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桂北四堡群火山岩锆石SHRIMP年龄及其地层学意义

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提要：四堡群为一套出露于桂北黔东南地区、变形强烈的浅变质、陆源碎屑岩火山岩、系，厚度大于5000 m，其下未见底，上被丹洲群（下江群相当地层）所覆盖。桂北四堡群自下而上划分为九小组、文通组和鱼西组3组。样品A20140731−3采自于文通组，岩性为灰绿色熔结火山岩，首次分选出600余粒岩浆型锆石，完成SHRIMP U−Pb定年测点15个，获得加权平均年龄（860±13）Ma。这表明四堡群主体属于新元古界，进而分析、讨论了江南造山带主要地层对比关系。

关　键　词：四堡群；锆石SHRIMP年龄；新元古界；江南造山带

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SHRIMP age of the lava from the Sibao Group in Guilin and its chronostratigraphic significance

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Abstract: The Sibao Group, outcropped in the north part of Guangxi and southeast part of Guizhou, is composed of over 5000 m thick succession of strongly−deformed, low−grade metamorphic volcanic rocks and terrigenous clastic rock, overlain unconformity

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by the Danzhou Group (Xiajiang Group). It is divided into three Formations: Jiuxiao Formation, Wentong Formation and Yuxi Formation. Sample A20140731−3 is lava, collected from the upper part of the Wentong Formation, and over 600 grains of zircon were sorted out from it. Fifteen of the zircons were analyzed with SHRIMP, and a weighed−mean U−Pb age of (860±13)Ma was obtained, which indicates that the volcanic rocks of the Sibao Group belong to Neoproterozoic. Based on this new zircon SHRIMP U− Pb age combined with the other high− quality ages obtained recently in the Jiangnan Orogen, the authors investigated the stratigraphic correlation between Sibao Group and the other main strata, such as Lengjiaxi Group, Shuangqiaoshan Group, and Fanjingshan Group.

Key words: Sibao Group; zircon SHRIMP age; Neo−Proterozoic; Jiangnan Orogen

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桂北四堡群为一套伏于丹洲群之下的一套巨厚层浅变质火山岩及陆源碎屑岩系[1−3]。传统上,主要根据四堡群的变质年龄和上覆下江群或丹洲群的年龄来确定四堡群地质时代。韩发、沈建忠、聂凤军等(1994)在四堡群下部的玄武岩中获得单颗粒锆石U−Pb年龄在1734~1863 Ma范围内、中部文通组镁铁质−超镁铁质火山岩Sm−Nd等时线年龄(1852±270)Ma,进而推断四堡群属中元古界[4]。王孝磊、周金城等(2006)采取四堡群和冷家溪群基底地层中的5个沉积岩样品,进行锆石微区定年工作,获得结果显示,这些样品最年轻年龄均靠近860 Ma。将获得年龄的数据点进行统计,平均年龄为(866.7±3.7)Ma,从而认为该基底沉积地层的沉积作用应发生在860 Ma之后[5]。高林志等(2010)在黔桂交界的十万大山东段获得侵入四堡群的摩天岭花岗岩锆石SHRIMP U−Pb年龄(826.8±5.9)Ma,高林志等(2012)在上覆地层下江群甲路组斑脱岩中获得SHRIMP锆石U−Pb年龄814 Ma,进而认为四堡群属新元古代中期[6−8]。显然,四堡群的地质年代学归属和顶、底界线并没有确定。为此我们通过测定四堡群文通组枕状熔结火山岩中锆石SHRIMP U−Pb年龄来直接揭示四堡群地层年龄。进而讨论四堡群的归属、时限范围和区域对比。

1　区域地层及采样位置

四堡群为一套深海浊流复理石建造和基性−超基性火山岩建造,主要由砂岩、粉砂岩和中基性火山岩夹层组成。自下而上依次为九小组、文通组、鱼西组[1−3,9]。

九小组主要为变质粉砂岩、泥岩,下未见底,出露厚度约600 m。该组下部为泥质粉砂岩、浅灰色厚层变质中−细粒长石石英砂岩;上部为变质细砂岩、粉砂岩。发育的沉积构造主要是水平层理、局部见有包卷层理、粒序层理及小型斜层理。粒序层理、小型斜层理等构成不完整鲍马序列,显示浊流沉积特征。

文通组以大量发育火山岩层为特征,与其上的鱼西组、其下的九小组均为整合接触,厚度约为1980 m。该组下部为泥岩和基性火山岩;中部为粉砂岩、杂砂岩夹基性火山岩;上部为杂砂岩、粉砂岩与灰绿色火山角砾岩、凝灰岩。

鱼西组主要为杂砂岩、粉砂岩和深灰色泥岩,出露厚度约1500 m。该组下部为长石岩屑杂砂岩,为典型的AE组合浊积岩;上部为杂砂岩、泥岩,鲍马序列发育完整。发育的沉积构造主要为粒序层理、小型斜层理、包卷层理、侵蚀底面构造和水平层理。

样品A20130731−3采自于罗城县四堡—两河口—鱼西—文得剖面北段文得村处,地理坐标为25°07′07.19″ N, 108°46′45.39″E(图1)。样品岩性为枕状火山岩,层位为四堡群文通组(图2)。样品呈灰绿色,枕状结构,为较典型的水下喷发特征组构。为火山熔岩,属海相火山喷出岩(图3)。

1.1 分析方法与测试结果

锆石的分离在河北廊坊区域地质调查所实验室

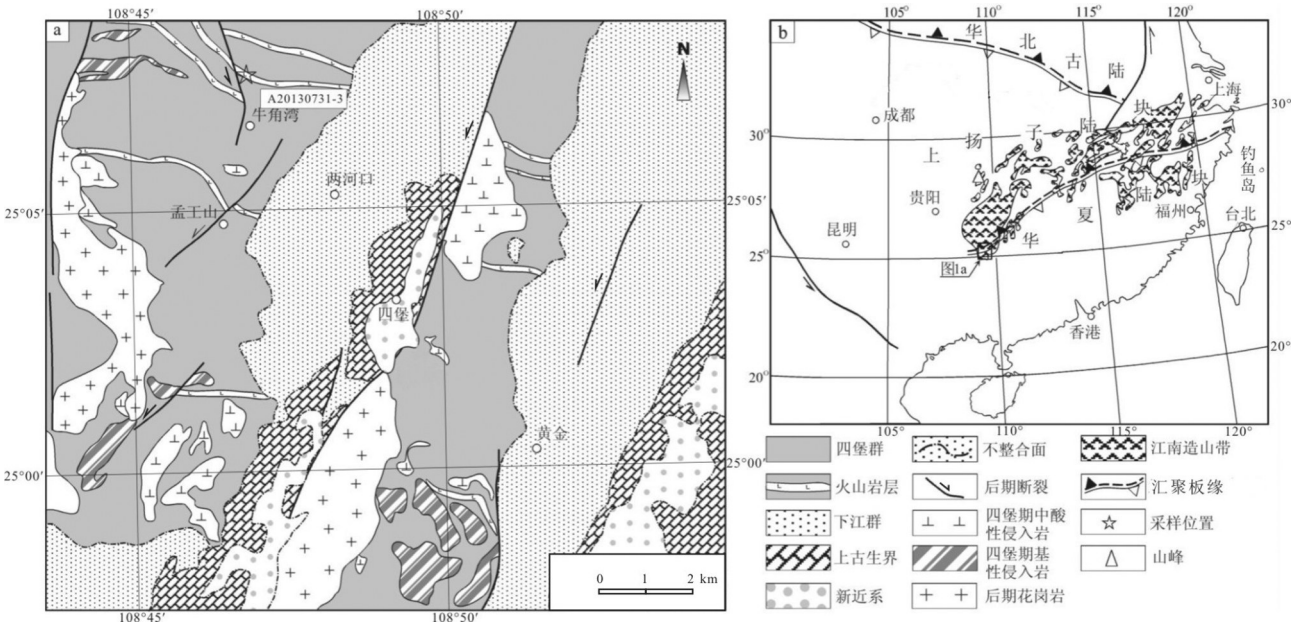

图1 桂北四堡地区地质略图及采样位置

Fig.1 Sketch geological map of Sibao area, Guilin, and the sampling positions

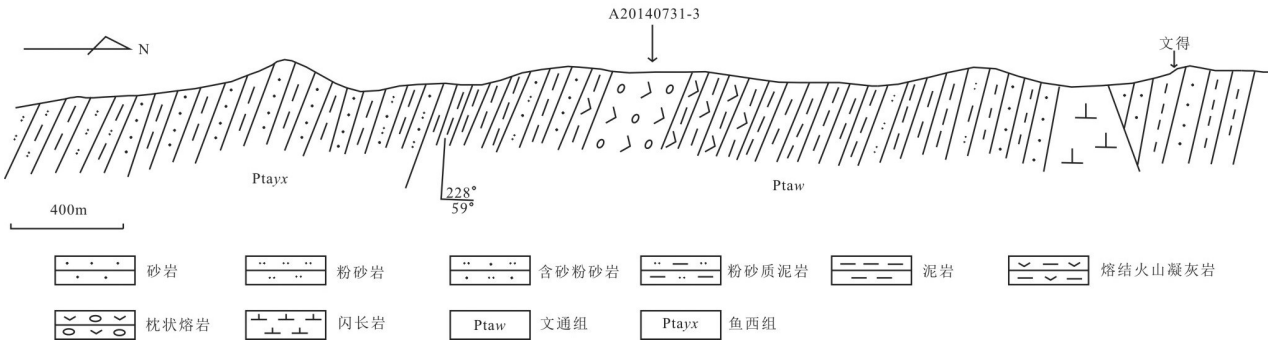

图2 文得—三岔剖面图,示采样位置

Fig.2 Geological profiles from Wende−Sancha, showing the sampling position for A20140731−3

进行,锆石的阴极发光图像在北京离子探针中心HITACHI−3000N扫描电镜上完成。锆石U−Pb年龄测定在北京离子探针中心的SHRIMP−Ⅱ上进行。

野外采获的用于分选锆石的样品首先经过手工粉碎。后按照常规重力及电磁法浮选出可能的锆石颗粒,在实体镜下挑出纯正的锆石625粒。将这些锆石在玻璃板上用环氧树脂固定、抛光,进行靶台的制作,再进行反射和投射光下的显微观察和照相,最后进行阴极发光图像分析,检查锆石的内部结构,并进行选样,排除裂隙发育和包裹体较多的颗粒,从中选取15粒进行测试,并确定测试锆石颗粒和位置。

年龄测定时仪器的质量分辨率约5000(1%峰高),一次离子流O^{-2}为4 nA。一次离子流束斑直径为25~30 μm,每个数据点的测定由5次扫描构成。测量质量峰为$^{90}Zr^{16}O^{+}$、$^{204}Pb^{+}$、背景值、$^{206}Pb^{+}$、$^{207}Pb^{+}$、$^{208}Pb^{+}$、$^{238}U^{+}$、$(^{232}Th^{16}O^{+})$和$(^{238}U^{16}O)^{+}$。分别采用标准锆石TEM和M257进行元素间的分馏校正及U含量的标定;其中TEM具有U−Pb谐和年龄,其$^{206}Pb/^{238}U$年龄为(416.8±1.1)Ma,但U、TH和Pb的含量不均一;标准锆石M257的$^{206}Pb/^{238}U$年龄为840 Ma。原始数据处理和锆石U−Pb血谐和图绘制采用Ludwig

图3 样品A20140731−3野外采样点
Fig.3 Sampling sites in Sibao Group

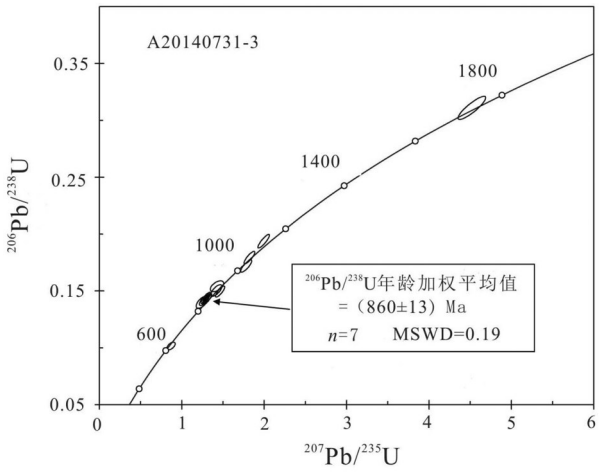

图4样品A20140731−3锆石U−Pb一致曲线
Fig.4 U−Pb concordia diagram for the zircons from sample A20140731−3

博士编写的Squid和Isoplot程序。普通铅的校正根据实测的^{204}Pb进行,普通铅的组成根据Stacey的模式计算得到。表1中的年龄误差为1σ绝对误差,同位素比值误差为1σ;$^{206}Pb/^{238}U$年龄加权平均值为95%置信度。

本次研究对所选15颗锆石进行U−Pb测年,锆石的阴极发光图像(CL)特征(图5):所采锆石虽然形态上不尽相同,但均显示出典型的岩浆生长振荡环带和韵律结构,明显属于岩浆结晶的产物。锆石颜色为浅黄色−无色透明,大部分样品锆石晶体晶型完好,多呈短柱状,少量长柱状和粒状。锆石粒度多在100~200 μm。其中U含量变化范围为107×10^{-6}~696×10^{-6};Th含量变化范围为56×10^{-6}~655×10^{-6}(表1);大部分锆石分析点位于明显的岩浆

表1 四堡群文通组火山岩样品A20140731−3锆石SHRIMP U−Pb定年数据
Table 1 U−Pb SHRIMP analytical results of the zircons from Sample A2014−731−3

测点	含量/10^{-6}				Th/U	$^{207}Pb/^{206}Pb^*$	1σ/%	$^{207}Pb/^{235}U$	1σ/%	$^{206}Pb/^{238}U$	1σ/%	表面年龄/Ma	
	Pbc	U	Th	$^{206}Pb^*$								$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$
1.1	0.08	696	345	85.5	0.51	0.06670	0.8	1.301	2.2	0.1429	2.0	861±16	807±18
2.1	0.14	278	148	46.4	0.55	0.07577	1.0	1.993	2.3	0.1938	2.0	1,142±21	1,058±22
3.1	--	108	106	9.43	1.01	0.0599	2.6	0.869	3.8	0.1016	2.2	624±13	675±67
4.1	--	192	123	28.3	0.66	0.0747	1.4	1.782	2.5	0.1719	2.1	1,023±20	1,073±27
5.1	0.00	539	655	66.2	1.26	0.06678	1.1	1.314	2.5	0.1428	2.2	860±18	830±24
6.1	--	107	95	28.6	0.92	0.1050	1.2	4.52	2.5	0.3110	2.2	1,746±33	1,721±22
7.1	0.44	109	116	13.1	1.11	0.0682	2.1	1.247	3.9	0.1402	2.5	846±20	759±62
8.1	0.06	430	59	52.8	0.14	0.06627	1.1	1.293	2.3	0.1427	2.0	860±16	798±23
9.1	0.06	508	56	63.1	0.11	0.06572	0.9	1.300	2.2	0.1446	2.0	871±16	780±21
10.1	--	205	67	26.3	0.34	0.0699	1.4	1.465	2.6	0.1495	2.1	898±18	960±29
11.1	0.19	326	221	43.2	0.70	0.06872	1.4	1.427	3.8	0.1542	2.1	924±18	842±66
12.1	--	330	57	50.8	0.18	0.07213	1.0	1.820	2.4	0.1794	2.0	1,064±20	1,031±25
13.1	0.35	206	202	26.7	1.02	0.0714	1.7	1.419	3.1	0.1504	2.2	903±19	882±46
14.1	0.04	363	139	44.8	0.39	0.06504	1.2	1.281	2.5	0.1435	2.1	865±17	765±25
15.1	0.16	152	122	18.5	0.83	0.0662	1.8	1.268	2.9	0.1418	2.1	855±17	770±41

注:误差为1σ; Pb_c代表普通铅、Pb^*代表放射成因铅; ^{204}Pb普通铅校正。

图5 样品A20140731−3锆石CL图像特征及测点位置(环形标注)

Fig.5 CL images for the zircons from sample A20140731−3 and testing positions

环带部位。

所获得的15组锆石年龄(表1)中测点3.1为不谐和年龄,其$^{206}Pb/^{238}U$年龄(624±13)Ma明显偏小,可能为后期混入的锆石。测点6.1$^{207}Pb/^{206}Pb$的年龄为(1721±22)Ma,为继承锆石。测点2.1、4.1、10.1、11.1、12.1、13.1年龄值明显偏大且偏离谐和曲线,可能代表早期热事件的残留锆石年龄。其余7个数据点均位于谐和线上,其$^{206}Pb/^{238}U$年龄加权平均值为(860±13)Ma,MSWD=0.19(图4),它应代表四堡群文通组年龄。四堡群文通组火山岩锆石U−Pb年龄(860±13)Ma为江南造山带西段的四堡群地层归属提供了直接的年代学证据,明确的将四堡群定为新元古代地层。并确定四堡群的年龄老于(860±13)Ma,鱼西组的碎屑岩沉积年龄应在(860±13)~820 Ma。

1.2 区域地层对比

江南造山带呈北西向弧形突出延伸将近2000 km,地质体多为不连续、孤立的块体,通过对这些块体的对比,进而讨论江南造山带的构造演化一直是地质学者研究的重点。近年来,随着高质量、高精度定年技术的出现、发展[10−15],地质学者也将这一技术运用在江南造山带区域地层对比上,获得了大量的高精度定年数据:(1)贵州梵净山群火山岩SHRIMP锆石U−Pb年龄为(840±11)Ma[16];其沉积岩碎屑岩锆石最小峰值年龄为(872±3)Ma;侵入梵净山群白云母花岗岩SHRIMP锆石U−Pb年龄为(835±5)Ma[17−18];(2)湖南冷家溪群班脱岩SHRIMP锆石U−Pb年龄为(822±10)Ma;其沉积岩锆石最小峰值年龄为866 Ma;覆盖在其上的板溪群张家湾组班脱岩锆石年龄为(802±7)Ma[19−20];(3)赣北及湘东北地区双桥山群中斑脱岩SHRIMP锆石U−Pb年龄为(831±5)Ma(横涌组)、(829±5)Ma(安乐林组)、(824±5)Ma(修水组),其沉积岩锆石最小峰值年龄为863 Ma[20−24]。

据此,结合四堡群新获得的年龄数据,确定:四堡群鱼西组大致相当于梵净山群、湖南冷家溪群、赣北及湘东北双桥山地层,而下部的文通组,九小组(有些学者认为该组相当于鱼西组地层)地层可能老于湖南冷家溪群、赣北及湘东北双桥山地层。

2 结 论

(1)获得四堡群文通组中火山熔岩SHRIMP锆石U−Pb年龄(860±13)Ma,结果表明四堡群底界年

龄应早于(860±13)Ma,并直接明确地将四堡群定位于新元古代地层。

(2)鱼西组的碎屑岩沉积年龄应在860~820 Ma。

(3)四堡群鱼西组大约相当于梵净山群、湖南冷家溪群、赣北及湘东北双桥山地层,而鱼西组下部的地层可能老于湖南冷家溪群、赣北及湘东北双桥山地层。

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