253	0.021079	0.086698	0.000960	1.046956	538.9	69.4	536.6	12.6	536.0	5.7	99
56	51.8	78.6	80.7	0.163174	0.002218	10.730739	0.190375	0.476348	0.005931	0.973687	2488.6	28.2	2500.1	16.5	2511.3	25.9	99
57	24.4	242.5	246.5	0.057250	0.001396	0.611935	0.016349	0.077480	0.000999	0.983862	501.9	49.1	484.8	10.3	481.1	6.0	99
58	139.0	254.7	360.5	0.102694	0.001157	4.343159	0.063062	0.306762	0.003438	0.706647	1673.1	20.4	1701.6	12.0	1724.8	17.0	98
59	205.9	181.1	424.2	0.161023	0.001748	9.029874	0.127776	0.406442	0.004113	0.426837	2466.4	18.5	2341.0	12.9	2198.6	18.9	93
60	70.2	69.5	357.6	0.072623	0.001056	1.821833	0.029966	0.181984	0.001746	0.194486	1003.4	29.3	1053.3	10.8	1077.8	9.5	97

续附表1

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
61	392.7	220.9	804.1	0.153819	0.001613	8.567563	0.110548	0.403848	0.003508	0.274690	2388.6	17.1	2293.1	11.7	2186.7	16.1	95
62	173.3	679.7	1403.7	0.116963	0.001330	1.415983	0.020042	0.087683	0.000708	0.484223	1910.2	15.7	895.7	8.4	541.8	4.2	50
63	103.1	167.5	218.4	0.125890	0.001920	6.231562	0.125289	0.359001	0.005248	0.766790	2042.6	27.2	2008.9	17.6	1977.4	24.9	98
64	50.4	47.7	99.4	0.158705	0.002036	8.837243	0.123047	0.404825	0.004441	0.480498	2441.7	22.4	2321.3	12.7	2191.2	20.4	94
65	43.0	141.7	224.0	0.070927	0.001201	1.559026	0.032901	0.159093	0.001893	0.632499	955.2	35.2	954.1	13.1	951.7	10.5	99
66	62.7	117.3	156.1	0.111379	0.001491	4.830106	0.075576	0.314706	0.003410	0.751356	1821.9	23.9	1790.2	13.2	1763.8	16.7	98
67	543.3	135.8	1110.8	0.159444	0.001490	9.296446	0.113551	0.422503	0.003692	0.122248	2449.7	15.3	2367.7	11.2	2271.8	16.7	95
68	243.0	564.6	719.0	0.097041	0.001004	3.550245	0.044319	0.265132	0.002177	0.785276	1568.5	18.7	1538.5	9.9	1516.0	11.1	98
69	17.8	281.3	303.2	0.057719	0.002719	0.354828	0.016367	0.044907	0.000835	0.927758	520.4	103.7	308.3	12.3	283.2	5.2	91
70	63.5	99.7	364.0	0.071776	0.001098	1.570834	0.027979	0.159001	0.002173	0.273845	988.9	31.2	958.8	11.1	951.2	12.1	99
71	197.5	546.2	837.5	0.106049	0.001420	2.746780	0.046758	0.188416	0.002986	0.652153	1732.4	28.7	1341.2	12.7	1112.8	16.2	81
72	16.7	164.7	161.3	0.060935	0.001831	0.657330	0.019453	0.078776	0.001079	1.021098	636.7	64.8	513.0	11.9	488.8	6.5	95
73	13.2	129.0	134.5	0.055230	0.001788	0.574782	0.018774	0.075774	0.000896	0.958833	420.4	76.8	461.1	12.1	470.9	5.4	97
74	161.3	230.1	953.8	0.078670	0.001617	1.670028	0.037262	0.153759	0.001800	0.241219	1164.8	40.7	997.2	14.2	922.0	10.1	92
75	23.7	183.5	258.1	0.056410	0.001588	0.602257	0.019329	0.077268	0.001247	0.711089	477.8	63.0	478.7	12.2	479.8	7.5	99
76	11.5	38.3	60.6	0.070775	0.002063	1.539353	0.046860	0.157719	0.001925	0.631788	950.0	54.6	946.2	18.7	944.1	10.7	99
77	149.3	332.6	359.9	0.117721	0.002433	5.105037	0.100908	0.314414	0.003587	0.924139	1921.9	37.0	1836.9	16.8	1762.4	17.6	95
78	73.9	304.3	442.2	0.075279	0.001275	1.461022	0.025202	0.140870	0.001460	0.688077	1075.9	33.3	914.4	10.4	849.6	8.3	92
79	183.5	171.4	231.2	0.208804	0.002306	16.743357	0.254613	0.579747	0.005755	0.741417	2896.0	17.1	2920.3	14.6	2947.7	23.5	99
80	83.4	53.6	385.4	0.083402	0.001533	2.319216	0.063155	0.199902	0.002946	0.139154	1279.6	35.6	1218.2	19.3	1174.8	15.8	96

附表2 平山湖盆地样品CQL2017-L1-42碎屑锆石U-Pb同位素测年数据表

Table2 Zircon U-Pb age data from sample CQL2017-L1-42 in Pingshanhu basin

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
1	95.5	123.7	162.2	0.162618	0.001802	10.128867	0.134680	0.451027	0.003799	0.762576	2483.0	18.5	2446.6	12.3	2399.8	16.9	98
2	24.5	100.6	141.3	0.070087	0.001407	1.416701	0.036466	0.146302	0.002369	0.712240	931.5	36.1	896.0	15.3	880.2	13.3	98
3	46.9	132.9	284.4	0.076674	0.001261	1.487866	0.029888	0.140142	0.001281	0.467286	1122.2	33.3	925.4	12.2	845.5	7.2	90
4	11.6	48.4	63.6	0.070150	0.001992	1.421555	0.038331	0.147641	0.001632	0.761471	933.0	59.3	898.0	16.1	887.7	9.2	98
5	165.5	237.7	276.5	0.163619	0.001485	10.144106	0.115703	0.449139	0.003962	0.859674	2494.4	14.4	2448.0	10.5	2391.4	17.6	97
6	53.3	370.0	312.1	0.064924	0.000879	1.142459	0.017833	0.127410	0.001128	1.185775	772.2	228.7	773.7	8.5	773.1	6.5	99
7	25.6	86.8	141.0	0.072375	0.001621	1.532678	0.035939	0.153432	0.001365	0.615680	998.2	46.3	943.6	14.4	920.2	7.6	97
8	104.9	159.4	203.0	0.146315	0.001585	8.483713	0.155763	0.419188	0.006260	0.785239	2303.4	18.8	2284.2	16.7	2256.8	28.4	98
9	176.8	192.1	439.6	0.117824	0.001179	5.563762	0.086932	0.341887	0.004340	0.437050	1924.1	18.7	1910.5	13.4	1895.7	20.8	99
10	110.1	253.7	539.8	0.076175	0.000849	1.879432	0.027278	0.178802	0.002041	0.469917	1099.7	22.2	1073.9	9.6	1060.4	11.2	98
11	119.0	191.2	193.9	0.159512	0.001665	10.142091	0.141376	0.460388	0.004707	0.986033	2450.3	17.6	2447.8	12.9	2441.3	20.8	99
12	99.9	106.4	593.2	0.072394	0.000820	1.636561	0.027342	0.163869	0.002254	0.179340	998.2	23.3	984.4	10.5	978.2	12.5	99
13	84.4	41.9	143.8	0.179794	0.001736	12.798329	0.206976	0.515491	0.007111	0.291327	2650.9	49.2	2664.9	15.2	2680.0	30.2	99
14	56.4	166.4	296.7	0.072852	0.001096	1.652932	0.025915	0.164465	0.001330	0.560794	1009.3	25.5	990.7	9.9	981.5	7.4	99
15	23.3	133.1	120.8	0.067790	0.001364	1.385809	0.033008	0.147865	0.001762	1.101629	861.1	41.5	882.9	14.0	889.0	9.9	99
16	251.9	108.3	522.9	0.161485	0.001609	9.407077	0.144408	0.421671	0.004978	0.207205	2472.2	16.7	2378.5	14.1	2268.1	22.6	95
17	131.4	42.6	491.7	0.126829	0.001994	4.324339	0.107235	0.244349	0.003515	0.086737	2054.6	27.8	1698.0	20.5	1409.3	18.2	81
18	16.0	144.7	196.7	0.056918	0.001846	0.531776	0.017225	0.068050	0.001110	0.735487	487.1	75.0	433.0	11.4	424.4	6.7	97
19	47.8	85.8	299.9	0.069931	0.001212	1.408270	0.030563	0.145827	0.002126	0.285989	927.8	30.6	892.4	12.9	877.5	12.0	98
20	86.3	64.0	190.8	0.141561	0.001720	7.943179	0.150000	0.405817	0.005789	0.335533	2246.6	54.2	2224.6	17.0	2195.8	26.5	98

续附表2

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
21	131.0	227.6	211.2	0.158943	0.001892	10.073705	0.129028	0.459038	0.003989	1.077885	2455.6	20.1	2441.6	11.8	2435.3	17.6	99
22	35.5	142.4	157.6	0.075220	0.001327	1.869827	0.035516	0.180161	0.001904	0.903845	1075.9	35.2	1070.5	12.6	1067.9	10.4	99
23	105.1	20.2	676.7	0.070212	0.000794	1.497085	0.020369	0.154408	0.001569	0.029789	1000.0	22.2	929.2	8.3	925.6	8.8	99
24	217.4	70.7	424.2	0.166830	0.001796	10.337611	0.183239	0.448833	0.007188	0.166648	2527.8	17.4	2465.5	16.4	2390.1	32.0	96
25	391.1	1334.5	995.7	0.182324	0.001727	8.206989	0.257908	0.324762	0.009615	1.340241	2675.9	20.8	2254.1	28.5	1812.9	46.8	78
26	287.2	188.3	984.4	0.117224	0.001757	4.234549	0.048852	0.264380	0.004054	0.191296	1914.5	27.6	1680.7	9.5	1512.2	20.7	89
27	235.9	214.5	599.4	0.116062	0.003137	5.566193	0.119965	0.359968	0.011110	0.357873	1898.2	48.5	1910.9	18.6	1982.0	52.7	96
28	178.9	270.7	298.2	0.164518	0.002146	10.250124	0.195311	0.450902	0.007838	0.907716	2502.8	21.9	2457.6	17.6	2399.3	34.8	97
29	90.3	105.4	509.0	0.073110	0.001716	1.649443	0.031983	0.164346	0.001816	0.207129	1016.7	48.2	989.3	12.3	980.9	10.1	99
30	234.8	322.7	427.3	0.152673	0.001987	8.816160	0.117109	0.417387	0.003637	0.755281	2376.2	21.9	2319.2	12.1	2248.6	16.5	96
31	1049	1035.6	111.7	0.091874	0.001616	3.315341	0.062263	0.261466	0.003244	9.269879	1464.8	33.3	1484.7	14.7	1497.3	16.6	99
32	936.7	906.2	107.3	0.108909	0.002103	3.914180	0.074067	0.260256	0.003349	8.447113	1781.2	35.2	1616.6	15.3	1491.2	17.1	91
33	16540	10039	399.8	0.159833	0.001701	10.076067	0.131384	0.455401	0.004568	25.109787	2454.0	18.2	2441.8	12.0	2419.2	20.2	99
34	13072	7775.6	372.7	0.161157	0.001537	10.139176	0.131616	0.454333	0.004687	20.863275	2467.6	16.1	2447.5	12.0	2414.5	20.8	98
35	8739	5327.8	280.4	0.163991	0.001511	10.219771	0.144896	0.450262	0.005762	19.000813	2498.2	14.7	2454.9	13.1	2396.4	25.6	97
36	2392	1591.8	100.0	0.188201	0.002356	11.548558	0.187040	0.443224	0.005263	15.911293	2727.8	20.7	2568.5	15.1	2365.1	23.5	91
37	4267	2827.6	123.6	0.124909	0.001196	6.536518	0.076601	0.378204	0.003563	22.877991	2027.5	17.0	2050.8	10.3	2067.9	16.7	99
38	1934	2934.8	181.0	0.069789	0.000914	1.493607	0.022647	0.154801	0.001641	16.212522	921.9	27.8	927.8	9.2	927.8	9.2	99
39	4747	7728.0	140.6	0.070568	0.001171	1.512117	0.027232	0.154881	0.001457	54.953818	946.3	39.0	935.3	11.0	928.3	8.1	99
40	48304	6378.8	128.8	0.893555	0.006657	28.796181	0.324505	0.232587	0.001713	49.539193	error	error	3446.6	11.1	1348.0	9.0	12

续附表2

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
41	1475	2047.2	341.6	0.072066	0.000709	1.625740	0.016664	0.163227	0.001334	5.993118	987.0	20.4	980.2	6.4	974.7	7.4	99
42	6843	4072.0	257.5	0.160370	0.001335	10.092051	0.150060	0.454458	0.005415	15.810828	2461.1	9.1	2443.2	13.7	2415.0	24.0	98
43	2669	4136.3	408.1	0.071931	0.000691	1.614424	0.018523	0.162311	0.001330	10.134345	983.3	19.3	975.8	7.2	969.6	7.4	99
44	1143	1789.5	245.6	0.072523	0.001142	1.648592	0.036798	0.164298	0.002592	7.286859	1011.1	31.5	989.0	14.1	980.6	14.4	99
45	699.9	922.4	728.7	0.066590	0.000757	1.261394	0.017340	0.136942	0.001296	1.265868	833.3	-175.0	828.5	7.8	827.3	7.3	99
46	5550	3407.0	224.0	0.161026	0.001490	10.042039	0.115275	0.451102	0.004085	15.208439	2466.4	16.2	2438.7	10.6	2400.2	18.1	98
47	2507	1184.9	190.6	0.222360	0.002064	17.574578	0.199201	0.571975	0.005223	6.216464	2997.8	14.8	2966.7	10.9	2915.9	21.4	98
48	1440	1530.5	227.7	0.096299	0.001337	3.473368	0.057183	0.261194	0.003118	6.722337	1553.7	30.6	1521.2	13.0	1495.9	15.9	98
49	282.3	1126.1	287.9	0.056292	0.001400	0.529167	0.015240	0.068054	0.001011	3.911139	464.9	53.7	431.3	10.1	424.4	6.1	98
50	151.2	656.7	245.9	0.056024	0.001598	0.532159	0.014562	0.069011	0.000823	2.670745	453.8	64.8	433.2	9.7	430.2	5.0	99
51	23.9	67.4	93.1	0.084103	0.001721	2.480737	0.057444	0.214945	0.003728	0.723882	1294.8	72.7	1266.4	16.8	1255.1	19.8	99
52	74.5	88.4	129.8	0.164927	0.002097	10.343553	0.167867	0.454854	0.006107	0.681033	2507.1	20.5	2466.0	15.0	2416.8	27.1	97
53	341.9	296.0	553.0	0.179430	0.001843	12.381527	0.162460	0.499648	0.005523	0.535309	2647.8	16.5	2633.8	12.3	2612.3	23.7	99
54	134.2	160.0	252.8	0.151981	0.002357	8.829850	0.204413	0.419068	0.005649	0.632775	2368.2	26.1	2320.6	21.1	2256.2	25.7	97
55	104.3	80.4	290.5	0.113247	0.001363	5.019468	0.069170	0.321122	0.003576	0.276741	1853.7	21.1	1822.6	11.7	1795.2	17.4	98
56	33.7	20.1	44.8	0.239499	0.003148	19.697116	0.337965	0.595830	0.008461	0.449851	3116.4	21.8	3076.6	16.6	3013.0	34.2	97
57	97.3	289.4	486.8	0.077442	0.001090	1.888038	0.030493	0.176390	0.001977	0.594514	1132.4	27.8	1076.9	10.7	1047.2	10.8	97
58	27.5	46.3	45.1	0.160943	0.002990	10.093865	0.235488	0.453862	0.007649	1.026732	2465.7	31.5	2443.4	21.6	2412.4	33.9	98
59	89.0	220.8	203.0	0.112923	0.001841	5.016201	0.090895	0.322336	0.004478	1.087521	1847.2	29.6	1822.1	15.3	1801.1	21.8	98
60	25.3	192.6	261.1	0.060837	0.002264	0.679930	0.024615	0.081041	0.001592	0.737728	635.2	86.1	526.7	14.9	502.3	9.5	95

续附表2

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
61	335.3	276.3	648.2	0.166561	0.002153	10.415349	0.196325	0.450489	0.005194	0.426220	2523.1	22.4	2472.4	17.5	2397.4	23.1	96
62	58.7	136.5	310.6	0.079088	0.001610	1.951908	0.045512	0.178419	0.002473	0.439330	1175.9	34.7	1099.1	15.7	1058.3	13.5	96
63	53.9	526.5	758.9	0.057145	0.001663	0.515345	0.013995	0.065492	0.000691	0.693761	498.2	64.8	422.0	9.4	408.9	4.2	96
64	18.0	100.7	116.0	0.069561	0.002342	1.319225	0.044670	0.137379	0.001720	0.868057	916.7	63.9	854.2	19.6	829.8	9.8	97
65	48.5	69.1	336.2	0.071228	0.001011	1.513743	0.026729	0.153996	0.002217	0.205598	964.8	-2.8	936.0	10.8	923.3	12.4	98
66	44.4	92.6	291.0	0.071044	0.001061	1.596200	0.029886	0.162612	0.002210	0.318122	959.0	30.4	968.7	11.7	971.3	12.3	99
67	238.9	300.4	711.7	0.155397	0.001670	7.128777	0.099589	0.331467	0.002888	0.422095	2406.5	18.2	2127.6	12.4	1845.5	14.0	85
68	34.8	265.7	237.1	0.064673	0.001112	1.163437	0.020050	0.130748	0.001304	1.120848	764.8	36.0	783.6	9.4	792.1	7.4	98
69	327.9	436.5	692.4	0.163429	0.001493	10.250641	0.122087	0.453975	0.004081	0.630475	2491.7	15.1	2457.7	11.0	2412.9	18.1	98
70	62.4	260.8	399.7	0.072220	0.000948	1.619805	0.025882	0.162622	0.001847	0.652514	992.3	27.8	977.9	10.0	971.3	10.2	99
71	59.0	223.1	358.7	0.071331	0.000894	1.609793	0.023150	0.163787	0.001694	0.622030	968.5	24.8	974.0	9.0	977.8	9.4	99
72	208.9	276.6	422.4	0.163259	0.001493	10.192864	0.132263	0.451945	0.004288	0.654908	2500.0	14.7	2452.4	12.0	2403.9	19.0	98
73	23.4	98.7	242.0	0.061277	0.001281	0.827357	0.018792	0.098095	0.001216	0.407857	650.0	41.7	612.1	10.4	603.2	7.1	98
74	16.0	110.0	114.0	0.065745	0.001631	1.162314	0.033769	0.128268	0.002000	0.965093	798.2	51.8	783.0	15.9	778.0	11.4	99
75	49.6	142.2	293.9	0.070816	0.000904	1.593361	0.023760	0.163463	0.001978	0.483774	953.7	31.6	967.6	9.3	976.0	11.0	99
76	81.4	160.0	290.1	0.090720	0.001001	3.259057	0.039323	0.260367	0.001889	0.551451	1440.4	20.5	1471.3	9.4	1491.7	9.7	98
77	89.4	137.2	588.4	0.074080	0.000950	1.595721	0.022294	0.156007	0.000953	0.233243	1043.5	58.3	968.5	8.7	934.5	5.3	96
78	176.9	229.9	334.7	0.163209	0.001536	10.252242	0.134401	0.455038	0.004596	0.687066	2500.0	16.1	2457.8	12.1	2417.6	20.4	98
79	123.5	125.3	740.2	0.074159	0.001283	1.668066	0.027693	0.163094	0.001323	0.169283	1055.6	34.4	996.4	10.5	974.0	7.3	97
80	147.7	305.6	676.5	0.085666	0.001241	2.517441	0.059754	0.213090	0.004089	0.451755	1331.5	28.1	1277.1	17.3	1245.3	21.7	97

附表3 平山湖盆地样品CQL2017-L1-88碎屑锆石U-Pb同位素测年数据表

Table3 Zircon U-Pb age data from sample CQL2017-L1-88 in Pingshanhu basin

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
1	28.3	239.6	329.4	0.057826	0.002071	0.595634	0.020569	0.074479	0.000714	0.727286	524.1	77.8	474.5	13.1	463.1	4.3	97
2	349.6	661.7	959.8	0.125575	0.001545	5.432112	0.093897	0.312142	0.004076	0.689451	2036.7	20.8	1889.9	14.8	1751.2	20.0	92
3	4.9	73.3	70.7	0.056316	0.003053	0.444642	0.023493	0.057558	0.000956	1.037284	464.9	125.0	373.5	16.5	360.8	5.8	96
4	38.7	518.7	563.1	0.085532	0.002280	0.685172	0.024433	0.058132	0.001526	0.921140	1327.8	56.5	529.9	14.7	364.3	9.3	62
5	53.7	1044.2	921.6	0.113971	0.005425	0.648285	0.030117	0.041422	0.000565	1.133044	1864.8	85.6	507.4	18.6	261.6	3.5	36
6	24.6	122.0	336.5	0.056509	0.001483	0.559157	0.018649	0.071634	0.001493	0.362658	472.3	57.4	451.0	12.1	446.0	9.0	98
7	22.6	355.4	409.5	0.076760	0.005879	0.468281	0.036163	0.044186	0.000391	0.867968	1116.7	153.7	390.0	25.0	278.7	2.4	66
8	19.3	133.2	239.4	0.055795	0.001669	0.559183	0.018805	0.072463	0.001023	0.556549	442.6	66.7	451.0	12.2	451.0	6.1	99
9	115.4	184.7	433.4	0.129127	0.001670	4.134632	0.074327	0.231677	0.003102	0.426049	2087.0	22.2	1661.2	14.7	1343.3	16.2	78
10	21.8	174.8	308.0	0.063092	0.001775	0.560586	0.017594	0.064271	0.000954	0.567605	722.2	60.0	451.9	11.4	401.5	5.8	88
11	96.7	187.1	314.0	0.126884	0.001722	4.641391	0.108428	0.264183	0.004634	0.595898	2055.2	24.2	1756.7	19.5	1511.2	23.6	84
12	129.6	87.7	400.1	0.115689	0.001563	5.086260	0.096401	0.317684	0.003808	0.219222	1890.4	24.1	1833.8	16.1	1778.4	18.6	96
13	30.5	470.0	612.2	0.055334	0.001810	0.333178	0.011896	0.043568	0.000677	0.767643	433.4	74.1	292.0	9.1	274.9	4.2	93
14	55.3	421.5	338.2	0.063603	0.001053	1.124413	0.019085	0.128069	0.001160	1.246528	727.8	35.2	765.1	9.1	776.8	6.6	98
15	32.1	526.4	636.9	0.055091	0.002048	0.325020	0.011562	0.042726	0.000414	0.826513	416.7	83.3	285.8	8.9	269.7	2.6	94
16	17.3	168.3	388.2	0.123082	0.003397	0.606302	0.022386	0.036119	0.001160	0.433546	2066.7	49.1	481.2	14.2	228.7	7.2	28
17	23.6	293.7	259.6	0.065617	0.002248	0.651108	0.024295	0.071365	0.000719	1.131358	794.4	72.2	509.2	14.9	444.4	4.3	86
18	16.8	319.7	316.7	0.076232	0.004674	0.441375	0.028752	0.041685	0.000698	1.009491	1101.9	123.6	371.2	20.3	263.3	4.3	65
19	146.6	334.8	635.5	0.087380	0.001406	2.569883	0.057844	0.211663	0.002886	0.526822	1368.8	30.4	1292.1	16.5	1237.7	15.4	95
20	121.9	79.8	266.5	0.160891	0.003737	9.206119	0.284477	0.413056	0.008289	0.299585	2465.1	40.3	2358.7	28.3	2228.9	37.8	94

续附表3

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
21	25.1	130.1	286.3	0.219407	0.027314	4.698940	0.986498	0.138204	0.030004	0.454423	2976.2	201.9	1767.1	177.6	834.5	170.0	28
22	17.2	155.1	200.4	0.054615	0.001760	0.556293	0.020979	0.073296	0.000885	0.773740	398.2	76.8	449.1	13.7	456.0	5.3	98
23	70.9	440.7	537.3	0.081124	0.001351	1.343375	0.052823	0.120525	0.004758	0.820280	1233.3	32.9	864.7	22.9	733.6	27.4	83
24	148.9	149.0	430.3	0.112408	0.001488	4.779824	0.074436	0.307496	0.003611	0.346185	1838.6	24.1	1781.4	13.1	1728.4	17.8	96
25	15.0	177.2	303.7	0.054565	0.002295	0.323296	0.013351	0.043019	0.000552	0.583326	394.5	94.4	284.4	10.2	271.5	3.4	95
26	47.0	227.9	592.9	0.121774	0.006701	1.062704	0.074231	0.061382	0.001701	0.384459	1983.3	98.1	735.2	36.6	384.0	10.3	37
27	39.8	239.0	530.7	0.059900	0.001474	0.544233	0.011104	0.066123	0.000832	0.450272	599.7	53.7	441.2	7.3	412.8	5.0	93
28	23.9	79.9	130.2	0.072864	0.001948	1.534453	0.039102	0.152830	0.001500	0.613857	1009.3	54.8	944.3	15.7	916.8	8.4	97
29	37.5	288.7	158.9	0.171218	0.006785	3.353580	0.153372	0.138868	0.002382	1.817115	2569.4	66.4	1493.6	35.8	838.3	13.5	43
30	10.3	83.0	116.9	0.054863	0.001944	0.546095	0.020045	0.072122	0.001090	0.710026	405.6	79.6	442.4	13.2	448.9	6.6	98
31	7.1	101.3	134.1	0.052590	0.002915	0.321072	0.018054	0.044391	0.000811	0.755232	309.3	121.3	282.7	13.9	280.0	5.0	99
32	8.9	113.3	172.3	0.053841	0.003110	0.322756	0.015792	0.043852	0.000861	0.657793	364.9	136.1	284.0	12.1	276.7	5.3	97
33	29.3	450.1	604.7	0.070334	0.002241	0.403754	0.009583	0.042961	0.001235	0.744434	938.9	69.4	344.4	6.9	271.2	7.6	76
34	8.4	135.3	157.3	0.054666	0.002628	0.331100	0.014584	0.044262	0.000667	0.860055	398.2	107.4	290.4	11.1	279.2	4.1	96
35	45.0	685.7	673.0	0.073198	0.001851	0.583885	0.016087	0.058099	0.000961	1.018881	1020.4	50.8	467.0	10.3	364.1	5.9	75
36	74.6	254.9	397.0	0.143388	0.007030	2.734453	0.134916	0.139737	0.002243	0.642076	2268.8	84.9	1337.9	36.7	843.2	12.7	54
37	103.6	42.8	216.7	0.161285	0.002202	9.930858	0.161404	0.444972	0.004982	0.197476	2469.4	23.1	2428.4	15.0	2372.9	22.2	97
38	21.0	180.6	249.8	0.201729	0.016307	8.439180	3.293184	0.253993	0.064354	0.723038	2840.4	132.1	2279.4	369.8	1459.0	331.1	56
39	146.9	109.2	434.2	0.144589	0.002251	6.426849	0.140210	0.322191	0.006645	0.251442	2283.0	26.1	2035.9	19.2	1800.4	32.4	87
40	334.0	395.3	702.0	0.160022	0.002360	9.690339	0.183280	0.437726	0.006631	0.563133	2457.4	25.0	2405.8	17.4	2340.5	29.7	97

续附表3

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
41	53.1	385.1	641.6	0.063897	0.001787	0.685074	0.021530	0.077360	0.001085	0.600213	738.9	59.3	529.8	13.0	480.3	6.5	90
42	135.8	64.7	395.5	0.114294	0.001652	5.448665	0.099234	0.344938	0.005087	0.163678	1868.8	26.2	1892.5	15.6	1910.4	24.4	99
43	19.4	202.8	335.3	0.054454	0.001387	0.401771	0.010133	0.053641	0.000671	0.604690	390.8	62.0	342.9	7.3	336.8	4.1	98
44	141.3	160.4	226.2	0.183673	0.002295	13.085552	0.209762	0.514990	0.006196	0.708798	2686.1	20.7	2685.8	15.1	2677.9	26.4	99
45	61.5	258.8	952.0	0.191289	0.013381	2.080111	0.174825	0.074026	0.003840	0.271787	2753.4	114.3	1142.3	57.7	460.4	23.1	14
46	25.4	86.8	101.8	0.089953	0.002559	2.571229	0.073486	0.207275	0.002487	0.853044	1424.4	55.1	1292.5	20.9	1214.3	13.3	93
47	33.6	294.1	380.0	0.078078	0.002051	0.785932	0.024164	0.072642	0.000871	0.774104	1150.0	85.3	588.9	13.7	452.1	5.2	73
48	33.2	268.6	405.3	0.057015	0.001475	0.563754	0.015709	0.071525	0.000749	0.662785	500.0	55.6	454.0	10.2	445.3	4.5	98
49	183.8	1871.5	1793.5	0.195091	0.004038	1.819679	0.037675	0.067681	0.000856	1.043491	2787.0	34.4	1052.6	13.6	422.2	5.2	14
50	15.8	392.8	254.2	0.054206	0.001527	0.327665	0.009372	0.043914	0.000568	1.545479	388.9	60.2	287.8	7.2	277.0	3.5	96
51	31.7	261.3	462.3	0.055711	0.001393	0.484278	0.012078	0.063101	0.000935	0.565086	442.6	55.6	401.0	8.3	394.5	5.7	98
52	81.3	48.6	314.4	0.100471	0.002340	3.581444	0.124842	0.253654	0.003407	0.154586	1633.0	42.6	1545.4	27.7	1457.3	17.5	94
53	70.8	55.2	476.5	0.071990	0.001070	1.551193	0.034546	0.155463	0.002233	0.115866	987.0	30.7	951.0	13.8	931.5	12.5	97
54	13.6	207.9	290.6	0.055182	0.003377	0.324660	0.020936	0.042589	0.000809	0.715284	420.4	137.0	285.5	16.0	268.9	5.0	94
55	188.0	186.0	365.5	0.156593	0.001544	10.141868	0.127699	0.469175	0.004456	0.509040	2420.4	17.0	2447.8	11.6	2479.9	19.6	98
56	144.9	229.5	594.5	0.109436	0.001902	3.510068	0.103136	0.229022	0.004159	0.386123	1790.7	31.5	1529.5	23.2	1329.4	21.8	86
57	168.8	529.8	680.5	0.184575	0.002034	5.579339	0.160383	0.218139	0.005239	0.778629	2694.1	18.2	1912.9	24.8	1272.0	27.7	59
58	95.4	318.1	590.9	0.078638	0.001083	1.738658	0.024982	0.160321	0.001268	0.538363	1164.8	23.1	1023.0	9.3	958.6	7.0	93
59	67.5	222.9	446.9	0.071134	0.000993	1.516849	0.022439	0.154925	0.001740	0.498817	961.1	29.6	937.2	9.1	928.5	9.7	99
60	17.2	408.0	349.7	0.051858	0.001528	0.321219	0.010529	0.044758	0.000531	1.166717	279.7	68.5	282.8	8.1	282.3	3.3	99

续附表3

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
61	12.2	157.2	261.5	0.076182	0.004071	0.466400	0.026328	0.044311	0.000640	0.601178	1099.7	106.3	388.7	18.2	279.5	4.0	67
62	66.5	154.5	124.7	0.158957	0.002094	9.574687	0.145736	0.436970	0.004726	1.239004	2455.6	27.9	2394.7	14.0	2337.1	21.2	97
63	7.6	85.8	181.5	0.054533	0.002696	0.324688	0.015965	0.043313	0.000874	0.472922	394.5	111.1	285.5	12.2	273.3	5.4	95
64	115.2	262.4	447.4	0.133016	0.001506	4.586661	0.102393	0.249209	0.004699	0.586412	2138.9	19.8	1746.8	18.6	1434.4	24.2	80
65	45.7	529.4	646.4	0.065991	0.001471	0.576270	0.012585	0.063481	0.000830	0.819079	805.6	43.5	462.1	8.1	396.8	5.0	84
66	39.1	279.1	526.2	0.055310	0.001276	0.557633	0.015902	0.072675	0.000711	0.530354	433.4	51.8	450.0	10.4	452.3	4.3	99
67	27.2	276.0	398.1	0.435362	0.140896	5.333800	1.500648	0.091101	0.013143	0.693384	4036.1	504.0	1874.3	245.2	562.0	77.7	-8
68	18.5	416.5	361.1	0.053689	0.002940	0.319130	0.017254	0.043095	0.000579	1.153272	366.7	124.1	281.2	13.3	272.0	3.6	96
69	34.8	105.5	228.1	0.072918	0.001601	1.554397	0.045107	0.154248	0.002952	0.462404	1013.0	44.5	952.2	17.9	924.7	16.5	97
70	12.9	175.2	267.2	0.050963	0.001556	0.312081	0.010072	0.044409	0.000706	0.655467	239.0	70.4	275.8	7.8	280.1	4.4	98
71	19.0	155.6	286.1	0.057387	0.001911	0.489909	0.018520	0.061566	0.000935	0.543957	505.6	78.7	404.8	12.6	385.1	5.7	95
72	26.5	206.9	543.9	0.061469	0.002516	0.384552	0.015104	0.045370	0.000570	0.380354	657.4	88.9	330.4	11.1	286.0	3.5	85
73	35.6	1160.7	689.4	0.217462	0.013904	0.880725	0.062724	0.028050	0.000483	1.683594	2962.0	103.1	641.4	33.9	178.3	3.0	-13
74	9.3	504.8	345.1	0.047284	0.002154	0.132712	0.006362	0.020257	0.000282	1.462820	64.9	103.7	126.5	5.7	129.3	1.8	97
75	37.8	91.2	549.1	0.107483	0.009407	1.020155	0.134860	0.075109	0.007453	0.166133	1766.7	160.5	714.0	67.9	466.9	44.7	58
76	41.6	65.8	209.5	0.076474	0.001264	1.958059	0.034571	0.185326	0.001893	0.314311	1109.3	32.3	1101.2	11.9	1096.0	10.3	99
77	19.5	276.2	381.9	0.052387	0.001391	0.318354	0.008638	0.044061	0.000512	0.723120	301.9	61.1	280.6	6.7	278.0	3.2	99
78	51.1	37.5	505.5	0.091039	0.001640	1.235013	0.030272	0.097647	0.001442	0.074137	1447.2	34.1	816.6	13.8	600.6	8.5	69
79	19.5	197.6	246.4	0.060734	0.002069	0.547645	0.017829	0.065461	0.000834	0.802110	631.5	74.1	443.5	11.7	408.8	5.0	91
80	27.0	391.2	518.4	0.054582	0.003427	0.324625	0.019206	0.043059	0.000546	0.754609	394.5	138.0	285.5	14.7	271.8	3.4	95

附表4 平山湖盆地样品CQL2017-L1-154碎屑锆石U-Pb同位素测年数据表

Table4 Zircon U-Pb age data from sample CQL2017-L1-154 in Pingshanhu basin

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
1	8.2	86.6	163.4	0.050804	0.002492	0.303346	0.014760	0.043884	0.000729	0.529994	231.6	110.2	269.0	11.5	276.9	4.5	97
2	177.1	678.1	904.0	0.087016	0.001034	1.913805	0.026519	0.159205	0.001626	0.750114	1361.1	22.2	1085.9	9.2	952.4	9.0	86
3	56.5	103.0	145.3	0.109966	0.001864	4.711083	0.087010	0.310013	0.003283	0.708651	1799.1	30.4	1769.2	15.5	1740.8	16.2	98
4	30.0	203.7	385.0	0.054482	0.001430	0.500880	0.013030	0.066651	0.000882	0.529026	390.8	59.3	412.3	8.8	415.9	5.3	99
5	12.0	143.6	187.1	0.070085	0.002981	0.485215	0.019634	0.050319	0.000675	0.767378	931.5	87.0	401.6	13.4	316.5	4.1	76
6	39.0	421.6	396.9	0.193825	0.010467	1.610039	0.110104	0.055108	0.001384	1.062092	2775.9	88.6	974.1	42.9	345.8	8.5	4
7	114.5	128.7	335.0	0.109978	0.001530	4.414418	0.062527	0.290127	0.002560	0.384127	1799.1	25.3	1715.0	11.7	1642.2	12.8	95
8	14.2	114.3	133.7	0.185658	0.006325	1.575501	0.050726	0.061658	0.000763	0.855070	2705.6	56.2	960.6	20.0	385.7	4.6	14
9	123.7	380.4	230.7	0.127806	0.001895	6.088428	0.099644	0.343886	0.003646	1.648729	2077.8	25.9	1988.6	14.3	1905.3	17.5	95
10	88.7	173.3	211.0	0.109167	0.001773	4.999563	0.098313	0.330688	0.004961	0.821531	1787.0	25.0	1819.2	16.6	1841.7	24.0	98
11	228.3	75.5	689.9	0.110427	0.001459	4.622614	0.061640	0.302056	0.002571	0.109372	1806.5	24.1	1753.4	11.1	1701.5	12.7	96
12	24.8	270.3	418.5	0.076345	0.004116	0.498103	0.026495	0.047228	0.000638	0.645757	1105.6	108.5	410.4	18.0	297.5	3.9	68
13	15.6	157.1	274.9	0.055134	0.001848	0.367844	0.012553	0.048293	0.000636	0.571271	416.7	78.7	318.1	9.3	304.0	3.9	95
14	16.4	298.9	266.7	0.055269	0.001535	0.355242	0.009611	0.046746	0.000677	1.120826	433.4	61.1	308.7	7.2	294.5	4.2	95
15	74.2	615.4	1062.9	0.077698	0.001999	0.626035	0.012371	0.058638	0.000940	0.578970	1138.9	51.9	493.6	7.7	367.3	5.7	70
16	18.3	218.8	315.0	0.052869	0.001461	0.357932	0.010252	0.048926	0.000507	0.694759	324.1	63.0	310.7	7.7	307.9	3.1	99
17	30.9	465.6	522.8	0.052243	0.001423	0.347727	0.011891	0.048187	0.000964	0.890573	294.5	67.6	303.0	9.0	303.4	5.9	99
18	17.7	327.3	349.6	0.049422	0.003362	0.270267	0.016934	0.040121	0.000838	0.936210	168.6	-39.8	242.9	13.5	253.6	5.2	95
19	5.0	127.7	97.7	0.049403	0.002900	0.257831	0.014381	0.038506	0.000695	1.307443	168.6	132.4	232.9	11.6	243.6	4.3	95
20	19.5	196.5	387.5	0.057966	0.001598	0.364659	0.011765	0.045455	0.000692	0.506988	527.8	54.6	315.7	8.8	286.6	4.3	90
21	16.3	223.2	280.6	0.050858	0.001764	0.341288	0.011631	0.048854	0.000688	0.795363	235.3	84.2	298.1	8.8	307.5	4.2	96
22	70.8	329.0	904.9	0.086740	0.002101	0.785582	0.019583	0.065489	0.000475	0.363614	1354.6	52.0	588.7	11.1	408.9	2.9	63
23	22.3	498.9	374.4	0.056350	0.002372	0.334409	0.014669	0.042879	0.000480	1.332554	464.9	99.1	292.9	11.2	270.7	3.0	92
24	90.6	118.5	233.6	0.115303	0.001433	5.264172	0.084661	0.330080	0.003670	0.507340	1884.9	22.5	1863.1	13.7	1838.8	17.8	98
25	13.6	176.2	249.5	0.054087	0.002800	0.337738	0.015614	0.045661	0.000572	0.706048	376.0	116.7	295.5	11.9	287.8	3.5	97

续附表4

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
26	120.2	77.2	439.9	0.105392	0.001140	3.655235	0.051976	0.250529	0.002399	0.175374	1721.3	20.4	1561.7	11.3	1441.2	12.4	91
27	82.9	172.8	196.7	0.111352	0.001557	5.077743	0.076890	0.329707	0.002872	0.878497	1821.9	25.3	1832.4	12.8	1837.0	13.9	99
28	115.0	123.3	299.8	0.122254	0.001487	5.523908	0.079427	0.326516	0.003115	0.411488	1990.7	21.1	1904.3	12.4	1821.5	15.1	95
29	10.1	162.7	170.1	0.056354	0.002564	0.365813	0.016261	0.047096	0.000674	0.956712	464.9	101.8	316.5	12.1	296.7	4.1	93
30	16.4	284.8	290.7	0.055875	0.001989	0.340001	0.012206	0.044262	0.000719	0.979623	455.6	79.6	297.2	9.2	279.2	4.4	93
31	221.3	237.9	683.0	0.114504	0.001372	4.582282	0.081897	0.288918	0.004113	0.348392	1871.9	22.1	1746.1	14.9	1636.1	20.6	93
32	72.0	155.8	727.7	0.083934	0.001242	1.022924	0.018029	0.088173	0.001176	0.214091	1300.0	29.2	715.4	9.0	544.7	7.0	72
33	14.7	252.4	231.3	0.057313	0.002651	0.383592	0.018186	0.048451	0.000602	1.091071	501.9	106.5	329.7	13.3	305.0	3.7	92
34	30.5	226.7	411.2	0.056580	0.001297	0.502346	0.011864	0.064306	0.000663	0.551290	476.0	45.4	413.3	8.0	401.8	4.0	97
35	213.5	311.7	637.1	0.116863	0.001336	4.811613	0.105414	0.297245	0.005523	0.489255	1909.3	20.7	1786.9	18.4	1677.6	27.4	93
36	13.6	100.7	194.3	0.073421	0.003625	0.622664	0.033645	0.061205	0.001163	0.518181	1025.6	100.0	491.5	21.1	382.9	7.1	75
37	28.1	172.4	46.3	0.111262	0.003081	4.670859	0.148217	0.303017	0.004272	3.726655	1820.4	50.3	1762.0	26.5	1706.3	21.1	96
38	43.0	401.0	666.6	0.077678	0.001913	0.605493	0.014767	0.056889	0.001267	0.601586	1138.9	49.2	480.7	9.3	356.7	7.7	70
39	34.3	153.4	209.5	0.071291	0.001679	1.318943	0.030165	0.134161	0.001346	0.732392	964.8	48.1	854.1	13.2	811.6	7.7	94
40	217.9	579.5	507.2	0.119249	0.001505	5.363741	0.077221	0.325210	0.003325	1.142626	1946.3	22.2	1879.1	12.3	1815.1	16.2	96
41	22.7	424.5	372.9	0.073918	0.002549	0.459193	0.015607	0.044996	0.000543	1.138353	1038.9	69.3	383.7	10.9	283.7	3.3	70
42	161.1	161.4	474.4	0.111408	0.001357	4.659574	0.061158	0.302253	0.002396	0.340334	1833.3	16.5	1760.0	11.0	1702.5	11.9	96
43	15.3	258.6	258.3	0.057425	0.002444	0.371273	0.016334	0.046808	0.000681	1.001378	509.3	92.6	320.6	12.1	294.9	4.2	91
44	11.7	111.1	201.0	0.053036	0.001886	0.369664	0.014935	0.050223	0.000792	0.552727	331.5	76.8	319.4	11.1	315.9	4.9	98
45	14.8	68.2	212.0	0.056954	0.001657	0.510027	0.015176	0.064804	0.000788	0.321773	500.0	60.2	418.5	10.2	404.8	4.8	96
46	36.0	303.2	465.8	0.054296	0.001622	0.495186	0.016871	0.065783	0.000991	0.650911	383.4	63.9	408.4	11.5	410.7	6.0	99
47	9.0	174.8	170.1	0.047677	0.002475	0.269902	0.014147	0.040974	0.000578	1.027763	83.4	127.8	242.6	11.3	258.9	3.6	93
48	59.6	281.3	840.9	0.055403	0.000914	0.498548	0.008704	0.065065	0.000682	0.334579	427.8	37.0	410.7	5.9	406.4	4.1	98
49	137.9	138.0	407.0	0.111591	0.001402	4.693175	0.089756	0.303569	0.004974	0.339163	1825.6	22.5	1766.0	16.0	1709.0	24.6	96
50	62.8	289.7	884.7	0.057340	0.001005	0.514664	0.008488	0.064921	0.000557	0.327424	505.6	38.9	421.6	5.7	405.5	3.4	96

续附表4

测试点	含量/10^{-6}			同位素比值							表面年龄/Ma						谐和度%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	Th/U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
51	19.9	248.0	356.3	0.058235	0.001569	0.379885	0.011185	0.047091	0.000666	0.695870	538.9	59.3	327.0	8.2	296.6	4.1	90
52	347.3	159.0	967.4	0.116782	0.001302	5.278482	0.062928	0.326357	0.002575	0.164345	1909.3	20.2	1865.4	10.2	1820.7	12.5	97
53	314.1	622.5	1294.2	0.092196	0.000975	2.705085	0.031602	0.211942	0.001766	0.480994	1472.2	20.1	1329.9	8.7	1239.2	9.4	92
54	79.1	596.0	1135.5	0.061605	0.001347	0.525079	0.012429	0.062019	0.001070	0.524894	661.1	46.3	428.5	8.3	387.9	6.5	90
55	59.1	324.8	849.7	0.056544	0.001291	0.488722	0.013663	0.062338	0.000912	0.382226	472.3	45.4	404.0	9.3	389.8	5.5	96
56	61.3	29.2	189.5	0.110953	0.001550	4.553977	0.073781	0.296691	0.003066	0.154242	1816.7	24.8	1740.9	13.5	1674.9	15.2	96
57	93.0	20.3	257.2	0.110566	0.001625	5.151816	0.082494	0.337635	0.004360	0.078896	1809.3	26.1	1844.7	13.6	1875.3	21.0	98
58	8.0	186.0	137.1	0.068139	0.003603	0.413553	0.024360	0.043594	0.000965	1.356909	872.2	115.0	351.4	17.5	275.1	6.0	75
59	24.8	429.0	395.9	0.084543	0.003776	0.512124	0.023120	0.043778	0.000499	1.083682	1305.6	87.0	419.9	15.5	276.2	3.1	58
60	274.3	102.5	837.8	0.108895	0.001246	4.576104	0.060385	0.303855	0.002584	0.122383	1781.2	20.2	1744.9	11.0	1710.4	12.8	98
61	134.3	327.7	371.3	0.122934	0.001563	5.308966	0.084245	0.312837	0.003961	0.882592	1999.1	22.8	1870.3	13.6	1754.7	19.4	93
62	100.0	88.4	264.4	0.109751	0.001461	5.080570	0.080074	0.335554	0.004253	0.334177	1795.4	24.1	1832.9	13.4	1865.2	20.5	98
63	55.3	390.5	1028.0	0.071644	0.001716	0.462014	0.011827	0.046699	0.000604	0.379879	975.9	52.8	385.7	8.2	294.2	3.7	73
64	5.9	81.3	106.2	0.067685	0.003608	0.423914	0.025099	0.045098	0.000858	0.765760	858.9	110.8	358.8	17.9	284.4	5.3	76
65	42.9	597.0	1140.0	0.052399	0.001199	0.239388	0.006301	0.032949	0.000308	0.523711	301.9	51.8	217.9	5.2	209.0	1.9	95
66	39.9	212.9	500.1	0.058646	0.001639	0.573390	0.015463	0.070934	0.000606	0.425674	553.7	56.5	460.2	10.0	441.8	3.6	95
67	27.6	215.8	343.0	0.057537	0.001643	0.539473	0.014511	0.068154	0.000939	0.629066	522.3	58.3	438.1	9.6	425.0	5.7	96
68	14.8	270.0	302.5	0.050298	0.002005	0.276732	0.012002	0.039705	0.000644	0.892403	209.3	88.0	248.1	9.5	251.0	4.0	98
69	18.8	265.3	383.5	0.050948	0.001760	0.285065	0.010207	0.040509	0.000497	0.691763	239.0	75.0	254.7	8.1	256.0	3.1	99
70	18.2	192.3	375.7	0.053999	0.002051	0.315526	0.011886	0.042418	0.000544	0.511863	372.3	85.2	278.5	9.2	267.8	3.4	96
71	147.3	50.9	463.1	0.111081	0.001247	4.478600	0.050907	0.291937	0.001947	0.109984	1817.0	20.4	1727.0	9.4	1651.2	9.7	95
72	6.7	126.2	127.3	0.050372	0.003378	0.275298	0.017041	0.040310	0.000808	0.991176	213.0	152.8	246.9	13.6	254.8	5.0	96
73	132.1	42.4	404.7	0.113638	0.001285	4.679936	0.061416	0.298062	0.002487	0.104760	1858.3	20.4	1763.7	11.0	1681.7	12.4	95
74	10.6	227.0	154.1	0.054696	0.002713	0.364525	0.017936	0.048649	0.000705	1.473155	398.2	111.1	315.6	13.3	306.2	4.3	96
75	45.9	885.2	705.0	0.055643	0.001275	0.368315	0.009651	0.047857	0.000543	1.255749	438.9	50.0	318.4	7.2	301.4	3.3	94

附表5 平山湖盆地样品CQL2017-L1-183碎屑锆石U-Pb同位素测年数据表

Table5 Zircon U-Pb age data from sample CQL2017-L1-183 in Pingshanhu basin

测试点	含量/10^{-6}			同位素比值						表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	$^{206}Pb/^{238}U$	
1	27.6	227.7	643.4	0.054560	0.001256	0.296523	0.006753	0.039436	0.000370	394.5	56.5	263.7	5.3	249.3	2.3	94
2	60.7	361.3	421.3	0.066039	0.001001	1.064325	0.018336	0.116706	0.001081	809.3	31.5	736.0	9.0	711.6	6.2	96
3	13.8	53.0	77.7	0.072225	0.002298	1.464856	0.048308	0.147814	0.002173	992.3	64.8	916.0	19.9	888.7	12.2	96
4	34.5	250.7	463.7	0.059027	0.001245	0.527915	0.011439	0.064910	0.000632	568.6	46.3	430.4	7.6	405.4	3.8	94
5	6.3	99.1	115.6	0.074537	0.004765	0.432224	0.029365	0.042314	0.000923	1057.4	133.5	364.8	20.8	267.2	5.7	69
6	8.9	109.9	190.0	0.058156	0.002336	0.319612	0.011874	0.040341	0.000596	600.0	82.4	281.6	9.1	254.9	3.7	90
7	22.4	297.8	470.1	0.050056	0.001250	0.282905	0.007026	0.041022	0.000406	198.2	57.4	253.0	5.6	259.2	2.5	97
8	47.3	303.8	624.0	0.056565	0.001835	0.529873	0.018557	0.067866	0.001126	476.0	39.8	431.7	12.3	423.3	6.8	98
9	18.6	211.3	415.8	0.053538	0.001376	0.299959	0.008183	0.040775	0.000598	350.1	54.6	266.4	6.4	257.6	3.7	96
10	37.4	270.9	471.2	0.059718	0.001859	0.562853	0.019042	0.068245	0.000819	594.5	68.5	453.4	12.4	425.6	4.9	93
11	92.7	168.9	209.4	0.125521	0.001651	6.091635	0.094535	0.352039	0.003740	2036.1	23.1	1989.1	13.5	1944.3	17.8	97
12	175.1	338.2	469.6	0.175973	0.002076	7.128698	0.136017	0.295828	0.006211	2616.7	19.8	2127.6	17.0	1670.6	30.9	75
13	17.5	324.6	345.6	0.056853	0.001472	0.318047	0.008055	0.040745	0.000457	487.1	57.4	280.4	6.2	257.4	2.8	91
14	23.6	329.7	548.1	0.050927	0.001583	0.262100	0.008546	0.037249	0.000333	239.0	72.2	236.4	6.9	235.8	2.1	99
15	77.5	109.0	142.7	0.158325	0.001945	9.337647	0.124473	0.428312	0.004162	2438.9	20.7	2371.7	12.2	2298.1	18.8	96
16	22.8	163.8	293.7	0.055317	0.001045	0.521641	0.010193	0.068566	0.000716	433.4	40.7	426.2	6.8	427.5	4.3	99
17	18.9	96.6	252.8	0.053423	0.001379	0.503125	0.013447	0.068426	0.000709	346.4	59.3	413.8	9.1	426.7	4.3	96
18	20.7	150.4	271.2	0.053641	0.001294	0.504569	0.014513	0.068034	0.000981	366.7	53.7	414.8	9.8	424.3	5.9	97
19	185.8	20.1	619.9	0.108006	0.001441	4.270604	0.062242	0.286576	0.001923	1766.4	24.1	1687.7	12.0	1624.4	9.6	96
20	211.5	57.3	487.8	0.161218	0.001716	8.608577	0.101335	0.387198	0.002755	2468.2	17.9	2297.5	10.7	2109.8	12.8	91
21	56.1	148.6	953.6	0.054353	0.000968	0.439957	0.008418	0.058658	0.000458	387.1	43.5	370.2	5.9	367.5	2.8	99
22	32.3	240.6	428.6	0.054489	0.001152	0.506236	0.010777	0.067394	0.000500	390.8	48.1	415.9	7.3	420.4	3.0	98
23	114.3	285.9	338.3	0.095710	0.001061	3.656099	0.046365	0.277025	0.002434	1542.6	20.7	1561.8	10.1	1576.4	12.3	99
24	127.7	132.5	409.5	0.117418	0.001382	4.518493	0.066481	0.279700	0.003672	1917.6	21.5	1734.4	12.2	1589.9	18.5	91
25	26.9	174.1	358.7	0.055423	0.001387	0.526449	0.013443	0.069071	0.000837	427.8	55.6	429.5	8.9	430.6	5.0	99

续附表5

测试点	含量/10^{-6}			同位素比值						表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	$^{206}Pb/^{238}U$	
26	28.6	228.4	370.3	0.051808	0.001080	0.492310	0.010907	0.069112	0.000886	276.0	48.1	406.5	7.4	430.8	5.3	94
27	20.1	300.0	290.5	0.054870	0.001475	0.423160	0.011243	0.056043	0.000603	405.6	59.3	358.3	8.0	351.5	3.7	98
28	14.3	76.8	199.3	0.052021	0.001449	0.487030	0.013592	0.068105	0.000895	287.1	64.8	402.9	9.3	424.7	5.4	94
29	60.5	276.2	814.6	0.055553	0.001196	0.541973	0.012326	0.070641	0.000656	435.2	48.1	439.7	8.1	440.0	4.0	99
30	12.7	232.9	217.3	0.055047	0.001909	0.358876	0.013020	0.047214	0.000684	413.0	77.8	311.4	9.7	297.4	4.2	95
31	68.6	94.9	165.9	0.115768	0.001928	5.663074	0.108107	0.354125	0.003775	1891.7	29.9	1925.8	16.5	1954.3	18.0	98
32	12.6	122.5	167.7	0.057224	0.001837	0.512908	0.016629	0.065173	0.000947	501.9	70.4	420.4	11.2	407.0	5.7	96
33	53.0	65.8	105.4	0.151776	0.001921	8.932741	0.192861	0.425682	0.007363	2365.7	21.6	2331.2	19.7	2286.2	33.3	98
34	41.2	66.7	108.0	0.112337	0.001788	5.001098	0.082088	0.323053	0.003192	1838.9	28.6	1819.5	13.9	1804.6	15.6	99
35	42.3	329.8	526.1	0.058472	0.001379	0.560461	0.014688	0.069232	0.000587	546.3	51.8	451.8	9.6	431.5	3.5	95
36	21.3	335.2	454.3	0.051830	0.001254	0.284129	0.006896	0.039894	0.000436	279.7	55.6	253.9	5.5	252.2	2.7	99
37	17.3	301.0	341.6	0.052240	0.001436	0.293578	0.008101	0.040858	0.000443	294.5	67.6	261.4	6.4	258.2	2.7	98
38	11.0	155.5	228.7	0.051275	0.001662	0.291134	0.009038	0.041408	0.000490	253.8	75.9	259.5	7.1	261.6	3.0	99
39	15.6	164.5	333.4	0.055118	0.001708	0.315156	0.010557	0.041393	0.000435	416.7	68.5	278.2	8.2	261.5	2.7	93
40	38.4	607.1	775.7	0.051160	0.001279	0.286759	0.007549	0.040590	0.000415	255.6	57.4	256.0	6.0	256.5	2.6	99
41	77.0	152.4	207.3	0.108742	0.001790	4.457664	0.080552	0.297107	0.003354	1788.9	30.7	1723.1	15.0	1676.9	16.7	97
42	25.2	161.1	326.0	0.054909	0.001312	0.518083	0.012218	0.068523	0.000686	409.3	53.7	423.9	8.2	427.3	4.1	99
43	11.2	84.9	141.2	0.051774	0.001937	0.494478	0.019557	0.069068	0.000807	276.0	89.8	408.0	13.3	430.5	4.9	94
44	13.1	160.1	225.8	0.057457	0.002052	0.383076	0.013927	0.048347	0.000520	509.3	79.6	329.3	10.2	304.4	6.0	92
45	29.4	180.5	384.2	0.056786	0.001476	0.535887	0.014867	0.068340	0.000873	483.4	52.8	435.7	9.8	426.1	5.3	97
46	6.4	71.0	140.7	0.049985	0.002489	0.277832	0.014496	0.040071	0.000429	194.5	114.8	248.9	11.5	253.3	2.7	98
47	13.5	128.3	182.5	0.056384	0.002011	0.486167	0.018873	0.062327	0.000767	477.8	79.6	402.3	12.9	389.8	4.7	96
48	26.6	153.8	343.6	0.057888	0.001415	0.551124	0.013092	0.069177	0.000706	524.1	58.3	445.7	8.6	431.2	4.3	96
49	31.4	267.1	387.5	0.055950	0.001237	0.529923	0.013197	0.068370	0.000606	450.0	15.7	431.8	8.8	426.3	3.7	98
50	15.5	133.6	193.6	0.055995	0.001797	0.522794	0.017599	0.067640	0.000873	453.8	65.7	427.0	11.7	421.9	5.3	98

续附表5

测试点	含量/10^{-6}			同位素比值						表面年龄/Ma						谐和度/%
	Pb	Th	U	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	$^{206}Pb/^{238}U$	
51	21.6	259.6	465.3	0.053806	0.001976	0.302949	0.009340	0.041136	0.000509	361.2	81.5	268.7	7.3	259.9	3.2	96
52	13.7	280.4	261.2	0.048005	0.001727	0.274319	0.010165	0.041366	0.000460	98.2	88.0	246.1	8.1	261.3	2.9	94
53	100.8	184.2	267.1	0.111251	0.001709	4.919764	0.084713	0.319989	0.003281	1820.4	28.1	1805.7	14.5	1789.7	16.0	99
54	92.8	159.0	259.1	0.116554	0.001631	5.113061	0.109943	0.316074	0.004452	1905.6	24.5	1838.3	18.3	1770.5	21.8	96
55	42.4	220.6	343.8	0.063759	0.001335	0.938071	0.020009	0.106914	0.001381	744.5	44.4	671.9	10.5	654.8	8.0	97
56	104.6	185.2	643.7	0.070690	0.000901	1.522354	0.021805	0.155807	0.001379	950.0	27.0	939.4	8.8	933.4	7.7	99
57	75.8	136.1	429.3	0.073255	0.001017	1.709242	0.025601	0.168817	0.001408	1020.4	27.8	1012.0	9.6	1005.6	7.8	99
58	25.4	138.5	147.8	0.068875	0.001812	1.343064	0.036038	0.141267	0.001360	894.4	55.6	864.6	15.6	851.8	7.7	98
59	105.8	145.6	180.2	0.165669	0.002009	10.78122	0.136220	0.471276	0.004201	2514.5	20.7	2504.4	11.7	2489.2	18.4	99
60	17.9	125.3	237.3	0.058087	0.001582	0.548955	0.014936	0.068564	0.000715	531.5	59.3	444.3	9.8	427.5	4.3	96
61	33.9	194.1	465.4	0.056798	0.001237	0.543516	0.013150	0.069110	0.000708	483.4	48.1	440.7	8.7	430.8	4.3	97
62	245.9	383.5	429.0	0.167703	0.002745	10.35401	0.176612	0.446767	0.003438	2534.9	27.5	2466.9	15.8	2380.9	15.3	96
63	11.5	97.5	149.4	0.059418	0.002467	0.554244	0.022050	0.068051	0.000983	583.4	116.7	447.8	14.4	424.4	5.9	94
64	18.6	121.1	246.9	0.056343	0.001397	0.538154	0.013438	0.069333	0.000744	464.9	55.6	437.2	8.9	432.1	4.5	98
65	87.8	685.6	1407.6	0.127710	0.004570	0.825915	0.015464	0.049684	0.001162	2077.8	63.3	611.3	8.6	312.6	7.1	35
66	81.7	179.6	277.2	0.092805	0.001132	3.274700	0.042275	0.255947	0.002363	1483.6	23.0	1475.1	10.0	1469.1	12.1	99
67	9.2	77.7	104.8	0.062833	0.002694	0.641251	0.026150	0.074683	0.001029	701.9	90.7	503.1	16.2	464.3	6.2	91
68	33.1	344.7	610.7	0.057168	0.001771	0.381334	0.013540	0.048106	0.000452	498.2	68.5	328.0	10.0	302.9	2.8	92
69	8.4	132.7	146.8	0.055418	0.002803	0.357118	0.018391	0.046767	0.000672	427.8	108.3	310.1	13.8	294.6	4.1	94
70	184.1	172.1	352.3	0.174564	0.001879	10.33648	0.208857	0.428679	0.007410	2602.2	17.9	2465.4	18.7	2299.8	33.4	93
71	49.8	226.4	521.6	0.082125	0.001311	0.976117	0.018061	0.085967	0.000688	1250.0	31.5	691.6	9.3	531.6	4.1	73
72	36.7	267.0	474.8	0.055523	0.001123	0.527609	0.010302	0.069032	0.000617	431.5	44.4	430.2	6.8	430.3	3.7	99
73	4.3	67.8	88.2	0.055312	0.003297	0.309716	0.017211	0.040727	0.000580	433.4	133.3	274.0	13.3	257.3	3.6	93
74	34.9	176.6	81.4	0.095969	0.001822	3.635452	0.080295	0.274093	0.002981	1547.2	36.3	1557.3	17.6	1561.5	15.1	99
75	82.5	209.6	242.7	0.099750	0.001344	3.856048	0.059857	0.279898	0.002873	1620.4	24.8	1604.5	12.5	1590.8	14.5	99