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豫西洛峪口组凝灰岩锆石LA-MC-ICPMS U-Pb年龄及地层归属讨论

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提要:洛峪群—汝阳群主要分布在华北克拉通南缘,它们主要由石英砂岩夹少量页岩及白云岩组成。通过对豫西汝州洛峪口村、阳坡村附近的洛峪口组野外调查,发现洛峪口组含有多层凝灰岩夹层。采用LA-MC-ICPMS测年方法,对不同地点的洛峪口组凝灰岩夹层进行了锆石U-Pb年代学研究,分别获得(1638±9)Ma、(1634±10)Ma的年龄,表明洛峪口组形成于中元古代长城纪,并非原来认为的中—新元古代蓟县纪和青白口纪。由于洛峪口组位于洛峪群的顶部,很显然洛峪群及下伏汝阳群的时代均应归属长城纪。该组年龄的精确标定从根本上改变了原来豫西洛峪群—汝阳群划分方案。这对华北克拉通中—新元古代地层的划分与对比,对探讨大地构造演化与哥伦比亚超大陆的关系及早期生命演化均具有重要的意义。

关 键 词:凝灰岩;洛峪口组;锆石LA-MC-ICPMS U-Pb测年;长城系;华北克拉通南缘

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Zircon U-Pb dating of tuff bed from Luoyukou Formation in western Henan Province on the southern margin of the North China Craton and its stratigraphic attribution discussion

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Abstract: Luoyu Group and Ruyang Group are cropped out extensively along the southern margin of the North China Craton (NCC), and are mostly composed of sandstone with minor shale and dolostone. Based on field investigation along Luoyukou and Yangpo Village section, Ruzhou City, Henan Province, a few interbedded tuff layers were found in the upper part of the Luoyukou Formation. By means of LA-MC-ICPMS zircon U-Pb dating, the ages of the volcanic eruption, 1638±9 Ma and 1634±10 Ma

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from Luoyukou Village and Yangpo section, were respectively obtained. These data mean that Luoyukou Formation was formed during Mesoproterozoic Changcheng period rather than during Meso–Neoproterozoic Jixian period and Qingbaikou period as previously held. According to the new dating data, the Luoyu Group and Ruyang Group which conformably underlies Luoyu Group ought to belong to the Mesoproterozoic Changcheng period, because Luoyukou Formation is at the uppermost part of Luoyu Group. This discovery has great significance for Meso-Neoproterozoic stratigraphic redivision and correlation in the NCC, and for the study of the relationship between the tectonic evolution history of the Late Paleoproterozoic to Early Mesoproterozoic geological records in the NCC and the breakup of the Columbia Supercontinent as well as for the evolution of the early life on the Earth.

Key words: tuff; Luoyukou Formation; LA-MC-ICPMS zircon U-Pb dating; Changchengian System; southern margin of the NCC

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1 引 言

豫西洛峪口组起源于阎廉泉和韩影山1952年在汝阳县洛峪口村创名的洛峪口层,1∶50万河南省地质图(1962)称其为洛峪口组,与崔庄组、三教堂组一起称为小顶山群。1964年河南区调队重新定义了洛峪口组的含义,将三教堂砂岩顶部的页岩划归洛峪口组,下部以页岩出现为标志与三教堂组整合接触,上部被黄连垛组或罗圈组、辛集组等平行不整合覆盖。岩性为一套白云岩、页岩、粉砂质页岩和白云质灰岩,白云岩中含有丰富的叠层石。关保德等(1980,1988)将崔庄组、三教堂组和洛峪口组命名为洛峪群,归青白口系,此划分方案被多数地质学者所接受。之后,河南岩石地层(1979)取消洛峪群,与下伏汝阳群的北大尖组、白草坪组和云梦山组一起统称(广义)汝阳群,分别归属青白口系和蓟县系。1999年中国地层典中元古界一书也称汝阳群(陈晋镳等,1999),将其归属蓟县系(表1)。

洛峪群(洛峪口组)形成时代一直存有争论。一种观点是根据三教堂组获得海绿石K-Ar 1012 Ma、1078 Ma和1089 Ma的年龄,崔庄组海绿石K-Ar 1038 Ma、1159 Ma的年龄,上覆董家组海绿石K-Ar 665 Ma、669 Ma的年龄,将该群底界定在(1150±30)Ma,顶界在800~900 Ma(关保德等,1980,1988),形成时代相当于青白口纪。而古生物研究者则根据该群中的遗迹化石、微古植物等组合特征,认为洛峪群可能属于中元古代末期(胡建民等,1991,1996;xiao et al., 1997; Yin et al., 2005)、新元古代青白口纪(尹崇玉和高林志,1999;邢裕盛等,1996;高林志等,2002),或者震旦纪(阎玉忠和朱士兴,1992;尹崇玉和高林志,2000)。上述时代归属依据由于海绿石年龄偏新及微古植物组合的不确定性受到一些学者的质疑,进而根据宏观地层接触关系,提出洛峪群及其下伏汝阳群的形成时代为中元古代长城纪的认识(武铁山,1982,2002)。苏文博等(2012)首次在洛峪口组的层凝灰岩中获得了1611 Ma年龄,将该套地层包括下部狭义的汝阳群均归属长城纪,这种归属与武铁山(1982,2002)的认识一致。

作者在汝阳洛峪口村(洛峪口层命名地)北西剖面,发现洛峪口组中发育一层凝灰岩层,对其进行了LA-MC-ICPMS U-Pb同位素年代学研究,获得(1638±9)Ma。同时对阳坡剖面进行观察,发现位于洛峪口组顶部的一层凝灰岩,获得(1634±10)Ma(LA-MC-ICPMS)年龄。该年龄对于整个华北地区中新元古界划分与对比具有非常重要的意义。

2 地质背景及样品特征

研究区位于华北克拉通南缘中—新元古界分布区,主要在三门峡、济源、汝州到确山一带,大地构造上属于中新元古代时期的中条—熊耳裂谷(图1)。中—新元古代地层主要有不整合在新太界或者古元古界之上的熊耳群,为一套中偏基性夹酸性火山岩的组合;之上为汝阳群、洛峪群,登封一带为五佛山群,在栾川一带发育高山河组、官道口群、栾川群;最上部的黄连垛组、罗圈组及东坡组等地层平行不整合在洛峪群之上(河南省地质矿产厅,1997)。洛峪口组位于洛峪群最上部,该组在豫西地区广泛发育,总体上西北和东南薄,以鲁山地区发育最全,叶县常村和方城小顶山一带缺失。岩性

表1 豫西地区中—新元古代地层划分沿革

Table 1 Conventional chart of the Meso-Neoproterozoic stratigraphic classification evolution on the southern margin of the North China Craton

组合:下部为一套灰绿、紫红色的泥页岩组合;上部为一套碳酸盐岩组合,以灰红色厚层状粉晶、细晶白云岩与中厚层状粉晶砂屑白云岩、具硅泥质条纹细晶白云岩互层为主,夹紫红色薄层泥岩及含叠层石白云岩。

2.1 洛峪口村西北洛峪口组及样品特征

洛峪村位于汝阳县北部,该区中新元古代地层发育,出露的地层有熊耳群马家河组;汝阳群云梦山组、北大尖组、白草坪组;洛峪群崔庄组、三教堂组和洛峪口组。洛峪群整合于汝阳群之上,汝阳群角度不整合在熊耳群之上。震旦系或者寒武系不整合覆盖在洛峪群之上。此外,有少量白垩系、新近系和第四系等出露(图2)。

作者测制的洛峪口组剖面位于洛峪口村西北4 km左右,紧邻一条公路,岩石露头良好,接触关系清楚,底部与三教堂组石英砂岩整合接触,剖面未见顶,被第四系覆盖,但区域上被寒武系平行不整合覆盖(图2)。该剖面可以分为四段:一段为杂色页岩(灰绿、紫色、灰色),夹一层白云岩,整合在三教堂组砂岩之上;二段下部为灰白色厚层状含叠层石白云岩,上部为灰红色薄层白云岩夹紫红色页岩;三段为灰白色厚层状白云岩;四段为灰红色与灰白色中厚层状白云岩、白云质灰岩,下部夹少量紫红色页岩,上部被第四系黄土覆盖(图3)。

本文发现的凝灰岩层出露在该剖面东侧公路人工露头,相当于剖面四段下部,夹于白云质灰岩之间,厚度7~8 cm,出露稳定(图4)。凝灰岩层为红灰、灰绿色,岩性为流纹质玻屑凝灰岩,岩石主要由火山玻屑、火山尘和少量晶屑组成。玻屑呈鸡骨状、棒状、弓状等,弧面棱角状,长轴具定向分布,已

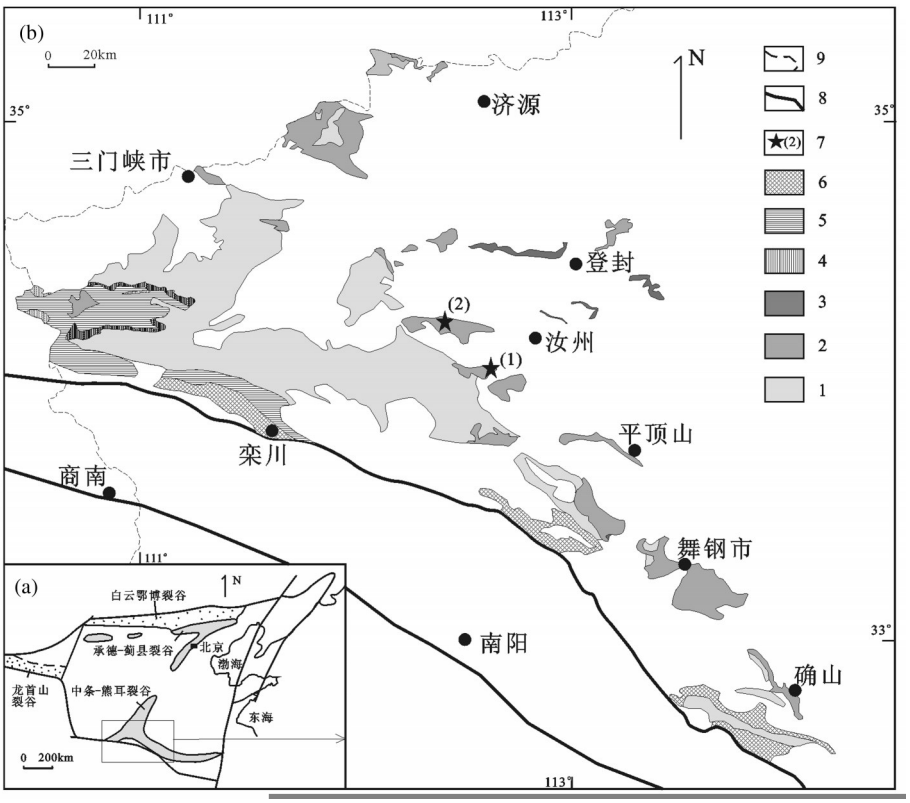

图1 豫西中—新元古界分布特征及构造背景

1—熊耳群;2—汝阳群、洛峪群及震旦系等;3—五佛山群;4—高山河组;5—官道口群;6—栾川群; 7—典型剖面:(1)阳坡村洛峪口组剖面,(2)洛峪口村洛峪口组剖面;8—大断裂;9—省界;a图:Zhai et al.,2000;b图:据1∶50万河南地质图简化

Fig. 1 Sketch of the distribution of the outcrop of the Meso- and Neoproterozoic succession and tectonic setting in western Henan Province on the south margin of North China Craton (NCC)

1-Xiong'er Group; 2- Ruyang Group, Luoyu Group and Sinian; 3- Wufoshan Group; 4- Gaoshanhe Formation; 5- Guandaokou Group; 6- Luanchuan Group; 7- Typical profile: (1) The profile of the Luoyukou formation in Yangpo Village; 2) The profile of the Luoyukou formation in Luoyukou Village; 8- Fault belt; 9- Provincial boundary (Fig.a after Zhai Mingguo et al., 2000; Fig.b after 1∶500000 geological map of Henan)

脱玻化,形成微粒长英矿物,并具蒙脱石、褐铁矿化,粒径多小于0.2 mm。玻屑 70%~75%,火山尘25%~30%。晶屑少量,成分为石英,呈棱角状,有的呈熔蚀浑圆状,粒径小于0.35 mm,零星可见。细小火山尘物质充填玻屑空隙间,已蒙脱石、褐铁矿化(图5)。13YX212定年样品,即取于该层凝灰岩。

2.2 阳坡洛峪口组及样品特征

对苏文博等(2012)获得洛峪口组层凝灰岩年龄的阳坡附近剖面进行了再观察,该剖面位于左景勋等(1997)所述阳坡剖面东侧,与其岩性组合基本相同。可以划分为4段:一段为灰绿、紫红色的泥页岩,整合于三教堂组含砾石英砂岩之上;二段下部为黄灰色、灰红色厚层状含叠层石白云岩,上部为薄层状灰红色白云岩夹紫红色薄层粉砂质页岩,顶部见有灰红色砾屑白云岩;三段为灰黄色厚层状白云岩,富含叠层石,底部夹有灰绿色泥页岩;四段为黄灰色-浅砖红色中—薄层状(页片状)白云岩-白云质灰岩,夹有少量灰黑色、绿色及紫色页岩。其上被震旦系罗圈组杂色块状-厚层状冰碛砾岩平行不整合覆盖(图6a)。

前人资料(左景勋等,1997)表明该地区罗峪口组的第二段上部含有沉凝灰岩层夹层,据作者观察,除发育多层砖红色沉凝灰岩之外(苏文博等,2012),还可见有灰绿色的沉凝灰岩薄层。更为重要的是,作者在该剖面的第四段近顶部薄板状白云岩中也发现一层绿色凝灰岩夹层,厚度9~10 cm,岩石坚硬,与上下岩层的特征明显不同,测年样品13YX206就取自该层绿色凝灰岩(图6)。13YX206岩性为流纹质玻屑凝灰岩,具玻屑凝灰结构,主要由火山玻屑(75%~80%)和火山尘组成(20%~

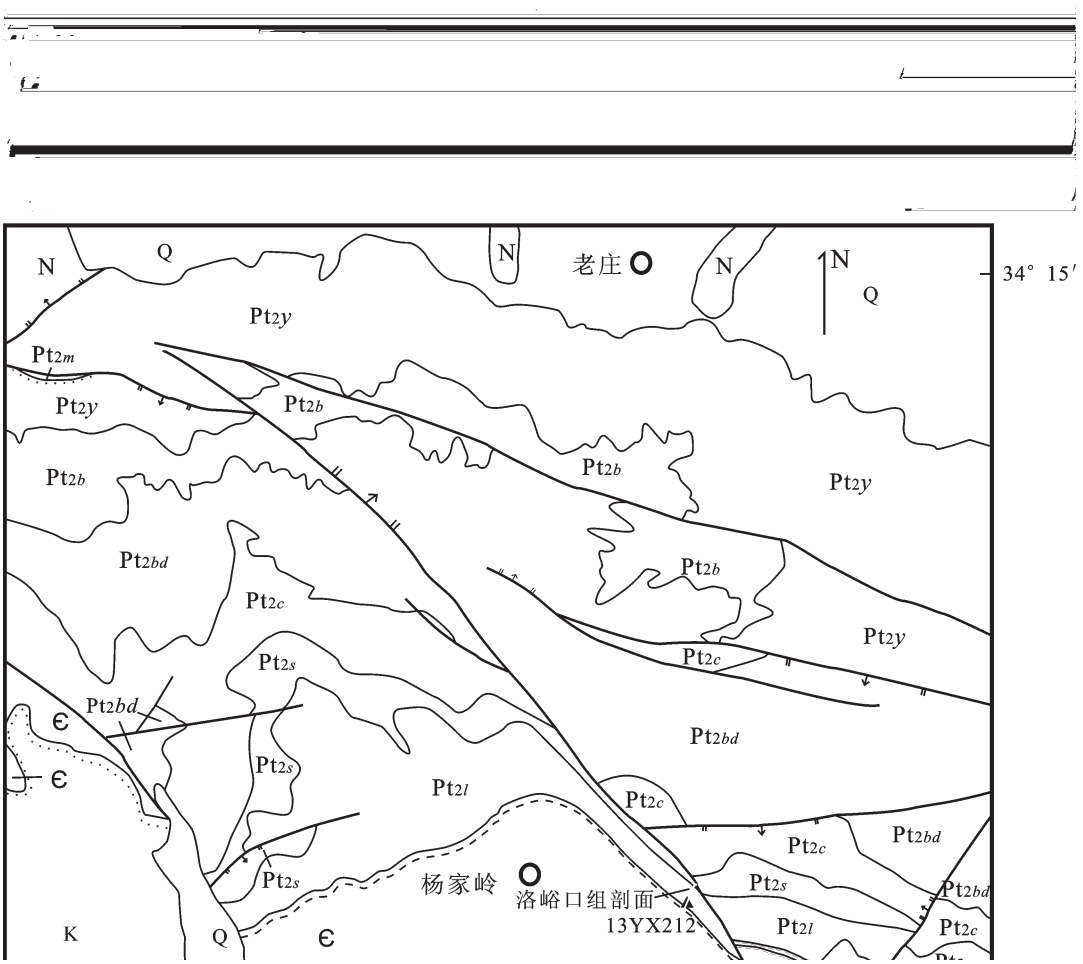

图2 汝阳洛峪地区地质简图(据1∶5万鸣皋幅地质图修改)

熊耳群：1—马家河组；汝阳群：2—云梦山组，3—白草坪组，4—北大尖组；洛峪群：5—崔庄组，6—三教堂组，7—洛峪口组；8—震旦系罗圈组；9—寒武系；10—白垩系；11—新近系；12—第四系；13—角度不整合界线；14—平行不整合界线；15—正断裂；16—取样位置及编号；17—测制剖面位置

Fig. 2 Simplified geological map of the Luoyukou section, Ruyang

Xiong'er Group: 1-Majiahe Formation; Ruyang Group: 2-Yunmengshan Formation; 3-Baicaoping Formation; 4-Beidajian Formation; Luoyu Group: 5-Cuizhuang Formation; 6-Sanjiaotang Group; 7-Luoyukou Formation; 8-Sinian Luoquan Formation; 9-Cambrian; 10-Cretaceous; 11-Neogene; 12-Quaternary; 13-Boundary of angular unconformity; 14-Boundary of parallel unconformity; 15-Normal fault; 16-Position and number of sample; 17-Position of the profile

25%)。玻屑呈鸡骨状、弓状、不规则状，已脱玻化，形成微粒长英矿物，粒径多小于0.4 mm，少部分达0.4~1 mm。细小火山尘物质充填玻屑空隙间，已蒙脱石化、局部褐铁矿化(图7)。岩石中没有发现陆缘碎屑物质，说明该凝灰岩虽然沉积在浅海的环境中，但没有受到陆缘碎屑的污染。

3　实验方法及U-Pb同位素测年结果

样品粉碎到80目，经过分选之后用手工在显微镜下挑选出锆石，然后挑选裂纹少、透明度较好、干净的锆石制靶，拍摄锆石透反射光照片、阴极发光(CL)图像，以便做锆石成因分析。锆石U-Pb分析在天津地质矿产研究所进行，采用激光剥蚀多接收器等离子体质谱仪(LA-MC-ICPMS)进行微区原位U-Pb同位素测定。仪器配置和实验流程见有关文献(李怀坤等，2009)。采用GJ-1作为外部锆石年龄标准进行U-Pb同位素分馏校正(Jackson et al., 2004)，采用中国地质大学刘勇胜研发的ICPMS Data Cal程序(Liu et al.,2009)和Ludwid的Isoplot程序(Ludwing,2003)进行数据处理，应用^{208}Pb校正法

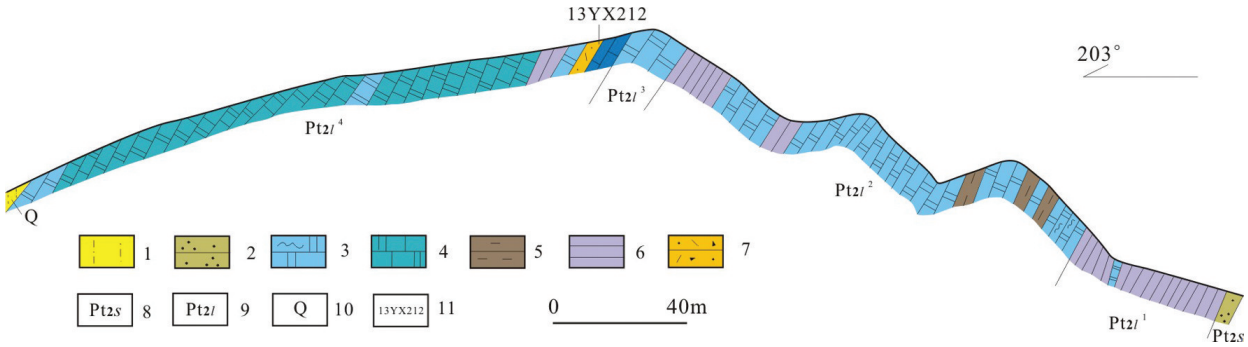

图3 汝阳洛峪口村洛峪口组实测剖面

1—第四系亚沙土;2—石英砂岩;3—含叠层石白云岩;4—白云质灰岩; 5—泥岩;6—页岩;7—流纹质凝灰岩;8—三教堂组;9—洛峪口组;10—第四系;11—采样编号

Fig. 3 Outcrop section of the Luoyukou Formation at Luoyukou Village, Ruzhou City, Henan Province

1−Clayey silt of Quaternary; 2−Quartz sandstone; 3−Dolomite containing stromatolite; 4−Dolomitic limestone; 5−Mudstone; 6−Shale; 7−Rhyolitic tuff; 8−Sanjiaotang Formation; 9−Luoyukou Formation; 10−Quaternary; 11−Serial number of sample

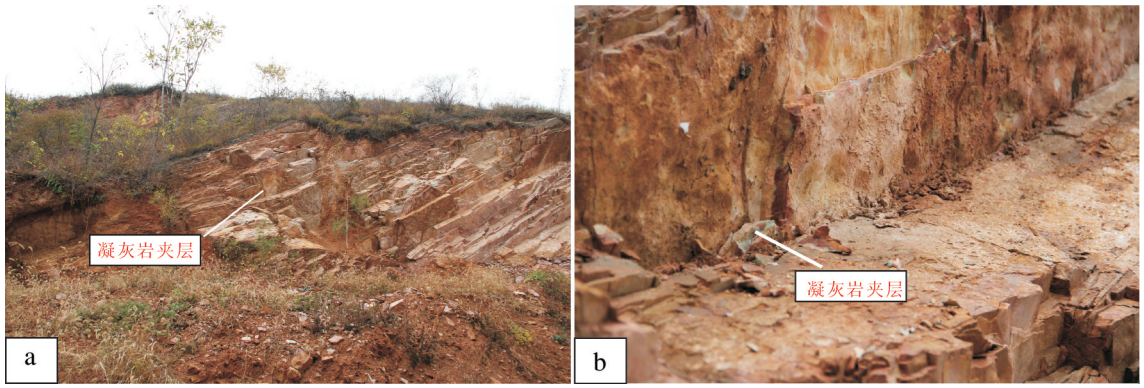

图4 罗峪口村洛峪口组剖面灰绿色流纹质凝灰岩特征

a—洛峪口组四段灰红色白云岩夹棕红、灰绿色凝灰岩;b—采样的凝灰岩(13YX212)夹层

Fig. 4 Characteristics of the grayish green rhyolitic tuff in the Luoyukou Formation at Luoyukou section of Luoyukou Village, Ruzhou City, Henan Province

a−Grayish red dolomite intercalated with brownish red, grayish green tuff in the fourth member of Luoyukou Formation; b−Sample of tuff layer (13YX212)

对普通铅进行校正(Anderson,2002),利用NIST610玻璃标样作为外标计算锆石样品的Pb、U、Th含量。

两个样品锆石LA−MC−ICPMS U−Pb同位素分析结果及年龄列在表2。图8是两个样品代表性锆石高清阴极发光特征。图9展示了两个样品锆石分析的U−Pb谐和曲线图。

样品13YX212,岩性为流纹质玻屑凝灰岩,其代表性锆石特征如图8。锆石CL图像显示,锆石为短柱状,晶棱清楚,发育生长环带,其Th/U比绝大部分大于0.4(表2),显示岩浆锆石成因特征。该样品共测试32个锆石,Th、U含量分别为4×10^{-6}~96×10^{-6}和44×10^{-6}~134×10^{-6}, Pb含量为14×10^{-6}~50×10^{-6}。从所测的数据看(表2),该样品U−Pb同位素体系保持的很好,谐和度只有一个测点为98%,其余测点在99%~100%(谐和度计算方法据Liu et al.,2009),31个锆石分析数据都落在谐和线上,它们的$^{207}Pb/^{206}Pb$表面年龄绝大多数在1615~1673 Ma,只有一个测点为1964 Ma。31个测点加权平均值为(1638±9) Ma(95%的置信度,MSWD=0.44,n=31,图9),该年龄被解释成岩石的形成年龄。另外1个分析点(22测点)数据(1964±20) Ma,为继承锆石年龄。

样品13YX206,岩性为流纹质玻屑凝灰岩。锆

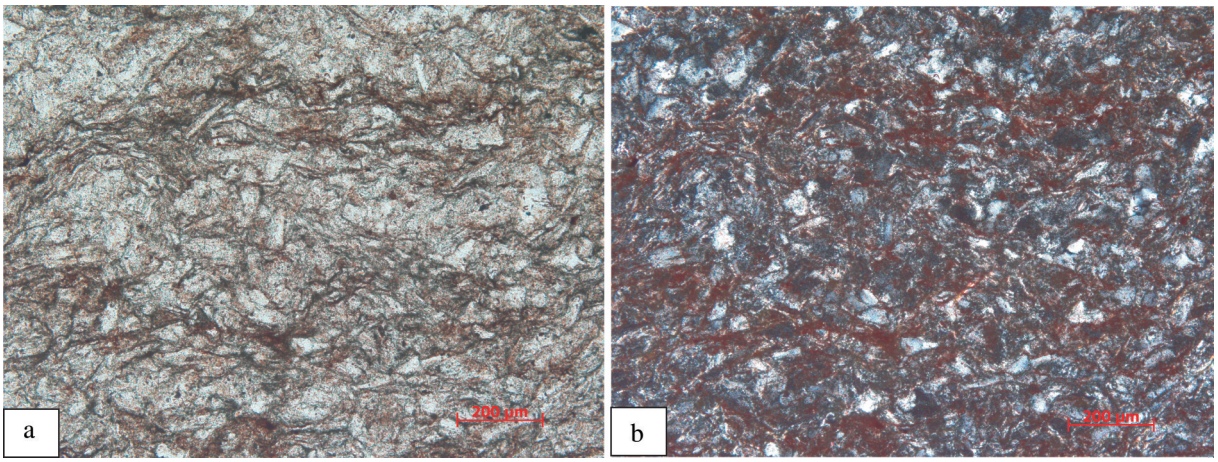

图5 洛峪口村洛峪口组流纹质凝灰岩(13YX212)显微照片(A 单偏光,B 正交偏光)

Fig. 5 Photomicrographs of the rhyolitic tuff sample13YX212 in the Luoyukou Formation at Luoyukou village (A-Plainlight, B-Crossed nicols)

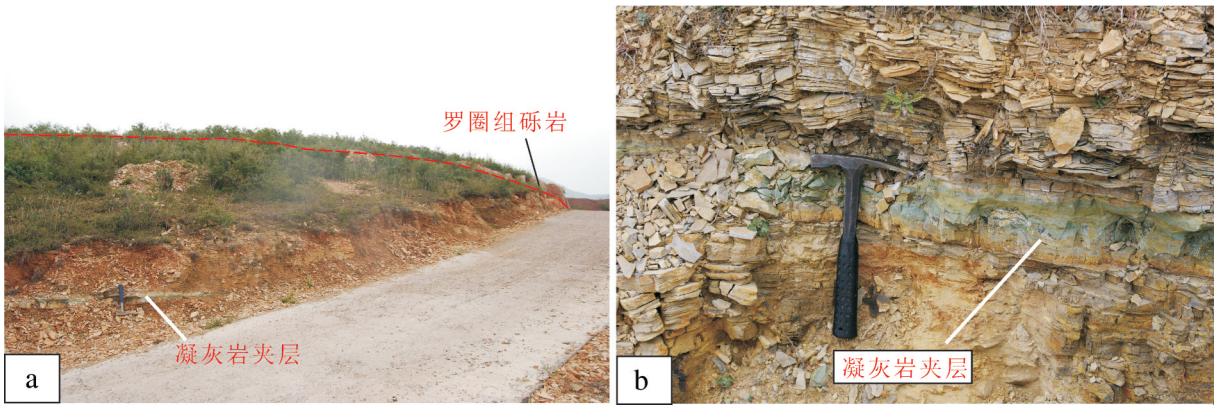

图6 河南汝阳阳坡村洛峪口组剖面灰绿色流纹质凝灰岩夹层特征

a—洛峪口组四段凝灰岩夹层及上覆罗圈组砾岩;b—采样的凝灰岩(13YX206)夹层

Fig. 6 Characteristics of the grayish green rhyolitic tuff in the Luoyukou Formation at Yangpo section, Ruzhou City, Henan Province

a-Tuff layer in the fourth member of Luoyukou Formation and overlying conglomerate in Luoquan Formation;
b-Sample of tuff layer (13YX206)

石CL图像显示锆石形态与13YX212十分相似(图8),自形、短柱状,晶棱清楚,发育生长环带,其Th/U比值均大于0.4(表2),同样显示岩浆锆石成因特征。该样品共测试32个锆石,Th、U含量分别为9×10^{-6}~89×10^{-6}和40×10^{-6}~196×10^{-6},Pb含量为13×10^{-6}~63×10^{-6}。从所测的数据看(表2),该样品U-Pb同位素体系保持的也很好,测点均落在谐和线上,谐和度有5个测点为98%,其余27个测点谐和度在99%~100%(谐和度计算方法据Liu et al., 2009)。32个锆石$^{207}Pb/^{206}Pb$分析数据为1575~1703 Ma,它们的$^{207}Pb/^{206}Pb$表面年龄加权平均值为(1634±10) Ma(95%的置信度,MSWD=1.3,n=32,图9),该年龄为岩石的形成年龄。

4 讨　论

4.1 洛峪口组形成时代

豫西中—新元古代地层时代归属一直存在争论。苏文博等(2012)在阳坡剖面获得洛峪口组沉凝灰岩U-Pb年龄(1611±8) Ma,为其归属中元古代长城纪提供了直接证据。但该年龄中的多数数据存在铅丢失,为25个数据点拟合的不一致线上交点年龄,其代表性仍需要进一步证明。本文在阳坡剖

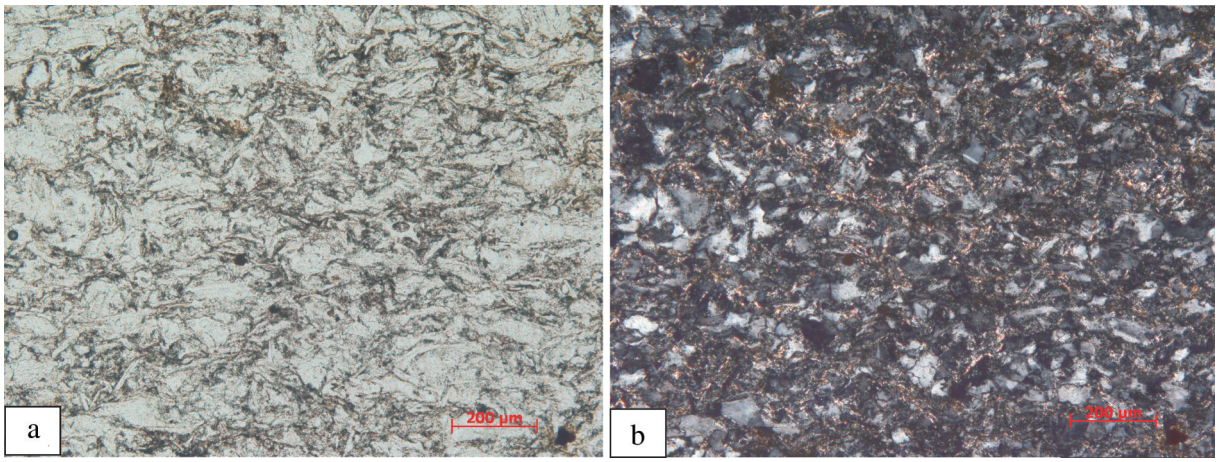

图7 阳坡村洛峪口组流纹质凝灰岩(13YX206)显微照片(a—单偏光;b—正交偏光)
Fig. 7 Photomicrographs of the rhyolitic tuff sample13YX206 in the Luoyukou Formation at Yangpo Village
(a−Plainlight, b−Crossed nicols)

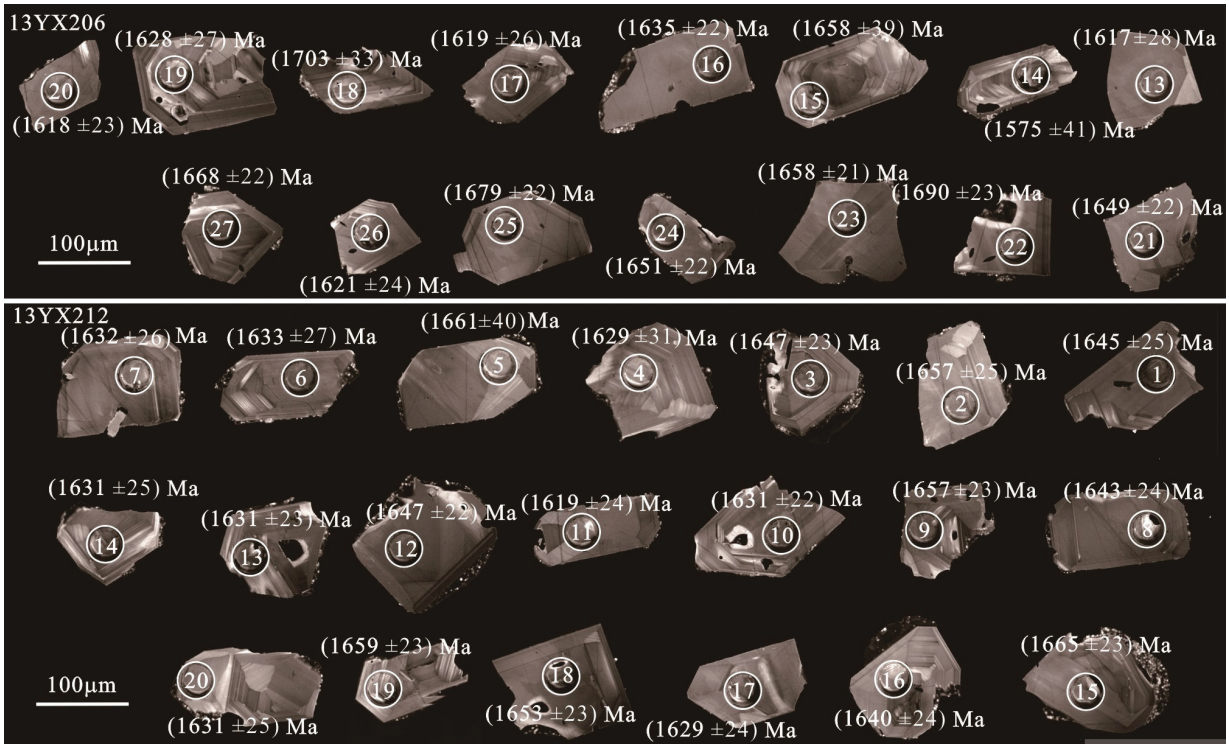

图8 洛峪口组凝灰岩(13YX212,13YX206)代表性锆石CL图像及测点位置
Fig. 8 Representative CL images and dating spots of zircons from tuff (13YX212,13YX206) of Luoyukou Formation

面顶部,即洛峪口组上部一层绿色凝灰岩中获得U−Pb锆石年龄(1634±10)Ma(图9,13YX206),明显较1611 Ma年龄(苏文博等,2012)偏老;同时在洛峪口村附近的洛峪口组上部凝灰岩中获得(1638±9)Ma年龄(图9,13YX212),二个不同地点的凝灰岩获得相近的年龄,精确地标定了洛峪口组的形成时代,即洛峪口组形成于长城纪晚期,接近长城纪与蓟县纪的分界时代(1600 Ma)。

4.2 豫西中新元古代地层划分与对比

洛峪口组位于洛峪群顶部;洛峪群之下为整合的汝阳群。根据洛峪口组获得的年龄,洛峪群—汝阳群时代自然归属长城纪,如果按照国际地层划分

表2洛峪口组凝灰岩LA-ICP-MIS锆石U-Pb分析结果

Table 2 Results of zircon U-Pb isotope LA-ICP-MS analyses of tuff from the Luoyukou Formation

号				$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ
13YX212 凝灰岩															
1	27	85	0.4617	0.1011	0.0027	4.052	0.115	0.2906	0.0026	1645	25	1645	47	1645	14
2	25	79	0.4445	0.1018	0.0027	4.053	0.117	0.2888	0.0031	1657	25	1645	47	1636	17
3	33	102	0.4515	0.1012	0.0026	4.052	0.109	0.2904	0.0026	1647	23	1645	44	1643	14
4	16	51	0.3539	0.1003	0.0034	4.006	0.138	0.2898	0.0027	1629	31	1635	56	1640	15
5	14	44	0.3740	0.1020	0.0044	4.076	0.177	0.2899	0.0028	1661	40	1650	72	1641	16
6	31	98	0.5348	0.1005	0.0029	4.004	0.123	0.2890	0.0029	1633	27	1635	50	1636	16
7	25	78	0.4903	0.1004	0.0028	4.024	0.120	0.2906	0.0028	1632	26	1639	49	1644	16
8	27	86	0.4746	0.1010	0.0027	4.079	0.110	0.2929	0.0028	1643	24	1650	45	1656	16
9	26	83	0.4497	0.1018	0.0026	4.100	0.110	0.2921	0.0028	1657	23	1654	44	1652	16
10	37	117	0.5420	0.1004	0.0024	4.028	0.105	0.2911	0.0027	1631	22	1640	43	1647	15
11	29	92	0.4684	0.0997	0.0026	3.962	0.113	0.2881	0.0033	1619	24	1626	46	1632	19
12	38	122	0.4333	0.1012	0.0023	4.042	0.107	0.2897	0.0036	1647	22	1643	44	1640	21
13	29	94	0.4265	0.1004	0.0025	3.988	0.105	0.2881	0.0026	1631	23	1632	43	1632	15
14	25	79	0.4924	0.1004	0.0027	4.022	0.120	0.2906	0.0029	1631	25	1639	49	1645	17
15	28	88	0.5198	0.1022	0.0026	4.111	0.112	0.2915	0.0025	1665	23	1656	45	1649	14
16	31	97	0.5560	0.1009	0.0026	4.048	0.109	0.2911	0.0029	1640	24	1644	44	1647	16
17	30	94	0.4626	0.1003	0.0026	3.999	0.112	0.2893	0.0030	1629	24	1634	46	1638	17
18	33	102	0.5438	0.1016	0.0026	4.082	0.111	0.2914	0.0027	1653	23	1651	45	1649	15
19	32	104	0.57	0.1019	0.0026	3.933	0.104	0.2800	0.0030	1659	23	1620	43	1591	17
20	25	80	0.40	0.1004	0.0027	3.971	0.114	0.2870	0.0029	1631	25	1628	47	1626	16
21	19	64	0.32	0.1011	0.0034	3.864	0.142	0.2770	0.0029	1645	31	1606	59	1576	16
22	50	134	0.33	0.1205	0.0027	5.900	0.150	0.3551	0.0041	1964	20	1961	50	1959	23
23	36	109	0.61	0.1009	0.0025	4.074	0.113	0.2928	0.0030	1641	23	1649	46	1655	17
24	17	60	0.06	0.1027	0.0034	4.109	0.141	0.2904	0.0031	1673	31	1656	57	1643	17
25	22	70	0.57	0.0995	0.0033	3.967	0.146	0.2890	0.0044	1615	30	1627	60	1637	25
26	21	68	0.49	0.0996	0.0028	3.998	0.121	0.2911	0.0028	1616	26	1634	49	1647	16
27	23	74	0.57	0.0998	0.0028	3.934	0.117	0.2858	0.0024	1621	26	1621	48	1620	13
28	23	76	0.49	0.0998	0.0029	3.907	0.123	0.2839	0.0021	1620	27	1615	51	1611	12
29	27	87	0.56	0.0996	0.0026	3.917	0.108	0.2853	0.0019	1616	25	1617	44	1618	11
30	27	89	0.57	0.0996	0.0026	3.928	0.110	0.2859	0.0022	1618	25	1620	45	1621	13
31	40	123	0.78	0.0996	0.0024	3.985	0.097	0.2902	0.0021	1616	22	1631	40	1642	12
32	32	104	0.535	0.1022	0.0025	4.015	0.106	0.2849	0.0022	1665	23	1637	43	1616	13
13YX206 凝灰岩															

续表2

点号	Pb/10^{-6}	U/10^{-6}	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	1σ
19	23	72	0.5212	0.1002	0.0022	4.044	0.092	0.2926	0.0022	1628	27	1643	37	1655	12
20	37	118	0.5276	0.0997	0.0018	4.011	0.076	0.2920	0.0026	1618	23	1636	31	1651	15

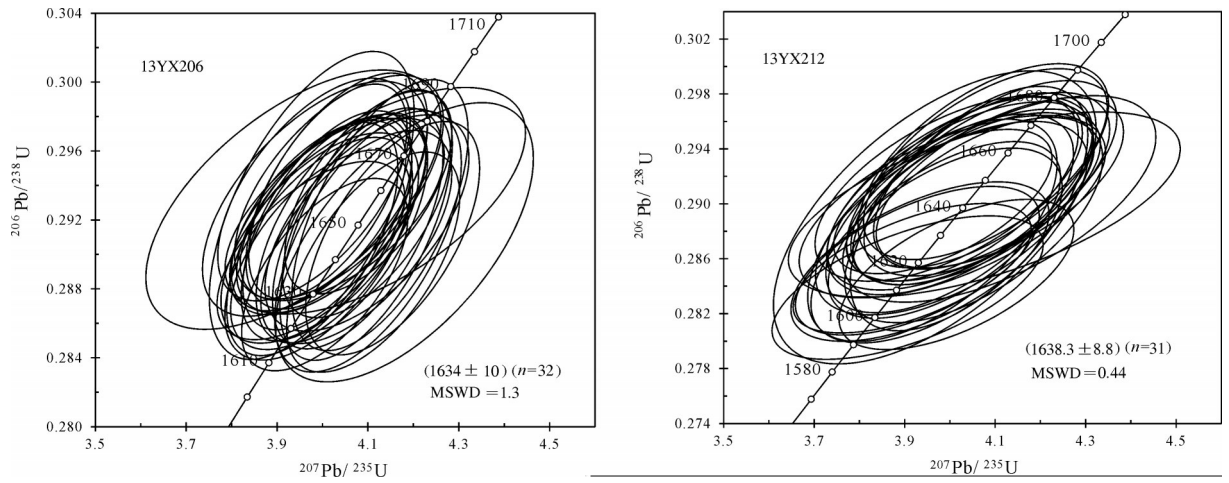

图9 洛峪口组凝灰岩13YX212和13YX206锆石U−Pb谐和曲线图

Fig.9 U−Pb concordia diagram of the zircons from the Luoyuzu Formation

表,它们属于固结纪晚期,表3为洛峪群—汝阳群地层划分新方案。考虑洛峪群与汝阳群为一套连续的沉积地层,在新的划分方案中,将洛峪群归入汝阳群。由于洛峪口组位于洛峪群—汝阳群顶部,接近固结纪与盖层纪的分界年龄1600 Ma,基本上限定了该套沉积地层的顶界时代,但其底界时代仍然没有定论。

汝阳群底界,前人曾做过一些工作,如李钦仲等(1985)在云梦山组火山岩中获得(1283 ±378)Ma(Rb−Sr)年龄,但由于方法的局限性可信度较低。最近,云梦山组底部砂岩获得最年轻碎屑锆石U−Pb年龄(1744±22)Ma(Hu et al., 2014),表明洛峪群—汝阳群为1.74 Ga之后的沉积产物。同时考虑下伏熊耳群形成时代在1.8~1.75 Ga(赵太平等,2004; He et al., 2009; Cui et al., 2011, 2013; Wang et al., 2010),可以推测汝阳群底界时代在1.75 Ga左右。也即豫西地区洛峪群—汝阳群形成时限可能在1600~1750 Ma。

如上所述,洛峪群—汝阳群归属长城纪,那么至少在豫西渑池—确山小区(河南省地质矿产局,1997)洛峪群—汝阳群之上缺失了大部分中新元古代地层。与冀北对比,缺失了相当于蓟县系—待建系(高于庄组—下马岭组)的一套地层。但是,在豫西地区是否真的没有发育其上的地层还不能定论,

表3 豫西地区中新元古代地层划分新方案

Table 3 New chart of the Meso-Neoproterozoic stratigraphic classification of the southern margin of the North China Craton

因为豫西的嵩山小区、华熊小区中还分布着五佛山群、栾川群和官道口群,至少目前的研究程度还不能排除他们不属于中新元古代地层的可能性。值得注意的是,豫西洛峪口组凝灰岩年龄(~1634 Ma)与蓟县大洪峪组(~1625 Ma)基本相当(略大),考虑蓟县剖面常州沟组底界年龄小于1670 Ma(李怀坤等,2011),豫西最底部云梦山组底界小于1744 Ma(Hu et al., 2014),且它不整合在熊耳群1750 Ma之上,可以推测,豫西地区该套地层沉积开始的时代要老于蓟县地区,也就是说该地区很可能发育了华北克拉通最老的中元古代地层。而且,如果将洛峪口组凝灰岩、大红峪组碱性火山岩与华北南缘相近时代的龙王撞碱性侵入体(陆松年等,2003)综合考虑,这次岩浆活动很可能与哥伦比亚超大陆的裂解有关(Zhai et al., 2000; Lu et al., 2002; Zhai and Santosh, 2011; Zhao et al., 2011; Peng et al., 2008)。可见,洛峪口组精确年代的获得,对豫西及整个华北克拉通中新元古代地层划分与对比、构造背景演化及其与超大陆的关系研究均具有十分重要的意义。

4.3 豫西南中元古代地层中后生生物演化的重新思考

豫西南中元古代地层洛峪群—汝阳群赋含的后生生物序列主要为具刺的疑源类化石(阎玉忠和朱士兴,1992;尹崇玉和高林志,1995,1999;Yin,1997;尹磊明等,2003,2004;高维等,2011)、宏观藻类化石(尹崇玉和高林志,2000)及后生生物遗迹化石(胡建民等,1991,1997;齐永安,2005)。根据具刺的疑源类化石,一些研究者推测洛峪群—汝阳群属于新元

古代(阎玉忠和朱士兴,1992;尹崇玉和高林志,1995,1999;李猛等,2012),另一些研究者认为它们归属中元古代与新元古代之间(Yin,1997;尹磊明等,2003;尹磊明和袁训来,2003),同时也疑惑为什么在中元古代地层中出现新元代的化石(Xiao et al., 1997)? 而洛峪口组中富含的宏观藻类,也支持洛峪群归属新元代(尹崇玉和高林志,2000)。然而,这些后生生物化石的动物学属性及对地层时代是否能够给予精确的厘定也受到了质疑(罗翠和朱茂炎,2010),现阶段后生动物化石处于通过不断的发现和研究,确定包括刺球藻类的等生物产出层位和出现于什么时代,而不是相反(武铁山,2002)。换言之,后生生物化石不能精确地限定地层的时代。

目前洛峪口组时代的精确测定,表明洛峪群—汝阳群时代均形成于1600 Ma之前,与后生生物给出的地层时限差距很大,提示用后生生物来限定地层时代应该谨慎,自然该套地层的后生生物起源时代及演化也需要重新认识。若这些后生生物确认无疑的话,洛峪群洛峪口组中的具刺疑源类化石时代,应该形成于1634 Ma或者1638 Ma左右,汝阳群白草坪组的具刺凝源类化石应形成于1634~1750 Ma(熊耳群),即它们均形成于中元代长城纪。更为重要的是,这些具刺疑源类化石,个体大,刺分叉有细网,它们是进化较高的一类微化石群体(阎玉忠和朱士兴,1992),那么完全可以推测,会有更加古老后生生物祖先的存在。而对华北南缘中元古代地层的深入研究,将有可能发现更加原始的生命遗迹,这对早期生命的起源和演化等重大科学问题具有重要意义。

5 结 论

(1)通过对河南汝州洛峪口村及阳坡村洛峪口组上部凝灰岩锆石LA-MC-ICPMS U-Pb同位素测年,获得了(1638±9)Ma和(1634±10)Ma的年龄,表明该组地层形成于长城纪晚期,按照国际地层划分表,归属固结纪。

(2)洛峪口组时代的确定,也意味着豫西地区洛峪群—汝阳群时代均归属长城纪(固结纪)。揭示至少在豫西渑池—确山地区缺失了大量的中新元古代地层。它对整个华北克拉通中新元古代地层的划分与对比,形成的大地构造背景及与超大陆演化的关系研究均具有十分重要的意义。

(3)赋存于洛峪群—汝阳群的后生生物可能形成于1600~1750 Ma,其祖先的起源时代可能更早。对它们开展系统深入的研究,对生命起源及演化具有重要意义。

致谢:本文在锆石阴极发光拍摄及测年过程中得到天津地质调查中心郭虎、耿建珍等帮助;成文过程与孙立新研究员进行了有益的讨论,在此表示衷心的感谢。

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