内蒙古克什克腾旗五道石门基性火山岩锆石 U-Pb 年龄及其地质意义*

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Abstract A series of volcanic-sedimentary rocks, composed of gray-green basalts, pillow basalts in lower part and siliceous siltstone in upper part, was recognized in Wudaoshimen area, Hexigten Banner, Inner Mongolia. Previous studies considered them as part of the Early Paleozoic ophiolite suite. In this paper, a pillow basalt sample was collected to date U-Pb ages of zircons by using LA-ICP-MS analytical techniques. Existed south of the Wudaoshimen dam, the pillows are irregular ellipsoidal with long axis ranging from 0.4~1.0m, and have obvious condensation rims and little pores inside. The pillow basalt sample display typical intergranular texture with plenty of narrow-strip feldspar and some tiny pyroxene under microscope. Most zircons are colorless, transparent, and euhedral to subhedral in shape. Cathodoluminescene (CL) imaging shows most of them have oscillatory zones. Combined with their high Th/U ratios (>0.1, except for one spot of 0.08), it is suggested that these zircons are of igneous origin. The 31 zircon analyses are concordant, and show four groups: 261~290Ma (group A, n=15), 301~345Ma (group B, n=5), 446~572Ma (group C, n=6) and 763~948Ma (group D, n=5), respectively. Group A zircons are euhedral and columnar with length:width ratios of 2:1~3:1, and display typical widely-spaced oscillatory zoning, which indicates they crystallized at relatively high temperature. Fifteen zircon analyses yield a concordant age of 277±3Ma (MSWD=0.02), representing that the Wudaoshimen pillow basalts formed in the late Early-Permian and belong to the Dashizhai Formation. Group B zircons are euhedral and columnar, while group C and D zircons are subhedral-euhedral and granular, respectively. Furthermore, most of these three group zircons display closely-spaced concentric oscillatory zoning. The remarkable differences between group A and the other three groups suggest different source. Combined with the lack of magmatic rims with age of 270~280Ma in older zircons, they may be more likely captured from the wall rocks when mafic magma intruding. Thus the scattered ages of 301~345Ma, 446~572Ma and 763~948Ma reflect information of the wall rocks. The Wudaoshimen pillow basalts were regarded as part of the Early Paleozoic ophiolites in previous research. However, based on the concordant age of 277±3Ma, we consider that they formed in the late Early-Permian. Because no ultramafic rocks have been found in research area, we suggest they are not part of ophiolite suite. The three group older captured zircons in the Wudaoshimen pillow basalts display that they formed in a continental crust with the Neoproterozoic to Paleozoic basement during an intraplate extension.

Key words Dashizhai Formation; Pillow basalts; Zircon U-Pb age; Xing'an-Mongolian orogenic belt

摘 要 内蒙古克什克腾旗五道石门水库出露一套由灰绿色玄武岩、枕状玄武岩和硅质粉砂岩组成的火山-沉积岩系。枕状玄武岩主要出露于水库大坝南岸,枕体呈不规则椭球状,长轴约0.4~1.0m,边部具有冷凝边,内部气孔和杏仁状构造较发育。镜下观察其矿物组成主要为细长条状斜长石和少量辉石,间粒结构。前人研究认为它们属于早古生代蛇绿岩,本次研究

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对枕状玄武岩样品进行了 LA-ICP-MS 锆石 U-Pb 年龄测试。锆石测年结果大致可分为四组,依次为 262 ~ 290Ma(A 组,15 颗)、301 ~ 345Ma(B 组,5 颗)、446 ~ 572Ma(C 组,6 颗)和 763 ~ 948Ma(D 组,5 颗)。其中 A 组锆石呈长柱状,自形,长宽比约 2:1 ~ 3:1,Th/U 值介于 0.22 ~ 0.98;振荡环带较宽,体现了基性岩浆锆石的特征。15 个点的谐和年龄为 277 ± 3Ma,应代表岩石的形成年龄,表明五道石门枕状玄武岩形成于早二叠世晚期,应属大石寨组。其余三组锆石多呈自形-半自形,粒状或短柱状,振荡环带较窄,且没有 270 ~ 280Ma 的生长边,表明可能是基性岩浆上升过程中从围岩捕获的锆石,表明五道石门玄武岩可能发育在具有晚元古-古生代基底的陆壳内,暗示早二叠世晚期本区处于板内拉张环境。五道石门枕状玄武岩曾被认为是早古生带大洋蛇绿岩,但综合我们的年代学结果和对锆石类型的分析,它应属早二叠世晚期伸展环境中基性岩浆活动的产物。

关键词 大石寨组;枕状玄武岩;锆石 U-Pb 年龄; 兴蒙造山带

中图法分类号 P588.145; P597.3

1 引言

中亚造山带是全球显生宙陆壳增生与改造最强烈的地区之一,其形成与古亚洲洋的演化密切相关(Sengör *et al.*, 1993; Tang, 1990)。中亚造山带的东段习称兴蒙造山带,作为华北板块与其北部陆块碰撞拼合的产物,兴蒙造山带的研究对于了解古亚洲洋的闭合及中亚造山带的演化历史具有重要意义。然而兴蒙造山带的位置、时代与形成过程一直未有定论。例如,有学者提出索伦科尔-西拉木伦(Solonker-Xar Moron)缝合带代表古亚洲洋晚古生代最后闭合的位置(任纪舜等, 1980; 李春昱等, 1982; 李锦轶等, 1986, 2007; Xiao *et al.*, 2003; Li, 2006);也有学者认为存在更大范围的早古生代造山带(何国琦和邵济安, 1983; Tang, 1990; 邵济安, 1991),可称为"双冲造山带",由南造山带和北造山带组成(Xu and Chen, 1993, 1997; Xu *et al.*, 2013)。关于古亚洲洋闭合的时代也有较大争议,一种观点认为晚古生代古亚洲洋进入闭合阶段,发育与俯冲-碰撞有关的构造格局(Xiao *et al.*, 2003, 2009; Li, 2006; Jian *et al.*, 2010);另一种观点则认为古亚洲洋在早-中古生代已经闭合,晚古生代处于伸展环境,发育与陆内裂谷有关的岩石建造(邵济安, 1991; 唐克东, 1992; 洪大卫等, 1994; Hong *et al.*, 1996)。

内蒙古赤峰市克什克腾旗-林西地区是涉及上述争议的关键地区之一。克什克腾旗五道石门水库出露一套由灰绿色玄武岩、枕状玄武岩和硅质粉砂岩组成的火山-沉积岩系,前人研究认为它们属于蛇绿岩。何国琦和邵济安(1983)根据五道石门枕状细碧岩中夹有硅质岩夹层和透镜体并有属于早古生代的微体化石,将五道石门、黄岗梁、杏树洼等地的基性、超基性岩等初步认定为早古生代蛇绿岩建造。李锦轶(1986, 1987)根据矿物学及岩石地球化学特征,认为五道石门地区的枕状基性熔岩可能是来源于上地幔的玄武质岩浆,并在早古生代洋盆扩张中心喷发,构成了古洋壳蛇绿岩套的一部分,并可能于志留纪末构造侵位于华北板块的北缘。而王玉净和樊志勇(1997)则根据杏树洼蛇绿岩中发现的放射虫化石认为上述蛇绿岩属中二叠世中晚期。然而目前缺乏对五道石门基性火山岩的同位素定年数据。本文对五道石门水库的基性火山岩进行了 LA-ICP-MS 锆石 U-Pb 年龄测定,并结合前人资料分析其构造环境。

2 地质背景与剖面描述

研究区位于内蒙古克什克腾旗西北部、浑善达克沙地以东,处于北造山带(苏尼特左旗-锡林浩特)和南造山带(温都尔庙南-吉中地区)之间。出露的地层为下元古界宝音图群、上石炭统本巴图组、二叠系和中生代侏罗系、白垩系火山碎屑岩及火山熔岩(图 1a)。五道石门水库一带(图 1b)主要出露上古生界二叠系和中生代侏罗系、白垩系陆相火山碎屑岩及火山熔岩,其中二叠系地层由老到新依次为大石寨组、哲斯组和林西组(内蒙古自治区地质矿产局, 1991)。

大石寨组为浅海-滨海相碎屑岩、细碧岩、角斑岩及凝灰岩组合,厚度大于 2680m。其底部为一套滨海相砂、页岩组合,下限不清。哲斯组原称西乌珠穆沁旗组或黄岗梁组,从五道石门到黄岗梁林场一带大面积出露,下部主要是黄绿色砂砾岩、粉砂岩、砾岩、灰色生物碎屑岩和硅质岩;上部为灰绿色、灰黑色块状炭质粉砂岩、板岩,夹灰岩透镜体,总厚约 2238m;其上与林西组为连续沉积,其下与大石寨组为角度不整合接触关系。林西组主要分布于五道石门水库西北侧和黄岗梁林场南侧,岩性比较单一,主要由一套黑色页岩、粉砂岩、砂岩组成,上限不清,下部与下哲斯组似为整合接触,出露厚度约为 2699m(内蒙古自治区地质矿产局, 1991)。

本文研究的火山岩分布于五道石门水库沿岸。由南往北依次为玄武岩、枕状玄武岩、玄武岩及硅质粉砂岩,剖面层序(图 2)如下:

4)灰白色硅质粉砂岩(图 3a),连续薄层状产出,镜下观察其由细小碎屑构成水平层理,成分主要为粉砂级的石英,少数可达 0.1mm;此外还含有较多细小的云母碎片(图 3d)。出露在水库大坝北岸陡坡上,偶见硅质粉砂岩与黑绿色玄武岩呈互层状产出,互层厚度 3 ~ 10cm。粉砂岩表现出明显的韵律性层理,厚约 15m。

3)厚层状灰绿色玄武岩,见于水库大坝北岸陡坡,破碎强烈,厚约 90m。

2)灰绿色枕状构造玄武岩,见于水库大坝南岸(图 3b)。

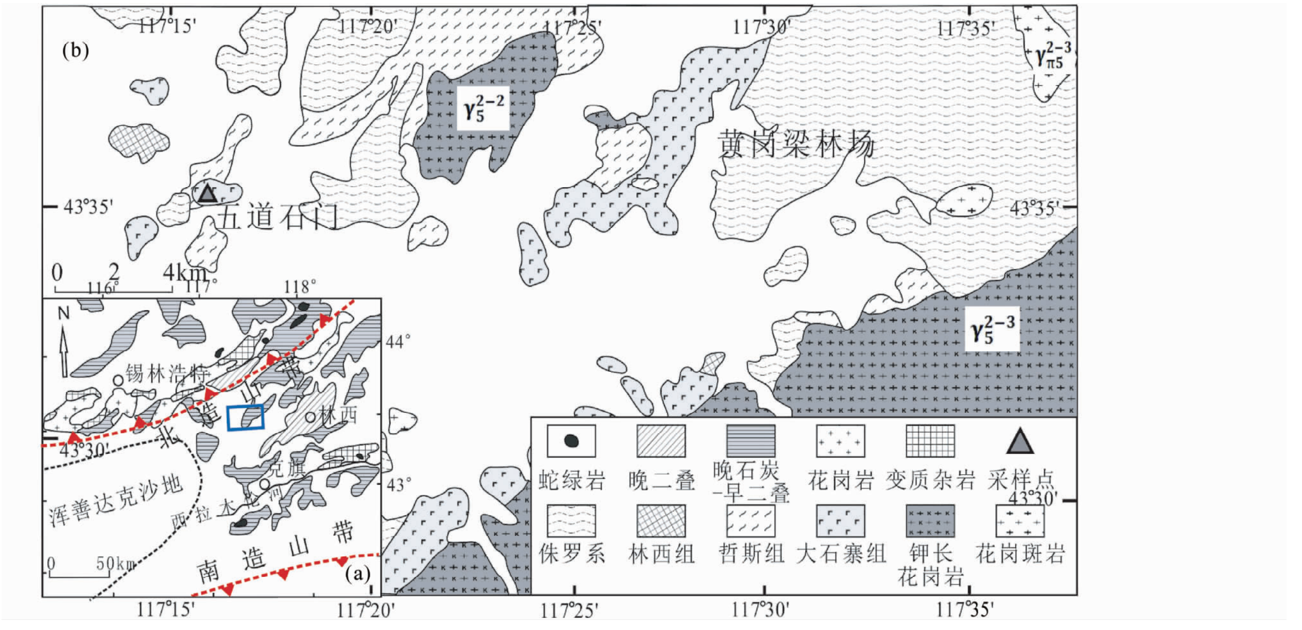

图 1 研究区地质简图（a，据 Miao *et al.*，2007，有修改；b 据内蒙古自治区地质调查院，1968①）

Fig. 1 Sketch geological map of study area (a, after Miao *et al.*, 2007)

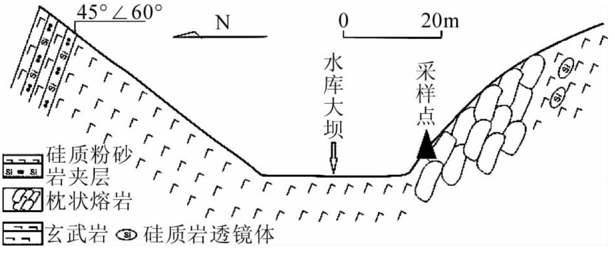

图 2 五道石门大坝地质剖面

Fig. 2 Cross-section of Wudaoshimen Dam

枕体呈上凸下平或略凹的不规则椭球状，其底面总体倾向北东方向。枕体长轴 0.4～1.0m 不等，边部具有冷凝边，内部气孔和杏仁状构造较发育，杏仁体多由绿泥石、方解石和硅质组成，厚约 20m。镜下观察其矿物组成主要为斜长石和少量辉石（图 3e），间粒结构；斜长石呈自形-半自形细板条状，辉石呈他形细粒状充填于斜长石空隙中。

1）厚层状灰绿色玄武岩夹少量透镜状红色硅质岩，见于水库大坝南岸，破碎强烈，未见底。红色硅质岩呈不连续的透镜状，质地坚硬，分布稀疏（图 3c）；镜下观察其主要由细小鳞片状石英组成（图 3f）。

3 样品采集和测试方法

样品 WD1019-01 为采自水库大坝南岸的灰绿色枕状玄武岩，采样点 GPS 坐标：43°35′27″N，117°15′58″E。岩枕大小约 0.4×0.3×0.3m。样品采用常规方法进行破碎，经浮选和磁选后，再在双目镜下挑选出晶型和透明度较好的锆石颗粒制成样品靶，锆石样品靶的制备与 SHRIMP 定年锆石样品制备方法基本相同（宋彪等，2002）。锆石的阴极发光（CL）显微照相在北京大学造山带与地壳演化教育部重点实验室完成。

锆石 LA-ICP-MS 原位 U-Pb 同位素年龄分析在北京大学造山带与地壳演化教育部重点实验室完成。测试仪器为电感耦合等离子体质谱仪（Agilent 7500c）和准分子激光剥蚀系统（COMPExPro102）联机，激光器为 ArF 准分子激光器。激光剥蚀束斑直径为 32μm，激光能量密度为 10J/cm^2，剥蚀频率为 5Hz。实验中采用 He 作为剥蚀物质的载气，Ar 为辅助气。锆石年龄计算采用标准锆石 Plesovice（337Ma）作为外标（Sláma *et al.*，2008），标准锆石 91500 为监控盲样。元素含量采用国际标样 NIST610 作为外标，为内标元素进行校正。剥蚀样品前先进行 15 次激光脉冲的预剥蚀，采集 20s 的空白，随后进行 60s 的样品剥蚀，剥蚀完成后进行 2 分钟的样品池冲洗。采样方式为单点剥蚀，每完成 5 个测点的样品测定，加测标样一次。在 15 个锆石样品点前、后各测 2 次 NIST610。样品的同位素比值和元素含量数据处理采用 GLITTER4.4.2 程序计算，普通铅校正使用 Anderson（2002）给出的程序计算，加权平均年龄及谐和图的绘制使用 Isoplot/Ex（3.0）（Ludwig，2003）完成。分析数据及锆石 U-Pb 谐和图给出误差为 2σ，95% 的置信度。

① 内蒙古自治区地质调查院．1968．1∶20 万刘家营子图幅区域地质调查报告

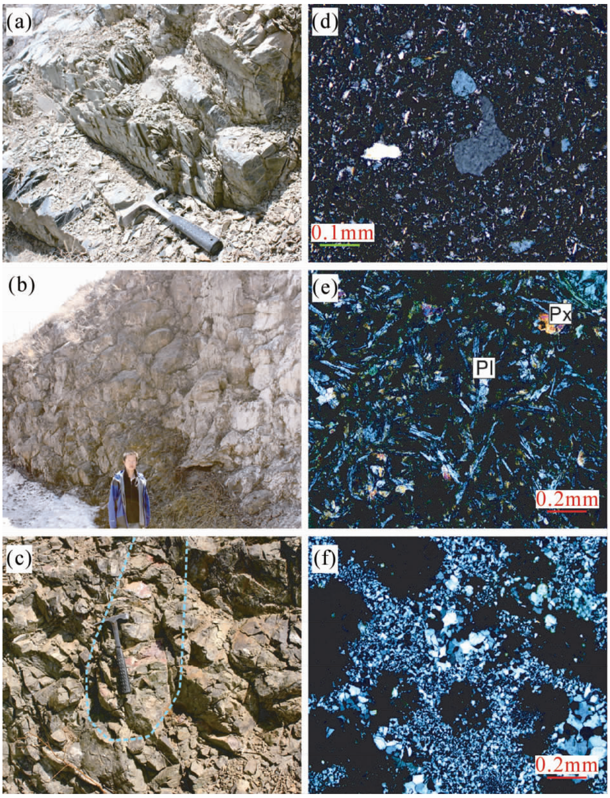

图 3 五道石门玄武岩及围岩的野外及镜下照片

(a)-粉砂岩;(b)-枕状熔岩;(c)-玄武岩中的红色硅质岩透镜体;(d)-硅质粉砂岩的显微结构;(e)-枕状熔岩的显微结构;(f)-红色硅质岩的显微结构. (d-f)为正交偏光下

Fig. 3 The field and microscopic photographs of Wudaoshimen basalts and wall rocks

(a)-siltstone; (b)-pillow lava; (c)-red siliceous rock lenses in basalts; (d)-microstructure of siliceous siltstone; (e)-microstructure of pillow lava; (f)-microstructure of red siliceous rock. (d-f) under perpendicular polarized light

4 测试结果

对五道石门枕状玄武岩(WD1019-01)的32颗锆石选取了32个点进行了测定,其测试结果见表1,锆石阴极发光(CL)图像见图4。根据其年龄分布范围(除1个测试点偏离谐和线未参加计算外)并结合CL图像特征,测试结果可分为四组(图5):261 ~ 290Ma(A组,15颗)、301 ~ 345Ma(B组,5颗)、446 ~ 572Ma(C组,6颗)和763 ~ 948Ma(D组,5颗)。A组锆石晶体形态好,自形长柱状,长宽比约2:1 ~ 3:1,Th/U值介于0.22 ~ 0.98;具有较宽的振荡环带,表现为基性岩浆锆石的特征。其测试结果基本集中于谐和线上并构成一个点群,15个点给出的谐和年龄为277 ± 3Ma(图5)。B组锆石晶体形态好,柱状,Th/U值为0.34 ~ 0.40,环带比较细密,属于岩浆锆石,测试年龄从301 ± 4Ma到345 ± 6Ma。C组锆石自形-半自形,短柱状或粒状,环带较细密或无环带,

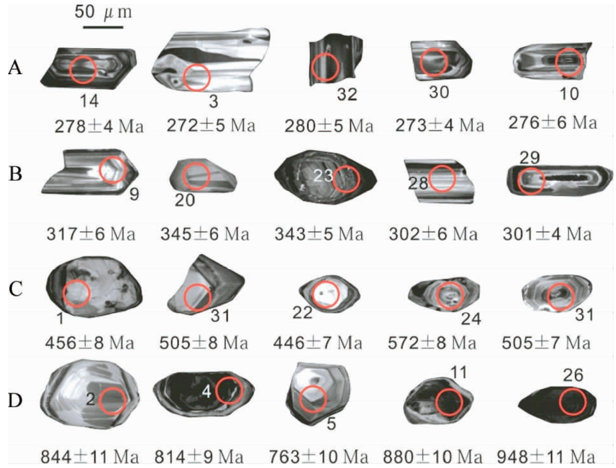

图 4 枕状熔岩部分锆石CL图像

Fig. 4 CL images of selected zircons from Wudaoshimen pillow lava

Th/U值介于0.16 ~ 0.99。D组锆石自形-半自形,短柱状或粒状,环带清晰细密,Th/U值较高,为1.12 ~ 1.55,测试年龄从763 ± 10Ma到948 ± 11Ma。

5 讨论

5.1 五道石门基性火山岩的形成时代及捕获锆石的解释

本文测试的五道石门枕状玄武岩样品(WD1019-01)的锆石U-Pb测年结果可分为四组:261 ~ 290Ma(A组,15颗)、301 ~ 345Ma(B组,5颗)、446 ~ 572Ma(C组,6颗)和763 ~ 948Ma(D组,5颗)。其中,A组15个测试点给出的谐和年龄为277 ± 3Ma(MSWD = 0.02)。鉴于该组锆石振荡环带符合基性岩浆锆石的特征,我们认为它代表岩石的形成年龄,表明五道石门枕状玄武岩形成于早二叠世晚期,应属大石寨组。

其余三组锆石测试结果分散,锆石多呈自形-半自形,粒状或短柱状,振荡环带较窄,且没有270 ~ 280Ma的生长边,表明它们应该是基性岩浆上升过程中从围岩捕获的锆石。因此这三组锆石测试结果应代表围岩通道的年龄信息。B组锆石年龄介于301 ± 4Ma到345 ± 6Ma之间,这与本区周边众多310 ~ 330Ma的岩浆事件相一致,反映了本区及周边早石炭世-晚石炭世初大规模岩浆侵位事件。例如鲍庆中等(2007)对锡林浩特杂岩体中的石英闪长岩进行SHRIMP锆石U-Pb年代学测定,所得年龄为313 ± 5Ma ~ 323 ± 4Ma;施光海等(2003)报道该杂岩体中的石榴石花岗岩SHRIMP年龄为316 ± 3Ma;而片麻状二长花岗岩和花岗闪长岩SHRIMP年龄分别为316.5 ± 1.8Ma和324.4 ± 2.4Ma,并普遍具有年龄为320Ma左右的锆石增生边(葛梦春等,2011);刘建峰(2009)报道林西-东乌旗一带本巴图组火山岩和花岗岩的锆石U-Pb年龄分别为315.4 ± 4.4Ma ~ 323.9 ± 3.5Ma和316.7

表 1 五道石门枕状熔岩锆石 U-Pb 测年结果

Table 1 Results of LA-ICP-MS zircon U-Pb age dating for the pillow lava from Wudaoshimen

测点号	Th ($\times10^{-6}$)	U ($\times10^{-6}$)	Th/U	同位素比值						同位素年龄(Ma)					
				$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$	
				比值	2σ	比值	2σ	比值	2σ	年龄	2σ	年龄	2σ	年龄	2σ
WD101901-01	80	105	0.75	0.05652	0.00376	0.57109	0.03749	0.07331	0.00125	473	115	459	24	456	8
WD101901-02	159	193	0.82	0.06725	0.00219	1.29639	0.04169	0.13986	0.00188	846	44	844	18	844	11
WD101901-03	76	161	0.47	0.05169	0.00451	0.30661	0.02636	0.04303	0.00087	272	158	272	20	272	5
WD101901-04	151	689	0.22	0.06598	0.00133	1.22401	0.02452	0.13459	0.00159	806	23	812	11	814	9
WD101901-05	126	135	0.93	0.06483	0.00228	1.12297	0.03896	0.12568	0.00178	769	49	764	19	763	10
WD101901-06	360	367	0.98	0.05175	0.00230	0.32086	0.01395	0.04499	0.00070	274	71	283	11	284	4
WD101901-07	246	616	0.40	0.05205	0.00251	0.31399	0.01482	0.04377	0.00070	288	79	277	11	276	4
WD101901-08	596	865	0.69	0.04684	0.00382	0.27244	0.02193	0.04218	0.00055	41	182	245	17	266	3
WD101901-09	164	251	0.66	0.05302	0.01373	0.36779	0.09510	0.05033	0.00100	330	449	318	71	317	6
WD101901-10	164	291	0.56	0.05157	0.00467	0.31119	0.02769	0.04378	0.00097	266	161	275	21	276	6
WD101901-11	388	1014	0.38	0.06804	0.00135	1.37103	0.02699	0.14619	0.00172	870	22	877	12	880	10
WD101901-12	47	97	0.49	0.05204	0.00828	0.31043	0.04897	0.04328	0.00110	287	296	275	38	273	7
WD101901-13	309	353	0.87	0.05145	0.00224	0.30262	0.01294	0.04268	0.00062	261	71	268	10	269	4
WD101901-14	258	334	0.77	0.05203	0.00226	0.31547	0.01346	0.04399	0.00063	287	71	278	10	278	4
WD101901-15	121	130	0.93	0.05741	0.00323	0.64539	0.03586	0.08157	0.00130	507	94	506	22	505	8
WD101901-16	332	535	0.62	0.05165	0.00202	0.31707	0.01212	0.04454	0.00064	270	61	280	9	281	4
WD101901-17	250	456	0.55	0.05193	0.00258	0.31922	0.01548	0.04460	0.00073	282	81	281	12	281	5
WD101901-18	142	654	0.22	0.05222	0.00163	0.33105	0.01016	0.04599	0.00061	295	46	290	8	290	4
WD101901-19	40	100	0.40	0.05617	0.00414	0.55972	0.04060	0.07231	0.00140	459	127	451	26	450	8
WD101901-20	105	163	0.65	0.05286	0.00464	0.40102	0.03493	0.05504	0.00095	323	166	342	25	345	6
WD101901-21	325	505	0.64	0.05124	0.00450	0.29206	0.02555	0.04135	0.00058	252	172	260	20	261	4
WD101901-22	31	194	0.16	0.05581	0.00249	0.55050	0.02410	0.07156	0.00110	445	70	445	16	446	7
WD101901-23	58	696	0.08	0.05334	0.00252	0.40205	0.01858	0.05469	0.00089	343	75	343	13	343	5
WD101901-24	132	177	0.75	0.05904	0.00226	0.75460	0.02834	0.09273	0.00139	569	56	571	16	572	8
WD101901-25	108	188	0.58	0.05213	0.00488	0.32260	0.02995	0.04490	0.00079	291	178	284	23	283	5
WD101901-26	77	311	0.25	0.07084	0.00160	1.54699	0.03471	0.15844	0.00198	953	26	949	14	948	11
WD101901-27	211	351	0.60	0.05199	0.00248	0.31798	0.01495	0.04438	0.00064	285	81	280	12	280	4
WD101901-28	104	128	0.81	0.05211	0.00446	0.34495	0.02913	0.04803	0.00093	290	156	301	22	302	6
WD101901-29	387	600	0.65	0.05235	0.00210	0.34473	0.01363	0.04778	0.00065	301	65	301	10	301	4
WD101901-30	259	346	0.75	0.05168	0.00245	0.30770	0.01425	0.04320	0.00069	271	77	272	11	273	4
WD101901-31	337	340	0.99	0.05740	0.00176	0.64426	0.01940	0.08143	0.00111	507	42	505	12	505	7
WD101901-32	90	282	0.32	0.05188	0.00844	0.31713	0.05138	0.04436	0.00086	280	310	280	40	280	5

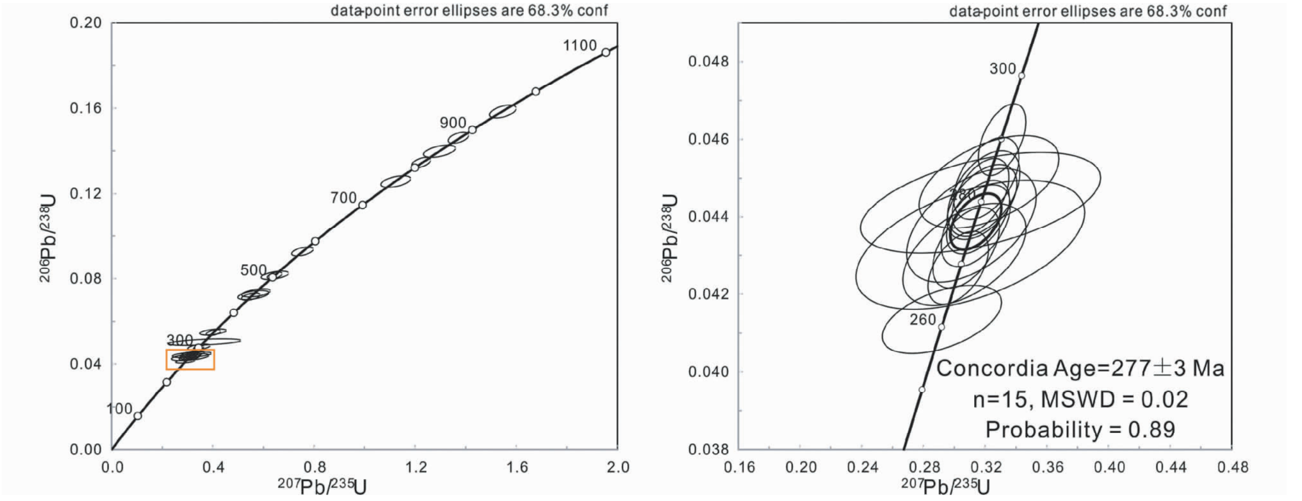

图 5 五道石门枕状熔岩锆石 U-Pb 谐和图

Fig. 5 Concordia diagram showing LA-ICP-MS zircon U-Pb dating for the pillow lava from Wudaoshimen

±2.1Ma ~ 323 ±5Ma。

C组锆石具有446 ~ 572Ma的年龄，与之可对比的是，在研究区以北的锡林浩特地区，葛梦春等(2011)报道了存在早古生代岩浆弧，而锡林郭勒杂岩中也含有大量早古生代的碎屑锆石(施光海等,2003)。与此同时，在研究区东北方向的松辽地块也具有518Ma的碎屑锆石年龄峰值(Zhou *et al.*, 2012)。因此五道石门基性岩中早古生代捕获锆石的出现，表明其围岩(基底)可能具有和邻区相似的岩石建造。

D组锆石的年龄分布于760Ma到950Ma之间研究表明，这也是华北板块北部兴蒙造山带的重要特征(Han *et al.*, 2011; Rojas-Agramonte *et al.*, 2011)。例如松辽地块的基底年龄为750 ~ 920Ma(权京玉等,2013)。Xu *et al.* (2013)曾推测研究区西部浑善达克沙地(图1)存在着一个未出露的浑善达克地块，其基底年龄范围为576 ~ 1044Ma。因此，D组锆石的年龄表明五道石门枕状玄武岩的围岩具有相似的基底信息，说明部分源区物质可能是记录了Rodinia超大陆聚合与裂解时期的岩浆活动的新元古代基底。

5.2 五道石门枕状玄武岩的形成环境

何国琦和邵济安(1983)考察了西拉木伦河一带(五道石门、黄岗梁、杏树洼等)出露的基性火山岩，认为五道石门地区的玄武岩和枕状玄武岩为细碧岩。对采自五道石门-黄岗梁地区的九个岩样的化学分析结果表明含量较高，含量较低；同时 добечов 图解表明它们具有大洋拉斑玄武岩的特征，属于残余洋壳。李锦轶(1986)根据该区枕状玄武岩的矿物学及地球化学特征分析，认为五道石门地区的枕状玄武岩可能是源于上地幔的玄武质岩浆在早古生代洋盆扩张中心喷发形成，构成了古洋壳-蛇绿岩套的一部分。

笔者根据五道石门枕状玄武岩定年结果，结合对层序和玄武岩中硅质岩数量和产状的观察，认为将其作为大洋蛇绿岩的观点值得商榷。首先，五道石门地区没有发现一套较为完整的蛇绿岩序列，即包含地幔橄榄岩、堆晶杂岩、席状基性岩墙和枕状熔岩以及深海相沉积物的三位一体建造(Coleman, 1977; Dilek, 2003; Dilek and Furnes, 2011)。另外目前仅在枕状构造玄武岩中见少量红色硅质岩透镜体(图3)，与大洋深海蛇绿岩中厚层状红色硅质岩相比有很大差别，例如北祁连山清水沟和百经寺变质硅质岩最大厚度可达50m，绵延1 ~ 2km(Song *et al.*, 2007)。且透镜体产出于玄武岩层内的成因尚不明确，而玄武岩层之上为灰白色硅质粉砂岩，并无红色硅质岩。另一方面，枕状玄武岩的出现仅能指示玄武岩浆在水下喷发，并不一定代表大洋环境。而前述玄武岩样品中三组捕获锆石的年龄结果显示源区(地壳基底)含有301 ~ 345Ma、446 ~ 572Ma和763 ~ 948Ma的年龄信息，表明五道石门玄武岩可能发育在具有晚元古-早古生代基底的陆壳内，暗示早二叠世晚期本区可能处于板内拉张环境。

6 结论

(1)五道石门地区出露的火山-沉积岩系应属于大石寨组，下部为灰绿色块状玄武岩和枕状玄武岩，镜下观察其矿物组成主要为细长条状斜长石和少量辉石，间粒结构；上部发育灰白色硅质粉砂岩。

(2)五道石门枕状玄武岩样品锆石U-Pb定年结果大致可分为四组：最年轻组锆石的谐和年龄为277 ±3Ma(n = 15, MSWD = 0.02)，结合锆石CL特征，应代表岩石的形成年龄，表明其形成于早二叠世晚期，应属大石寨组；其余三组锆石年龄较分散，分别为301 ~ 345Ma、446 ~ 572Ma和760 ~ 950Ma，代表了基性岩浆上升过程中从围岩捕获的老锆石信息，表明五道石门玄武岩可能发育在具有晚元古-早古生代基底的陆壳之下。

(3)五道石门枕状玄武岩应是早二叠世晚期基性岩浆活动的产物，可能发育于具有新元古-古生代基底的陆壳之下，暗示早二叠世晚期本区处于板内拉张环境，并不存在大洋。

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