沉积学报
ACTA SEDIMENTOLOGICA SINICA
ISSN 1000-0550
CN 62-1038/P

扬子陆块西北缘旺苍地区火地垭群沉积时代、物源及构造意义——来自碎屑锆石U-Pb年代学的约束

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引用本文:
邓奇, 汪正江, 宁括步, 等. 扬子陆块西北缘旺苍地区火地垭群沉积时代、物源及构造意义——来自碎屑锆石U-Pb年代学的约束[J]. 沉积学报, 2024, 42(6): 1948-1957.
DENG Qi, WANG ZhengJiang, NING KuoBu, et al. Depositional Age, Provenance and Tectonic Significance of the Huodiya Group in the Wangcang Area, Northwestern Margin of the Yangtze Block: Constraints from detral zircon U-Pb geochronology[J]. *Acta Sedimentologica Sinica*, 2024, 42(6): 1948-1957.

文章编号:1000-0550(2024)06-1948-10 DOI: 10.14027/j.issn.1000-0550.2024.014

扬子陆块西北缘旺苍地区火地垭群沉积时代、物源及构造意义
——来自碎屑锆石U-Pb年代学的约束

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摘 要 **【目的】**火地垭群是扬子陆块西北缘前寒武纪重要的地层单元,同时也是中国重要的石墨矿含矿层位,但其沉积时代、物源及形成的构造背景长期存在争论。**【方法】**对旺苍地区火地垭群上两组的绢云千枚岩进行了LA-ICP-MS锆石U-Pb定年研究。**【结果与结论】**获得碎屑锆石的年龄范围为832~988 Ma,集中分布于832~843 Ma 、855~883 Ma 、895~936 Ma 和952~973 Ma 四个区间,最大沉积年龄为837.6±6.0 Ma(MSWD=0.60,n=5)。结合已有研究成果,将旺苍地区火地垭群的沉积时代限定为910~835 Ma,而非前人长期认为的中元古代;物源主要来自周围的岩体,主体方向为东(南)和西北;综合沉积时代、物源、碎屑锆石年龄及区域地质特征,旺苍地区火地垭群上两组形成于接收双向物源的弧后盆地,是Rodinia超大陆聚合晚期在扬子陆块西北缘的响应。

关键词 火地垭群;沉积时代;物源;锆石U-Pb定年;扬子陆块;新元古代

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中图分类号 P512.2 **文献标志码** A

0 引言

新元古代是地球演化历史上重大的变革时期之一,该时期全球发生了一系列重要的地质事件,特别是罗迪尼亚(Rodinia)超大陆由聚合向裂解的转换,以及对全球海平面变化、大气含氧量变化、气候变化、矿产资源形成及生命演化等有着深刻、广泛的影响[1-6]。扬子陆块因参与了Rodinia超大陆的聚散过程而备受关注,也造就了该时期时空各异的盆山结构,其形成演化过程一直是国际研究的热点和难点[7-12]。一方面,许多原来被认为中元古代褶皱基底的地层实际为新元古代,如扬子陆块东南缘的冷家溪群形成于860~830 Ma,江南造山带的形成时间要晚于全球格林威尔造山期[13-15];另一方面,现有成果多集中在岩浆岩领域[16-22],极少将岩浆岩、沉积地层和物源相结合来综合分析盆地的性质与演化。随着研究的不断深入,扬子陆块周缘的构造演化及盆山格局需要重新认识。

沉积地层时代的确定是区域地层划分对比的重要依据,也是进行古地理重建和沉积盆地演化研究的重要前提[23-28]。物源作为连接造山带与沉积盆地的纽带,能够反映块体亲缘关系、古地理格局、盆地性质、构造演化等关键信息[29-34]。因此,地层时代和物源的确定,可以有效制约区域大地构造背景和构造演化过程。

火地垭群是扬子陆块前寒武纪重要的地层单元,创名于四川南江,原称火地垭层,并与三峡陡山沱组进行对比[35]。经过一系列的变革,现指铁船山组之下、后河杂岩之上的一套岩系,自下而上划分为麻窝子组和上两组。早期火地垭群的沉积时限主要是依据野外地质关系、变质程度和叠层石进行约束,多被置于中元古代,其形成时代、物源和大地构造背景

收稿日期:2023-12-02;**修回日期**:2024-01-20;**录用日期**:2024-03-08;**网络出版日期**:2024-03-08
基金项目:四川省自然科学基金项目(2023NSFSC0275,2023ZYD0153);国家自然科学基金项目(41772115,U2344209);中国地质调查局项目(DD20230208,DD20230227)[**Foundation**: Natural Science Foundation of Sichuan Province, No. 2023NSFSC0275, 2023ZYD0153; National Natural Science Foundation of China, No. 41772115, U2344209; China Geological Survey Project, No. DD20230208, DD20230227]

对理解扬子陆块西北缘乃至整个华南前寒武纪构造演化至关重要。虽然也有少量K-Ar和U-Pb法年龄数据的报道[35-36],但其数据的准确度不高,因此其形成时代存在较大争论,一种观点认为是中元古代中晚期的产物,可与扬子陆块北缘神农架群和打鼓石群进行对比[37];另一种观点认为其时代为中元古代早期,与西缘东川群等是同时代的产物[38]。另外,火地垭群的物源特征、沉积大地构造背景等也鲜有研究和报道。鉴于此,对四川旺苍地区火地垭群进行了碎屑锆石U-Pb年代学研究,目的在于(1)限定火地垭群的沉积时代,分析其物源特征;(2)结合已有研究成果,综合判定火地垭群形成的大地构造背景,从而为重建区域构造演化历史提供依据。

1　区域地质概况及样品特征

研究区位于扬子陆块西北缘米仓山地区,其北侧为汉南古隆起和秦岭造山带,西接龙门山推覆构造带,东邻大巴山推覆构造带(图1a)。米仓山地区出露的前震旦纪岩石地层主要有后河杂岩、火地垭群和铁船山组,以及大面积的侵入岩(图1b)。后河杂岩由原火地垭群解体出来,主要由花岗质片麻岩、混合岩、斜长角闪岩等组成[39];铁船山组分布于碑坝地区,以火山岩和火山碎屑岩为主,其流纹岩锆石U-Pb定年为817±5 Ma[40]。区内前寒武纪岩浆侵入活动较为强烈,岩性主要为辉长岩、闪长岩、花岗闪长岩、花岗岩等,时代多为新元古代[19]。如前所述,火地垭群是区内重要的前寒武纪地层单元,同时也是中国重要的石墨矿含矿层位,主要分布于四川的旺苍—南江地区、陕西的碑坝地区,与下伏的后河杂岩和上覆的铁船山组或震旦系观音崖组均为不整合接触,包括下部麻窝子组和上部上两组,其中麻窝子组主要为长英角岩、(石墨)大理岩、白云岩、钙质板岩、硅质板岩、碳质板岩、钙质砾岩、白云母片岩等;上两组以绢云板岩、粉砂质板岩、碳质板岩、绿泥板岩、白云质灰岩、绢云千枚岩、石英片岩、变砂岩为主(图2)。

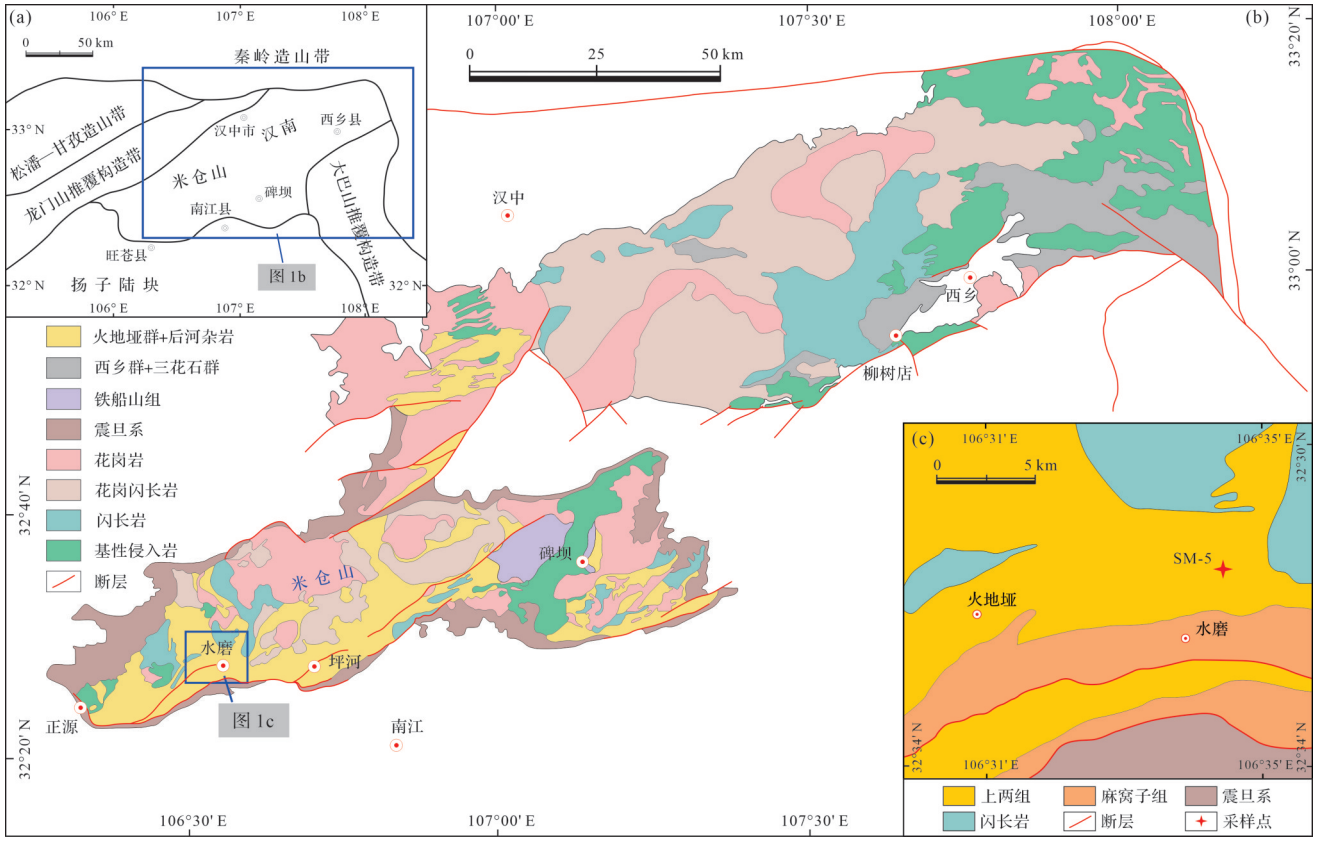

图1　(a)扬子陆块北缘及周缘构造纲要及研究区大地构造位置图(据文献[23]修改);(b)米仓山—汉南地区前寒武纪地质简图(据文献[19]修改);(c)研究区区域地质图

Fig.1　(a) Tectonic outline of the northwestern margin of the Yangtze Block and its periphery and the tectonic position of the study area (modified from reference [23]); (b) simplified geological map showing the distribution of Precambrian rocks in the Micangshan and Hannan area (modified from reference [19]); (c) regional geological map of the study area

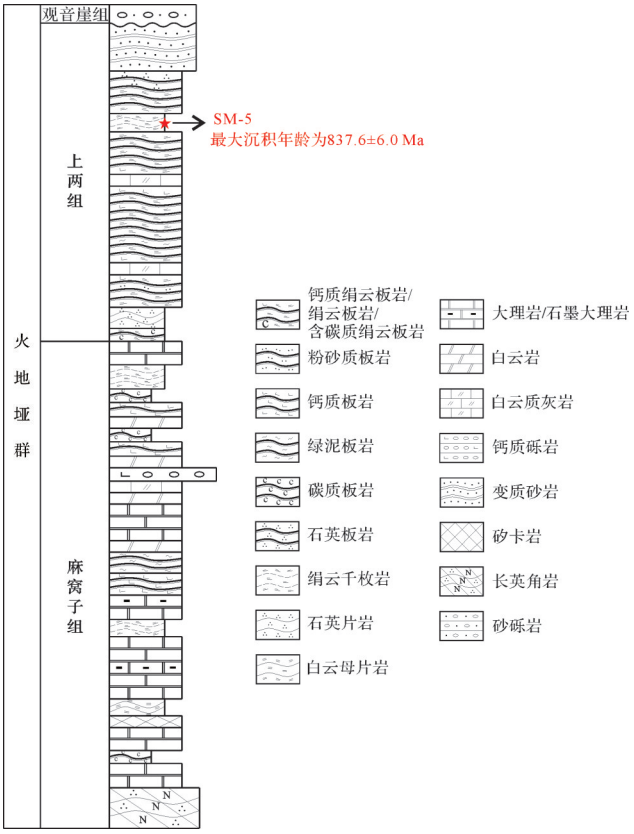

图2 旺苍地区火地垭群综合柱状图
(据文献[35]、内部资料①修改)

Fig.2 Comprehensive stratigraphic column of the Huodiya Group in the Wangcang area
(modified from reference [35], research report①)

样品SM-5采于旺苍县水磨镇北东约8 km处(图1c),位于火地垭群上两组的上部,上下均为绢云板岩,野外露头呈灰色,中—薄层状,向上地层厚度变厚、岩石粒度变粗(图2),地理坐标为32°28′27″ N、106°34′24″ E。

显微镜下观察表明,岩石具斑点状结构,基质为粒状鳞片状变晶结构、千枚状构造。岩石原岩为粉砂质泥岩,由粉砂级碎屑和泥质组成。主要成分为泥质,其成分主要为黏土矿物及粒径小于0.005 mm的长英质成分,约占岩石总量的65%;砂级碎屑,主要为粉砂级的长英质碎屑,少量碎屑粒径达细粒级,约占岩石总量的35%。在后期变质作用下,岩石中大部分泥质变质为鳞片状的绢云母和微粒的石英,绢云母定向排列,呈千枚状构造;岩石中未变质的黏土矿物与少量的石英碎屑、鳞片状的绢云母形成斑点状的集合体,斑点呈椭圆状、透镜状,其长轴方向与千枚理方向一致,斑点粒径介于0.5~2.0 mm,含量约占总量的15%。镜下定名为斑点状绢云千枚岩(图3)。

2 分析方法

岩石样品经破碎、淘洗、重液分离和电磁分离后,在双目镜下挑选晶形完好、具有代表性的锆石颗粒粘在树脂台上,打磨抛光,制成样靶,然后对锆石进行反射光、透射光显微照相和阴极发光(CL)图像分析,确定锆石的内部结构和成因,以选取最佳的待测锆石部位。锆石U-Pb同位素定年和微量元素含量在武汉上谱分析科技有限责任公司利用LA-ICP-MS同时分析完成。GeolasPro激光剥蚀系统由COMPexPro 102 ArF 193 nm准分子激光器和MicroLas光学系统组成,ICP-MS型号为Agilent 7700e。本次分析的激光束斑为32 μm。U-Pb同位

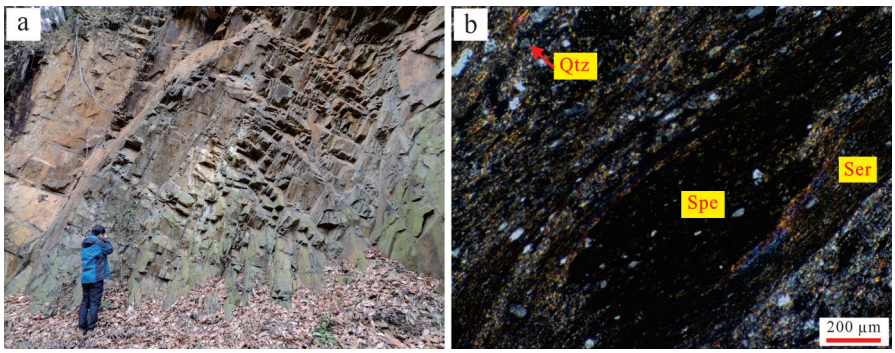

图3 旺苍地区火地垭群上两组绢云千枚岩样品SM-5野外露头(a)和镜下显微照片(b)
Qtz.石英;Ser.绢云母;Spe.斑点

Fig.3 Field photographs (a) showing outcrops and photomicrographs (b) illustrating petrographic characteristics of sericite phyllite sample SM-5 from the Shangliang Formation of the Huodiya Group in the Wangcang area

①四川省地质局第2区测队. 南江幅I-48-35 1/20万区域地质测量报告[R]. 北京:全国地质资料馆,1965.

素定年和微量元素含量处理中采用锆石标准91500和玻璃标准物质NIST610作外标分别进行同位素和微量元素分馏校正。每个时间分辨分析数据包括20~30 s空白信号和50 s样品信号。详细的仪器参数和分析流程见文献[41]。

3　分析结果

样品SM-5锆石粒度较小,长轴一般介于60~100 μm,长宽比以1.5∶1~2∶1为主。锆石多呈自形至半自形、棱角状至次圆状的形态特征,少数表面发育裂纹。阴极发光(CL)图像中,绝大部分锆石显示岩浆振荡环带结构,指示岩浆成因。根据磨蚀程度,这些锆石可大致分为两类:第一类以自形为主,棱角分明;第二类有不同程度的磨圆,多呈自形至半自形、次棱角状至次圆状的形态特征(图4)。

对该样品的41颗锆石进行了41个分析点的U-Pb同位素年龄测定,分析结果列于表1。其中40颗给出了有效年龄(谐和度≥90%),这些有效年龄颗粒的Th和U的含量分别介于13×10^{-6}~315×10^{-6}和29×10^{-6}~492×10^{-6},Th/U比介于0.30~1.22,也说明它们为岩浆结晶的产物。40个有效年龄介于832~988 Ma,集中分布于832~843 Ma、855~883 Ma、895~936 Ma和952~973 Ma四个区间;相对概率峰值为ca. 840 Ma、ca. 868 Ma、ca. 918 Ma、ca. 954 Ma(图5)。最年轻一组锆石^{206}Pb/^{238}U年龄的加权平均值为837.6±6.0 Ma(MSWD=0.60,n=5)(图5a),代表了该样品的最大沉积年龄。

4　讨论

4.1　沉积时代

如前所述,早期火地垭群虽然有一些数据的报道,但由于受测定方法所限,其年龄数据的准确度均不高。如四川省地质矿产局[35]根据侵入火地垭群角闪辉石岩1 065 Ma的K-Ar年龄和石英闪长岩956 Ma的U-Pb年龄,将火地垭群限定为中元古代;何政伟等[36]在火地垭群上两组纤闪钠长黑云千枚岩中获得单颗粒锆石Pb-Pb年龄为1 619±28 Ma,而麻窝子组含华北蓟县系贝加尔叠层石、喀什叠层石、铁岭叠层石等,时限相当于1 000~1 400 Ma,因此将上两组置于麻窝子组之下,时代也定为中元古代[42]。最近,Li *et al.*[43]对陕西碑坝地区麻窝子组的砾岩进行锆石U-Pb定年研究,获得砾岩最大的沉积年龄为1 970±27 Ma,并根据区域上ca. 1.79 Ga的白玉花岗岩[44],将麻窝子组砾岩的沉积时代限定在1.79~1.97 Ga[43]。值得一提的是,碑坝地区ca. 1.79 Ga花岗岩与火地垭群没有确凿的侵入关系的证据,因此根据花岗岩的侵位年龄来限定火地垭群的上限年龄有待商榷。

限定地层单元的绝对年龄,提供地层的最大沉积年龄是碎屑锆石U-Pb年代学的重要应用之一,高质量的碎屑锆石定年数据对限定地层时代十分有效[45-46]。所采的绢云千枚岩(SM-5)位于火地垭群上部,其锆石最年轻一组^{206}Pb/^{238}U年龄的加权平均值为837.6±6.0 Ma(MSWD=0.60,n=5),代表了样品的最大沉积年龄。如前所述,本次样品的锆石可分为两类,最年轻一组的锆石棱角分明,而其他组(较老)锆石

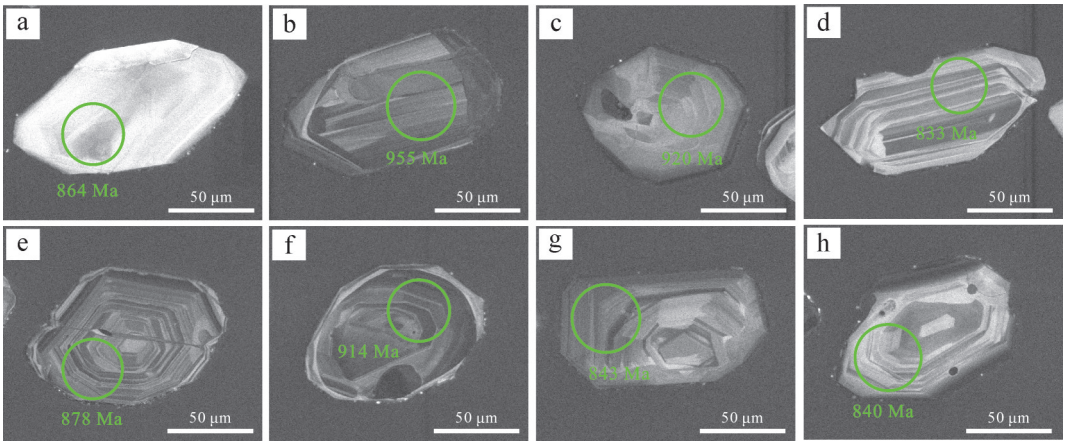

图4　旺苍地区火地垭群上两组绢云千枚岩样品SM-5代表性锆石CL图像(比例尺均为50 μm)

(a)SM-5-07;(b)SM-5-10;(c)SM-5-12;(d)SM-5-13;(e)SM-5-16;(f)SM-5-25;(g)SM-5-27;(h)SM-5-35

Fig.4　Cathodeluminescence (CL) images of typical zircon grains of sericite phyllite sample SM-5 from the Shangliang Formation of the Huodiya Group in the Wangcang area

表1 旺苍地区火地垭群上两组绢云千枚岩样品SM-5锆石U-Pb 同位素定年结果

Table 1 Zircon U-Pb isotope data of the sericite phyllite sample SM-5 from the Shangliang Formation of the Huodiya Group in the Wangcang area

测试点号	Th/U	同位素比值						同位素年龄/Ma						谐和度/%
		$^{207}Pb/^{206}Pb$	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	
1	0.54	0.071 7	0.002 2	1.577 7	0.045 9	0.159 5	0.001 5	976	57.0	961	18.1	954	8.6	99
2	0.55	0.069 7	0.002 6	1.388 6	0.051 3	0.144 6	0.001 4	918	78.0	884	21.8	871	8.0	98
3	0.75	0.070 9	0.002 4	1.510 8	0.048 2	0.154 2	0.001 2	955	68.0	935	19.5	924	6.5	98
4	0.53	0.073 2	0.002 4	1.611 6	0.050 7	0.159 8	0.001 5	1 020	68.0	975	19.7	956	8.6	98
5	0.69	0.081 4	0.002 8	1.610 0	0.052 5	0.143 3	0.001 5	1 232	67.0	974	20.4	863	8.3	87
6	0.66	0.070 5	0.001 9	1.406 8	0.037 4	0.144 0	0.001 2	943	54.2	892	15.8	867	6.6	97
7	0.71	0.066 0	0.002 5	1.303 6	0.048 7	0.143 4	0.001 8	807	78.9	847	21.5	864	10.2	98
8	0.75	0.067 5	0.001 8	1.324 8	0.035 9	0.142 2	0.001 5	852	55.6	857	15.7	857	8.7	99
9	0.43	0.069 2	0.001 9	1.332 0	0.035 8	0.139 3	0.001 2	906	52.8	860	15.6	841	7.1	97
10	0.30	0.071 1	0.001 6	1.573 5	0.034 3	0.159 7	0.001 1	961	44.4	960	13.6	955	5.9	99
11	0.47	0.072 2	0.002 6	1.588 8	0.053 5	0.161 2	0.002 0	992	74.1	966	21.0	963	11.3	99
12	0.63	0.068 2	0.001 8	1.445 6	0.039 7	0.153 4	0.001 7	876	55.6	908	16.5	920	9.3	98
13	1.22	0.065 9	0.002 2	1.251 9	0.040 7	0.137 9	0.001 4	806	70.4	824	18.4	833	7.7	98
14	0.43	0.068 0	0.003 6	1.402 3	0.067 5	0.152 2	0.002 0	878	105.0	890	28.5	913	11.4	97
15	0.58	0.072 1	0.003 3	1.449 3	0.065 0	0.146 9	0.002 0	991	93.4	910	26.9	883	11.3	97
16	0.53	0.072 0	0.001 5	1.454 4	0.032 4	0.145 9	0.001 3	985	42.6	912	13.4	878	7.3	96
17	0.46	0.069 0	0.002 1	1.431 5	0.040 8	0.150 7	0.001 3	898	65.7	902	17.0	905	7.4	99
18	0.71	0.073 3	0.001 8	1.527 3	0.037 1	0.151 2	0.001 4	1 022	51.1	941	14.9	907	7.6	96
19	0.76	0.069 4	0.001 7	1.489 8	0.037 4	0.155 4	0.001 5	909	50.8	926	15.2	931	8.4	99
20	0.51	0.074 9	0.003 0	1.550 6	0.059 2	0.151 0	0.001 7	1 065	80.1	951	23.6	907	9.8	95
21	0.90	0.072 6	0.001 3	1.665 5	0.032 6	0.165 6	0.001 5	1 003	36.7	995	12.4	988	8.1	99
22	0.54	0.071 1	0.001 4	1.601 7	0.031 6	0.162 8	0.001 4	961	39.7	971	12.3	973	7.5	99
23	0.45	0.073 1	0.001 7	1.551 7	0.035 7	0.153 7	0.001 3	1 017	48.2	951	14.2	922	7.4	96
24	0.67	0.071 1	0.002 1	1.516 6	0.045 8	0.154 2	0.001 6	961	61.1	937	18.5	924	9.0	98
25	0.64	0.069 7	0.001 5	1.470 3	0.033 3	0.152 4	0.001 4	920	44.4	918	13.7	914	7.6	99
26	0.30	0.070 1	0.001 3	1.546 3	0.028 9	0.159 2	0.001 1	931	37.0	949	11.5	952	6.2	99
27	0.73	0.070 3	0.001 7	1.360 5	0.032 7	0.139 7	0.001 0	939	49.2	872	14.1	843	5.9	96
28	0.81	0.072 4	0.001 7	1.516 9	0.034 3	0.151 5	0.001 3	998	47.1	937	13.9	909	7.2	96
29	0.76	0.071 8	0.001 9	1.511 5	0.038 7	0.152 2	0.001 2	989	53.2	935	15.6	913	7.0	97
30	0.64	0.068 1	0.002 0	1.455 7	0.042 0	0.154 5	0.001 6	872	60.0	912	17.4	926	8.9	98
31	0.34	0.069 8	0.002 2	1.456 8	0.043 8	0.151 2	0.001 5	924	64.8	913	18.1	908	8.4	99
32	0.62	0.068 0	0.001 7	1.295 7	0.030 5	0.137 7	0.001 0	878	50.0	844	13.5	832	5.9	98
33	0.56	0.069 5	0.001 6	1.472 0	0.032 8	0.153 0	0.001 2	922	47.1	919	13.5	918	6.7	99
34	0.58	0.068 5	0.002 2	1.336 3	0.040 3	0.141 9	0.001 5	883	65.6	862	17.5	855	8.4	99
35	0.58	0.067 4	0.002 6	1.294 6	0.050 0	0.139 3	0.001 6	850	79.6	843	22.1	840	9.1	99
36	0.49	0.070 5	0.001 7	1.584 8	0.040 6	0.162 2	0.001 5	944	50.0	964	16.0	969	8.3	99
37	0.46	0.068 7	0.001 9	1.480 7	0.041 3	0.155 9	0.001 5	900	57.4	923	16.9	934	8.1	98
38	1.00	0.069 3	0.001 5	1.465 8	0.031 6	0.153 1	0.001 2	906	45.2	916	13.0	918	6.7	99
39	0.66	0.069 0	0.002 3	1.480 6	0.047 7	0.156 3	0.001 6	900	70.4	922	19.5	936	8.8	98
40	1.05	0.073 9	0.001 9	1.581 2	0.039 1	0.154 9	0.001 3	1 039	50.0	963	15.4	928	7.2	96
41	0.54	0.071 4	0.001 9	1.469 1	0.037 9	0.148 9	0.001 3	969	49.5	918	15.6	895	7.5	97

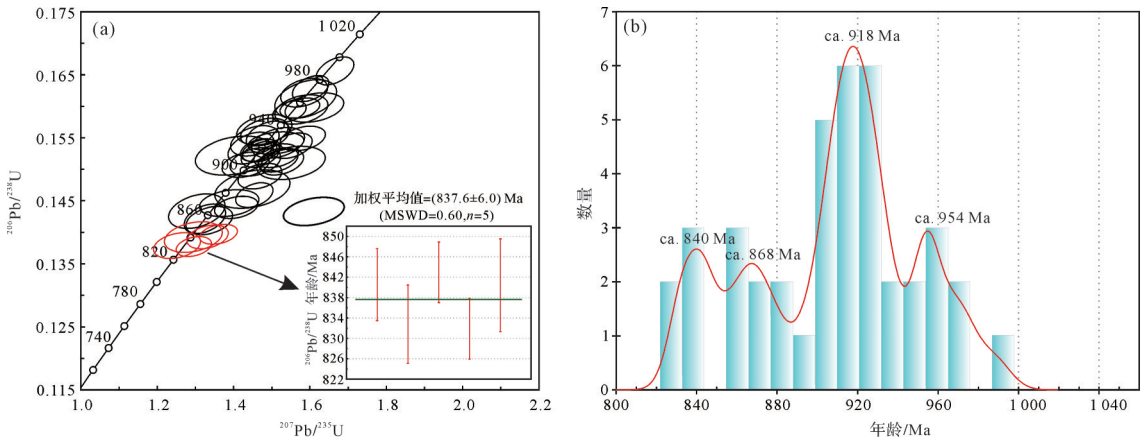

图5　旺苍地区火地垭群上两组绢云千枚岩样品SM-5锆石U-Pb年龄谐和图(a)与年龄分布直方图(b)

Fig.5　U-Pb isotopic Concordia diagrams (a) and age histograms (b) of sericite phyllite sample SM-5 from the Shangliang Formation of the Huodiya Group in the Wangcang area

多有搬运磨蚀痕迹,呈次棱状至圆状(图4),因此最年轻一组锆石有同沉积火山灰喷发形成的可能,其838 Ma的年龄应该趋近于顶界年龄。另外,火地垭群上覆铁船山组流纹岩锆石U-Pb定年为817±5 Ma[40],而火地垭群和铁船山组之间又为不整合接触,因此火地垭群的沉积时限应大于817 Ma,其上限年龄在838~817 Ma。鉴于上述讨论,将旺苍地区火地垭群的顶界年龄限定为ca. 835 Ma。汪正江等①从火地垭群下部凝灰岩中获得锆石U-Pb年龄为ca. 907 Ma。据此,进一步将旺苍地区火地垭群的沉积时代限定为910~835 Ma,而非前人长期认为的中元古代,可与扬子陆块东南缘冷家溪群及其相当地层进行对比。

4.2　沉积物源及对构造背景的启示

火地垭群上两组上部的碎屑锆石U-Pb有效年龄记录了多期构造热事件,统计表明主要分布于832~843 Ma、855~883 Ma、895~936 Ma和952~988 Ma四个区间,相对概率峰值为ca. 840 Ma、ca. 868 Ma、ca. 918 Ma、ca. 954 Ma(图5)。这几期岩浆事件在研究区的周围均有发现,如Dong *et al.*[19]报道了米仓山地区840±6 Ma的南江闪长岩、838±17 Ma的光雾山正长花岗岩、871±77 Ma的旺苍花岗闪长岩;Zhou *et al.*[47]获得米仓山地区坪河霓霞岩的年龄为891±7 Ma;Berkana *et al.*[22]报道了旺苍地区865~860 Ma的火山岩;凌文黎等[48]和Luo *et al.*[21]分别获得碑坝地区花岗闪长岩和辉长岩的年龄为863±10 Ma和879±6 Ma;Wu *et al.*[49-50]发现略阳地区985~930 Ma的岩浆岩,并认为其形成于格林威尔期的洋内弧环境。由于研究区未出露比火地垭群更老的地层,且样品的锆石形态以近源特征为主(图4),因此认为火地垭群的物源主要来自上述周围的岩体。905~988 Ma可作为物源的岩浆岩主要出露于研究区西北部的略阳地区,而832~843 Ma和855~883 Ma的岩浆岩在研究区的西北部和东(南)部(碑坝地区)均有发育,因此火地垭群上两组的物源可能西北部和东(南)部均有供应。

碎屑锆石近年来在约束构造背景方面发挥了重要作用[51],汇聚板块边缘以强烈的岩浆活动为特征,在这种背景下的沉积盆地中存在大量结晶年龄与寄主岩石沉积时代非常接近的碎屑锆石颗粒(50%以上),如弧前盆地和海沟盆地碎屑锆石年龄谱存在一个与沉积年龄接近的年龄单峰,而弧后盆地随着与相邻陆块的距离而展现不同的年龄谱;相比而言,形成于碰撞和伸展构造背景下的沉积物中则包含更多年龄偏老的锆石颗粒。如果将838 Ma作为上两组样品SM-5的沉积年龄,其碎屑锆石结晶年龄(CA)与沉积年龄(DA)之差小于150 Ma的碎屑锆石比例为98%,该特征指示样品可能形成于汇聚构造环境,考虑到样品的碎屑锆石年龄呈多峰式分布,倾向认为形成于弧后盆地。另外,米仓山地区ca. 860 Ma与俯冲相关的基性岩脉[52]、ca. 840 Ma弧相关的中酸性侵入岩[19]、865~860 Ma的富Nb玄武岩[22],碑坝地区ca. 860 Ma形成于弧后伸展背景的I型花岗岩[21]等都证实了该时期弧环境的存在。以目前的研究成果来

①待刊.

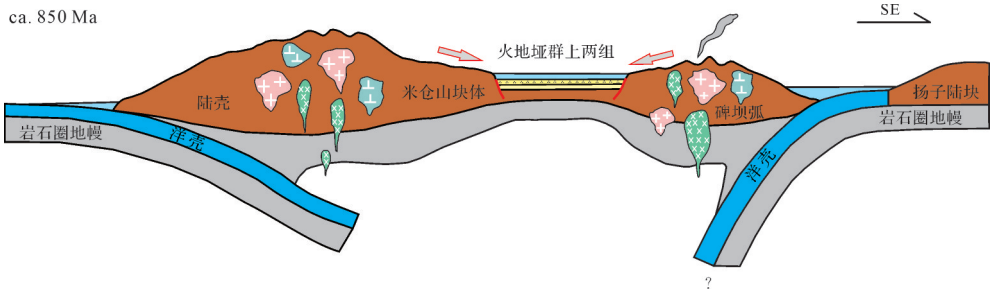

图6 扬子陆块西北缘新元古代早期构造演化示意图

Fig.6 Simplified cartoon model showing the evolution of the northwestern margin of the Yangtze Block during the Early Neoproterozoic

看,本次研究的旺苍地区火地垭群从岩石组合、地层序列和碎屑锆石年龄谱系特征等方面均与碑坝地区的火地垭群存在差异,如果它们产于同一沉积盆地,应该能接收到相似的物源信息,特别是碑坝地区发育了大规模879~860 Ma的岩浆岩,但是碑坝地区的火地垭群中并未发现该时期的锆石信息[43],且有资料认为碑坝地区该时期的岩浆岩侵入到火地垭群中[21,48];而本文厘定的旺苍地区火地垭群的沉积上限已达ca. 835 Ma,碑坝地区879~860 Ma的岩浆岩可能是其物源之一,因此认为这两个地区的火地垭群应该区别看待,可能是不同时代的产物。

另外值得注意的几个方面是:(1)目前整个汉南—米仓山地区只有碑坝发现了古元古代的结晶基底物质[39,44,53],因此推测碑坝地区有微陆块的可能,早期与其他块体拼贴,新元古代早期在洋壳俯冲作用下,形成碑坝弧;(2)火地垭群及其相当地层的上覆地层,如以双峰式火山岩为特征的铁船山组[40]、以紫红色碎屑岩及火山碎屑岩为特征的西乡群[23],它们都是典型陆内裂谷盆地的沉积充填物,应是Rodinia超大陆初始裂解响应的产物,与火地垭群是不同的构造—沉积旋回。因此推测火地垭群与铁船山组之间(即835~817 Ma)应该有一次构造热事件,代表了整个扬子陆块真正的"克拉通化",其他地区与之对应的、较为典型的是东南缘冷家溪群与板溪群之间的"晋宁造山运动",之后的裂谷作用形成了广泛的、大规模的以莲沱组为代表的陆相紫红色砂砾岩。综合火地垭群沉积时代、物源、碎屑锆石年龄、区域岩浆岩时空分布及成因特征等,认为旺苍地区的火地垭群上两组形成于接收双向物源的弧后盆地(图6),是Rodinia超大陆聚合晚期在扬子陆块西北缘的响应。

5 结论

(1)旺苍地区火地垭群上两组绢云千枚岩最大沉积年龄为837.6±6.0 Ma,结合已有研究成果,火地垭群的沉积时限为ca. 910 Ma至ca. 835 Ma。

(2)碎屑锆石年龄集中分布于832~843 Ma、855~883 Ma、895~936 Ma和952~973 Ma四个区间,相对概率峰值为ca. 840 Ma、ca. 868 Ma、ca. 918 Ma、ca. 954 Ma;物源主要来自周围的岩体,主体方向为东(南)和西北。

(3)样品碎屑锆石结晶年龄与沉积年龄非常接近,指示形成于汇聚构造环境。综合其他成果,旺苍地区火地垭群上两组形成于接收双向物源的弧后盆地,是Rodinia超大陆聚合晚期在扬子陆块西北缘的响应。

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Depositional Age, Provenance and Tectonic Significance of the Huodiya Group in the Wangcang Area, Northwestern Margin of the Yangtze Block: Constraints from detral zircon U-Pb geochronology

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Abstract: [**Objective**] The Huodiya Group is an important Precambrian stratigraphic unit in the northwestern margin of the Yangtze Block and an important graphite-bearing stratum in China. However, its depositional age, provenance, and tectonic attribution have long been debated.[**Methods**] In this study, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) zircon U-Pb dating was conducted on the sericite phyllite from the Shangliang Formation of the Huodiya Group, Wangcang area. [**Results and Conclusions**] The results show that maximum depositional age of the sample is 837.6±6.0 Ma (MSWD=0.60, n=5). Combined with existing data, the depositional age of Huodiya Group in the Wangcang area is constrained between ca. 910 Ma and ca. 835 Ma, rather than previously-considered Mesoproterozoic strata. The age populations of detrital zircons are concentrated in four peaks of 832-843 Ma, 855-883 Ma, 895-936 Ma, and 952-973 Ma, and the detrital provenance is mainly from the southeast and northwest magmatic rocks. A synthesis of depositional age, provenance and regional geological background indicates that the Shangliang Formation of the Huodiya Group in the Wangcang area were likely deposited in a back-arc basin receiving provenance from both sides, which is a response to the late-stage convergence of the Rodinia supercontinent in the northwestern margin of the Yangtze Block.

Key words: Huodiya Group; depositional age; provenance; zircon U-Pb dating; Yangtze Block; Neoproterozoic