

引用格式: 夏磊, 夏文静, 卫巍, 等, 2025. 南盘江盆地、八布-高平构造带和越北地块碎屑锆石年龄对比及其构造意义[J]. 地质力学学报, 31(4): 576–588. DOI: [10.12090/j.issn.1006-6616.2025068](https://doi.org/10.12090/j.issn.1006-6616.2025068)

Citation: XIA L, XIA W J, WEI W, et al., 2025. Correlation of detrital zircon ages among the Nanpanjiang basin, the Babu–Cao Bang tectonic belt, and the Northern Vietnam terrane: Tectonic implications[J]. Journal of Geomechanics, 31(4): 576–588. DOI: [10.12090/j.issn.1006-6616.2025068](https://doi.org/10.12090/j.issn.1006-6616.2025068)

南盘江盆地、八布-高平构造带和越北地块碎屑锆石年龄对比及其构造意义

夏磊^{1,2}, 夏文静^{2,3}, 卫巍^{2,4}, 宋超^{2,4}, 王印^{2,5}, 刘飞^{2,6,7}
XIA Lei^{1,2}, XIA Wenjing^{2,3}, WEI Wei^{2,4}, SONG Chao^{2,4}, WANG Yin^{2,5}, LIU Fei^{2,6,7}

1. 昆明学院建筑工程学院, 云南昆明 650214;
 2. 中国科学院大学地球与行星科学学院, 北京 100049;
 3. 北京航空航天大学人文社会科学学院(公共管理学院), 北京 100037;
 4. 中国科学院地质与地球物理研究所岩石圈演化学科中心, 北京 100029;
 5. 中石化经纬有限公司地质测控技术研究院, 山东青岛 266071;
 6. 中国地质调查局武汉地质调查中心(中南地质科技创新中心), 湖北武汉 430205;
 7. 中国地质调查局花岗岩成岩成矿地质研究中心, 湖北武汉 430205
1. *School of Architectural and Civil Engineering, Kunming University, Kunming 650214, Yunnan, China;*
 2. *College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing 100049, China;*
 3. *School of Humanities and Social Sciences (School of Public Administration), Beihang University, Beijing 100037, China;*
 4. *State Key Laboratory of Lithospheric and Environmental Coevolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China;*
 5. *Geosteering & Logging Research Institute, Sinopec Matrix Corporation, Qingdao 266071, Shandong, China;*
 6. *Wuhan Center, China Geological Survey (Geosciences Innovation Center of Central South China), Wuhan 430205, Hubei, China;*
 7. *Research Center for Petrogenesis and Mineralization of Granitoid Rocks, China Geological Survey, Wuhan 430205, Hubei, China*

Correlation of detrital zircon ages among the Nanpanjiang basin, the Babu–Cao Bang tectonic belt, and the Northern Vietnam terrane: Tectonic implications

Abstract: [Objective] During the opening and closing of the Paleo-Tethys ocean, multiple continental blocks rifted from the northern margin of Gondwana, drifted northward, and eventually merged with the southern boundary of the Asian continent, forming multiple serpentinite belts. As part of the Paleo-Tethys orogenic belt, the Indosinian orogenic belt records the evolution history of the Paleo-Tethys ocean; however, key scientific issues, such as the location of the ocean basin and the subduction polarity, remain controversial. The keys to addressing these questions lie in defining the structural characteristics of the Babu–Cao Bang tectonic belt along the Sino-Vietnamese border and clarifying the tectonic affinity of the North Vietnam terrane. Specifically, it has to be determined, whether the Babu–Cao Bang tectonic belt represents a suture zone of a wide ocean basin, and whether the North Vietnam terrane is a component of the South China block or an

基金项目: 国家自然科学基金项目(92355302); 中国地质调查局地质调查项目(DD20160201-07); 云南省基础研究计划项目(202401CF070004); 云南省地方本科高校基础研究联合专项项目(202301BA070001-007)

This work is financially supported by the National Natural Science Foundation of China (Grant No. 92355302), the Geological Survey Project of the China Geological Survey (Grant No. DD20160201-07), the Yunnan Fundamental Research Project (Grant No. 202401CF070004), and the Special Basic Cooperative Research Program of the Yunnan Provincial Undergraduate Universities' Association (Grant No. 202301BA070001-007).

第一作者: 夏磊(1989—), 男, 助理研究员, 主要从事沉积大地构造学研究。Email: xialei@kmu.edu.cn

通信作者: 卫巍(1983—), 男, 副研究员, 主要从事构造地质学研究。Email: weiweigeo@mail.iggcas.ac.cn

收稿日期: 2025-06-13; 修回日期: 2025-07-14; 录用日期: 2025-07-15; 网络出版日期: 2025-07-21; 责任编辑: 范二平

independent micro-continental block. [Methods] In order to clarify these two questions, detrital zircon age data were collected from 31 sedimentary rocks in three tectonic units including the Nanpanjiang basin along the southwestern margin of the South China block, the Babu-Cao Bang tectonic belt, and the North Vietnam terrane. Furthermore, age data of inherited igneous zircon from the Song Chay massif in the North Vietnam terrane were obtained. The zircon age distribution histograms and probability curve peaks were compared within these three tectonic units. [Results] It was found that the age spectra of these samples mostly have peaks at 270–250 Ma, 460–420 Ma, and 1000–900 Ma. In addition, the age data are relatively concentrated around 1800 Ma and 2500 Ma, which reflects good consistency in the provenance of the three tectonic units. [Conclusion] Based on the stratigraphic correlation between the Nanpanjiang basin and the North Vietnam terrane from the late Paleozoic to the early Mesozoic and the faunal similarities during the same period, this study speculates that an extensional event led to the development of rifts, deep-water sediments, and even oceanic crust in the Babu-Cao Bang tectonic belt during the Permian. However, due to its limited extensional magnitude, this rift failed to evolve into a mature oceanic basin, preserving the tectonic connection between the North Vietnam terrane and the Nanpanjiang basin. The North Vietnam terrane is an important component of the South China block, and the open basin of the Paleo-Tethys ocean should have been located to the south of the North Vietnam terrane. [Significance] This study provides evidence for the division of tectonic units in the Indosinian orogenic belt, and guides our understanding of Indosinian orogenic processes in the Sino-Vietnamese border area.

Keywords: Nanpanjiang basin; Babu-Cao Bang tectonic belt; North Vietnam terrane; detrital zircon age; Indosinian orogenic belt; Paleo-Tethys ocean

摘要: 古特提斯洋的形成与演化导致了冈瓦纳大陆北缘多个陆块的裂解分离、向北漂移并最终拼贴到亚洲大陆的南侧,该洋盆的闭合形成了多条蛇绿岩带。印支造山带作为古特提斯造山带的一部分,记录了古特提斯洋的演化历史,但其洋盆位置、俯冲极性等相关科学问题仍存在争议。回答上述问题的关键在于厘定中国-越南(中越)边境地区的八布-高平构造带的构造属性和越北地块的构造归属,即八布-高平构造带是否代表开阔洋盆的缝合带,以及越北地块是华南地块的组成部分还是一个独立的小陆块。因此,通过搜集华南地块西南缘南盘江盆地、中越边境地区的八布-高平构造带和越北地块3个构造单元中的31个碎屑岩锆石年龄数据和越北地块斋江岩体的岩浆结晶-继承锆石的年龄数据,进行了锆石年龄分布直方图和概率曲线谱峰对比。研究结果发现,这些样品多具有270~250 Ma、460~420 Ma、1000~900 Ma的年龄谱峰,另外年龄数据在1800 Ma左右以及2500 Ma左右也相对集中,这体现了3个构造单元物源存在较好的一致性。结合南盘江盆地和越北地块晚古生代—早中生代地层对比结果,以及同时期动物区系的相似性,研究推测自泥盆纪以来的伸展作用导致了八布-高平构造带在二叠纪时发育裂谷、深水沉积,甚至演化至初始洋盆;然而由于其扩张幅度有限,未发育成广阔的大洋,也未完全裂解进而阻断了越北地块和南盘江盆地的联系。越北地块是华南地块的重要组成部分,古特提斯开阔洋盆应位于越北地块南侧区域。研究成果为印支造山带中大地构造单元划分提供了证据和论证,对理解中越边境地区印支造山作用和过程具有一定程度的指导价值。

关键词: 南盘江盆地;八布-高平构造带;越北地块;碎屑锆石年龄;印支造山带;古特提斯洋

中图分类号: P54; P597 **文献标识码:** A **文章编号:** 1006-6616(2025)04-0576-13

DOI: 10.12090/j.issn.1006-6616.2025068

0 引言

印支造山带位于中国西南诸省与印支半岛之间,是横跨欧亚的东西向古特提斯造山带的一部分(吴福元等, 2020)。在古特提斯洋闭合过程中,自冈瓦纳大陆北缘裂离的多个陆块(如华南地块、印支地块和滇缅泰马地块等)逐渐在亚洲大陆东部完

成聚合,奠定了中国东部的构造格局(Metcalf, 2021)。在此过程中,广泛的岩浆活动导致大量温室气体从地球内部排放至大气圈中,并伴随着诸陆块从低纬向北漂至高纬地区引起的地球反射率的变化,引起了强烈的环境效应(万博等, 2023)。作为一个对亚洲乃至全球的地质格架和环境演化有着重要影响的构造域,其蛇绿岩的数量、陆块的归属以及大洋俯冲极性均存在着争议。古特提斯造

山带是一个多岛洋系统,以发育多条缝合带为特征(刘本培等, 1993)。有学者认为,印支造山带中的一些蛇绿岩带,如斋江(Song Chay)和马江(Song Ma)缝合带的构造特征一致,可能是由新生代红河断裂走滑运动所肢解的同一条古特提斯缝合带(Faure et al., 2016a)。另有学者注意到,在中越边境地区的八布-高平构造带内广泛发育深水沉积、超基性-基性岩,进而提出了滇-琼缝合带,并认为其代表了古特提斯开阔洋盆(Cai and Zhang, 2009)。大洋俯冲极性的推测主要依据岩浆活动发育的构造部位,也存在较多争议。杜远生等(2009)认为,马江缝合带为古特提斯开阔洋盆所在的位置,该洋盆向北俯冲,在越南北部形成越北岩浆弧,并在中国境内形成一系列的弧后伸展盆地。一些学者认为,马江-斋江缝合带所代表的古特提斯洋盆向南俯冲,在越南中部形成长山岩浆弧(Wang et al., 2021; Li et al., 2021; Lin et al., 2024; 林伟等, 2024)。Halpin et al.(2016)认为,在古特提斯大洋向南俯冲过程中,在华南大陆边缘形成了裂谷盆地,持续的伸展拉张过程导致岩石圈细颈化并在现今八布-高平构造带发育洋壳,在特提斯洋闭合后形成了 Song Hien 蛇绿岩。还有学者对八布-Song Hien 蛇绿岩的地质意义有不同的解释, Cai and Zhang(2009)认为中越边境的超基性-基性岩、深水沉积是存在古特提斯洋盆的关键证据,该洋盆向南俯冲,在越南北部形成越北岩浆弧。Xia et al.(2021, 2022)则认为中越边境八布-高平构造带的超基性岩、深水沉积只是一个分支洋盆,越北地块是一个独立的微陆块,其北部的分支洋盆向北俯冲,在富宁-那坡-凭祥一带形成了岩浆弧,而南部的马江-斋江分支洋盆则向南俯冲,在越南中部形成了长山岩浆弧。

综上所述,目前对印支造山带构造演化和古特提斯闭合过程的关键争议在于中越边境八布-高平构造带的构造属性,以及越北地块的构造归属。相关学者曾对中越边境的超基性-基性岩进行过地球化学工作,发现这些超基性-基性岩来自富集型(E-MORB)或亏损型(N-MORB)洋中脊玄武岩源区,并将其解释为蛇绿岩(Halpin et al., 2016)。但越北地块和南盘江盆地逐渐过渡的变质级序以及顶部指向北东方向的变形特征似乎又暗示越北陆块和华南是一体的(Lepvrier et al., 2011)。为了更完善地厘定中越边境八布-高平构造带的构造属性,以及越北地块的归属,需要从更多方法的视角来审视这一

问题。碎屑锆石可以较好地反映所研究构造单元中沉积物的来源,广阔的大洋会天然分割位居其两侧的陆块,使其物源具有差异性。虽然近年来不同学者对南盘江盆地、八布-高平构造带以及越北地块进行了丰富的碎屑锆石研究,但尚缺少对这3个构造单元系统的碎屑锆石年龄数据比较。因此,研究通过搜集近年来中越边境八布-高平构造带及其两侧的南盘江盆地和越北地块的碎屑锆石年龄数据,开展碎屑锆石年龄谱峰对比分析,并进一步探讨中越边境八布-高平构造带的构造属性以及越北地块构造归属。

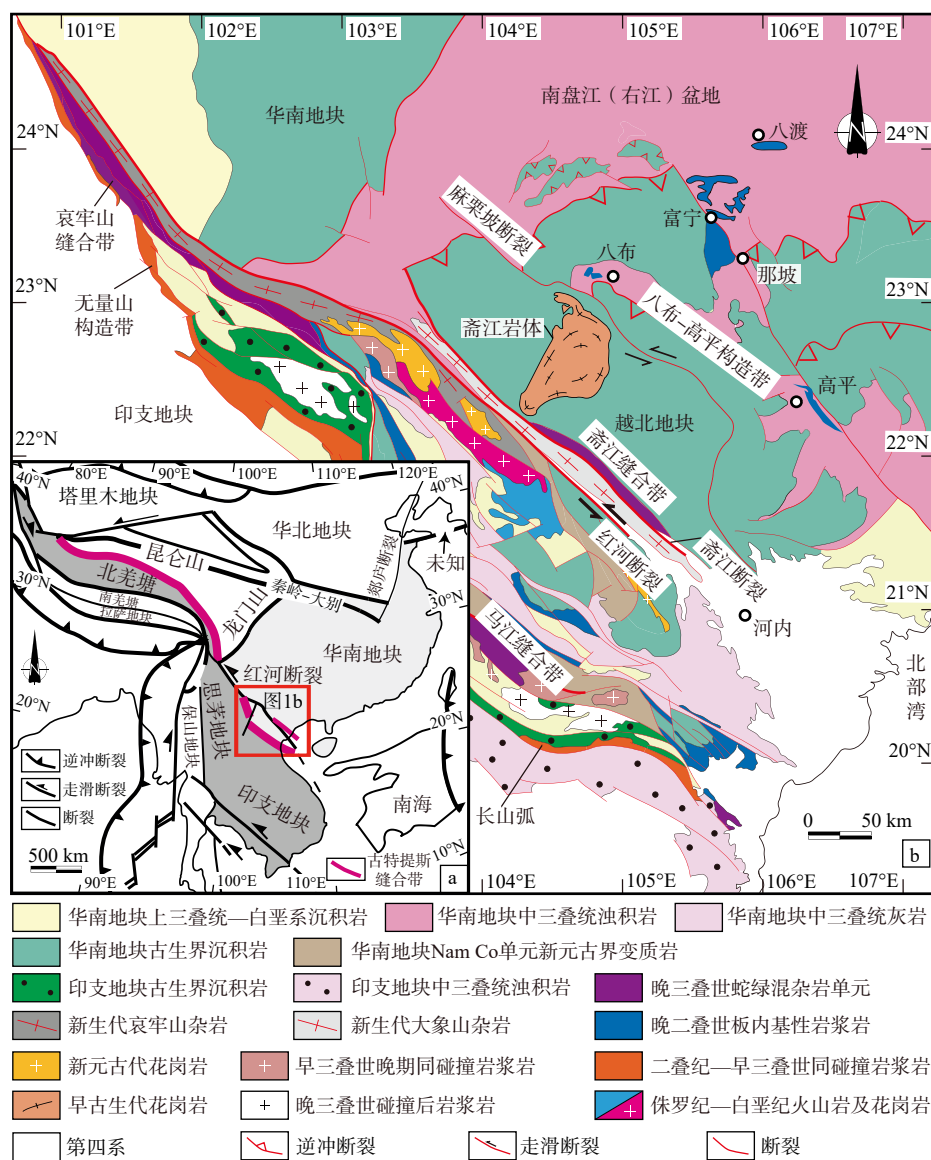
1 地质背景

1.1 古特提斯洋与印支造山带地质特征

在南方冈瓦纳大陆和北方劳亚大陆拼合成盘古大陆后,在大陆的核心部位存在一个向东开口的大洋,即为特提斯洋。特提斯洋的演化历史可以总结为不断有陆块从冈瓦纳大陆北缘裂解分离,向北漂移并最终拼贴在劳亚大陆的南缘之上,并在此过程中形成原特提斯、古特提斯、中特提斯和新特提斯洋板块,以及这些大洋板块的扩张、俯冲和消亡的历史(Metcalf, 2021)。在东亚,古特提斯洋的演化导致中国东部和印支(中南)半岛拼合成为一个大陆(图 1a; Metcalfe, 2021),该过程被称为印支运动(Faure et al., 2014)。

古地理和古地磁证据表明,华南地块和印支地块可能在泥盆纪时期从冈瓦纳大陆北缘裂解分离并开始向北漂移(Sone and Metcalfe, 2008; Metcalfe, 2021)。华南地块西南缘和越南地区广泛分布的上三叠统与下伏中三叠统及更老地层之间的不整合接触、晚三叠世的造山后岩浆活动以及早-中三叠世的变质作用,很好地限定了印支造山事件发生和结束的时间(Faure et al., 2014)。

印支造山带中存在哀牢山(双沟)、马江、斋江、八布等多条超基性岩带,其被认为可能是蛇绿岩带(张旗等, 1988; Zhong et al., 1999; 张斌辉等, 2013; Lin et al., 2024)。多条蛇绿岩是否代表了多岛洋环境? 其对比研究是回答该问题的关键。Faure et al.(2014, 2016a)认为斋江和马江地区的构造特征相似,在恢复新生代哀牢山-红河断裂走滑运动所造成的位移后,这2条蛇绿岩带应同属于一条缝合带,且该缝合带与哀牢山蛇绿岩带一起代表了古特



a—东南亚地区大地构造单元图; b—南盘江盆地、八布-高平构造带及越北地块区域地质简图(据 Li et al., 2021 修改)

图1 华南地块及邻区大地构造单元与中越边境地区地质简图

Fig. 1 Tectonic units of the South China block and adjacent regions, and simplified geological map of the Sino-Vietnamese border area

(a) Tectonic units of Southeast Asia; (b) Simplified geological map of the Nanpanjiang basin, Babu-Cao Bang tectonic belt, and North Vietnam terrane (modified from Li et al., 2021)

提斯洋的洋盆。斋江和马江蛇绿岩所代表的洋盆向南俯冲在越南导致了广泛的岩浆活动,被称为大象山(Day Nui Con Voi)岩浆弧和长山(Truong Son)岩浆弧(图1b; Liu et al., 2012; Faure et al., 2014, 2016b)。

1.2 南盘江盆地地质特征

南盘江盆地又称右江盆地。泥盆纪时期,华南地块西南缘的碳酸盐台地开始裂解(姚仕祥等, 2018),形成一系列孤立碳酸盐台地(刘超, 2017)以及台地之间的深水沉积(高军波等, 2017),此为南盘江盆地作为一个独立单元演化的肇始。该事件

和冈瓦纳大陆北缘裂解及古特提斯洋形成的时代可对比(Metcalf, 2021)。广西那坡地区上泥盆统硅质岩的地球化学特征显示出Ce负异常,这意味着这些硅质岩沉积在开阔的裂谷或洋盆环境中,陆源碎屑输入很少,为此时古特提斯洋的张开提供了进一步的证据(黄志强等, 2013)。二叠纪时,沿大断裂分布的水体逐渐加深,暗示南盘江盆地持续伸展(夏文静等, 2018)。早一中三叠世时期,南盘江盆地广泛发育浊积岩(Duan et al., 2023),在印支造山作用下,这些浊积岩卷入褶皱和变形,并最终被上三

叠统不整合覆盖(Qiu et al., 2016)。需要指出的是,南盘江盆地变形过程中,岩石的变质程度极低(陈暑荣等, 2007)。

自泥盆纪至中三叠世,南盘江盆地除了具有连续丰富的沉积记录外,在二叠纪还记录了广泛的基性岩浆活动(图 1)。八渡基性岩墙(约 263 Ma)的活动拉开了南盘江二叠纪基性岩活动的序幕(夏文静等, 2019)。之后,整个南盘江盆地范围内的基性岩浆活动多集中在 260 Ma 左右,且以侵入相岩墙、岩床和喷出相枕状熔岩、火山碎屑岩居多,其地球化学具有洋岛玄武岩(OIB)特征,分为高 Ti 系列和低 Ti 系列,可作为峨眉山大火成岩省的边缘相与四川等地的中心相对比(Liu et al., 2017; Huang et al., 2019; Zhang et al., 2021; Hu et al., 2024)。进入三叠纪后,南盘江南部的富宁、那坡地区发育了一套中—基性火山岩(250~210 Ma),被不同的学者分别解释为八布—高平古特提斯分支洋盆(滇—琼洋)向北俯冲、或者古太平洋向西俯冲的产物(向忠金等, 2021; Jiang et al., 2021; Xiang et al., 2022)。

1.3 中越边境地区八布—高平构造带地质特征

八布—高平构造带分割了南盘江盆地和越北地块(图 1b)。自西向东,八布—高平构造带自云南麻栗坡县八布乡向东经广西那坡县的南部进入越南高平省境内(图 1b),该构造带在泥盆纪时,曾发生伸展裂陷作用,硅质岩存在 Ce 负异常,被认为当时已经处于开阔海的环境(黄志强等, 2013)。该带西段八布乡发育超基性岩,被解释为蛇绿岩(Zhong et al., 1999)。斜长角闪岩锆石 SHRIMP 定年指示其成岩年龄为中二叠世早期(272±8 Ma; 张斌辉等, 2013)。另外,该带还发育早二叠世的放射虫硅质岩(冯庆来和刘本培, 2002)。在那坡地区,沿富宁断裂发育大量早三叠世的碳酸盐岩滑塌堆积和碳酸盐浊流沉积,指示了斜坡—深海扇沉积环境(夏磊等, 2018)。在该带东南部越南境内的高平地区,沿深大断裂广泛分布着橄榄岩、闪长岩与玄武岩、碳酸盐岩和浊流沉积,其中玄武岩的 Rb-Sr 定年指示这些基性岩石形成于 334±31 Ma 或 263±15 Ma(Tran et al., 2007; Thanh et al., 2014)。这些基性岩、超基性岩的地球化学特征表明,其中部分样品具有 N-MORB 特征,指示该区域在早石炭世—中二叠世期间可能发生持续扩张,并形成了洋壳(Tran et al., 2007; Halpin et al., 2016)。但另有学者认为,高平地区的镁铁质—超镁铁质岩浆就位于昌宁—孟连古特提

斯洋盆俯冲作用形成的弧后环境(Thanh et al., 2014)。

另外,有学者认为高平地区的超镁铁质岩和镁铁质岩(图 1b)与峨眉山地幔柱相关(Tran et al., 2016)。Lepvrier et al.(2011)和 Faure et al.(2014)进一步指出,该地区出露的枕状熔岩、流纹岩、花岗岩、闪长岩、橄榄岩和灰岩是裂谷边缘重力搬运的外来块体,即海底滑塌堆积。

1.4 越北地块地质特征

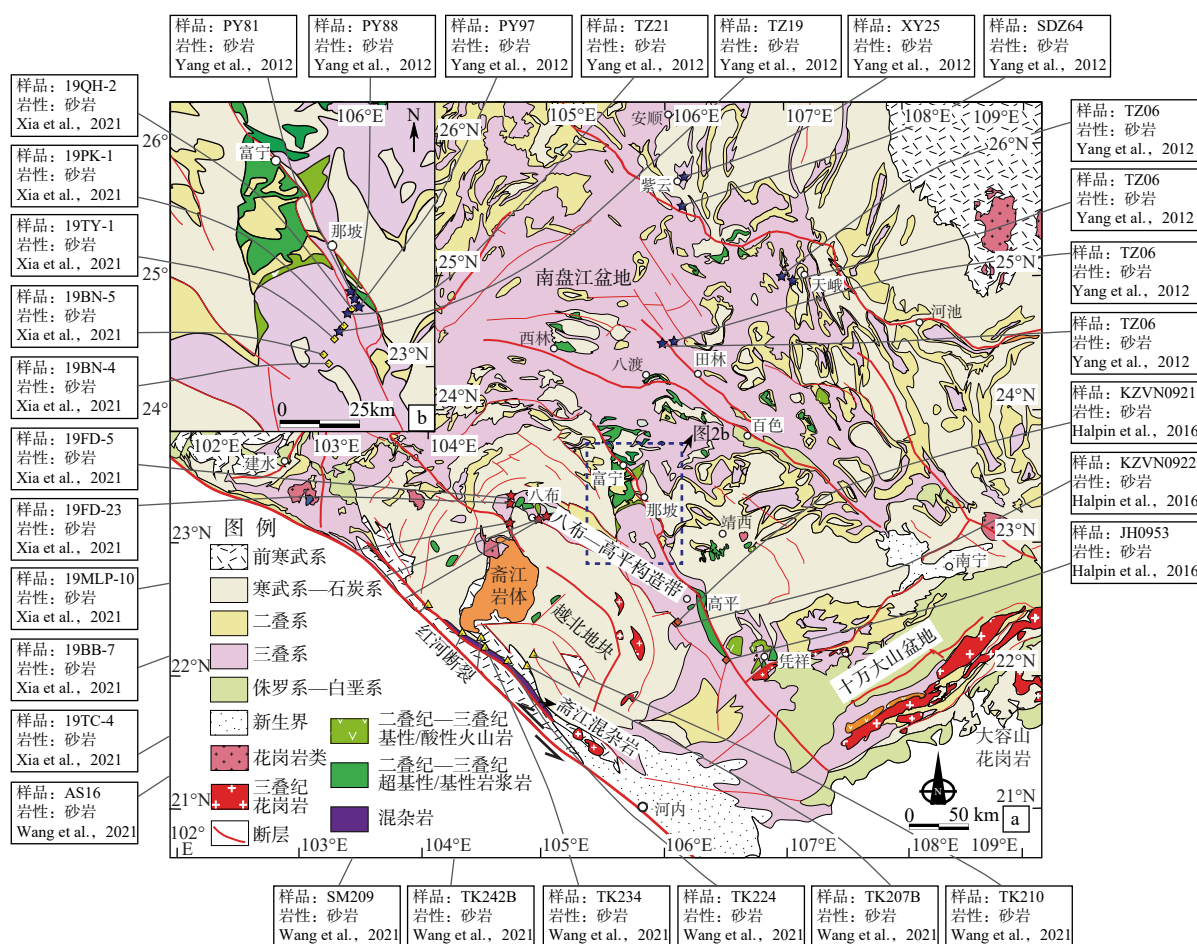
越北地块的沉积地层主要为上元古界至三叠系的海相地层,其中上三叠统不整合覆盖在下伏地层之上。侏罗纪时地层开始由海相转变为陆相,直至现今第四纪的地层均为陆相沉积(Thanh and Khuc, 2006)。上古生界碳酸盐岩岩石或未变质而保存了丰富的化石,或强烈变形变质并转化为大理岩(Thanh and Khuc, 2006)。早泥盆世地层以碳酸盐岩为主,从中泥盆世开始水体逐渐变深,由陆架相逐渐转变为晚泥盆世的深海相沉积(Thanh and Khuc, 2006)。石炭纪和二叠纪地层与上泥盆纪地层具有连续性,由海相碳酸盐岩(主要为灰岩和硅质灰岩)组成(Thanh and Khuc, 2006)。下三叠统位于二叠系陆架相碳酸盐沉积物上,主要由陆源重力流沉积物(砾岩、砂岩、凝灰质砂岩、粉砂岩、页岩)组成,部分为海相碳酸盐岩,属于复理石沉积序列(Thanh and Khuc, 2006)。

越北地块最显著的花岗岩是 420 Ma 侵位的斋江二长花岗岩(图 1),已变质变形为眼球状片麻岩(Zhou et al., 2017)。二叠纪—三叠纪基性—酸性岩浆岩被归因于与峨眉山地幔柱相关的板内成因(Tran et al., 2016)。越北地块同样也发育 252~245 Ma 的花岗岩,被解释成印支造山带的同碰撞花岗岩(Hoa et al., 2008; Roger et al., 2012; Chen et al., 2014)。

越北地块以斋江花岗片麻岩为核心,发育了顶部指向北东向的逆冲断层系,该逆冲系统的变质程度自南西向北东逐渐变弱(Lepvrier et al., 2011)。

2 碎屑锆石年龄

为了进行系统的物源对比,探讨八布—高平构造带的构造属性以及越北地块的归属,文章汇总了已报道的南盘江盆地、八布—高平构造带、越北陆块内的 31 件碎屑锆石样品和 1 件岩体(斋江岩体)锆石样品(结晶锆石+捕掳的继承锆石)的年龄数据(样品位置见图 2),在使用 density plot 软件按照统一



a—南盘江盆地紫云、天峨和田林地区、八布-高平构造带和斋江混杂岩碎屑锆石样品位置; b—南盘江盆地那坡地区碎屑锆石样品位置

图2 南盘江盆地、八布-高平构造带及越北地块碎屑锆石样品位置图

Fig. 2 Map showing the origins of detrital zircon samples from the Nanpanjiang basin, the Babu-Cao Bang tectonic belt, and the North Vietnam terrane

(a) Locations of detrital zircon samples in the Ziyun, Tian'e, and Tianlin areas of the Nanpanjiang basin, the Babu-Cao Bang tectonic belt, and the Song Chay mélange; (b) Locations of detrital zircon samples in the Napo area of the Nanpanjiang basin

标准进行直方图和概率曲线计算投图后,进行样品的年龄分布特征总结和谱峰比较(图3)。

2.1 南盘江盆地

南盘江盆地16件碎屑锆石样品主要采自盆地北部紫云、东部天峨、中部田林及南部那坡地区,包括下三叠统罗楼组和中三叠统新苑组、边阳组、百逢组、兰木组及河口组,采样位置见图2。通过对这16件样品的锆石年龄谱(图3)进行系统分析,发现其所有样品均显示以270~250 Ma(早二叠世—中三叠世)和460~420 Ma(晚奥陶世—早志留世)为主的单/双峰年龄组合。盆地北部紫云地区(样品SDZ64、XYZ5)和东部天峨地区(样品TZ02、TZ06)表现出2个主要年龄组(~275 Ma和~435 Ma);中部田林地区(样品LCG1、LCG2)也呈现相似特征,

但中元古代锆石(1083 Ma和1858 Ma)有增多趋势。南部那坡地区则存在显著差异,其中下三叠统罗楼组(样品19QH-2)表现出双峰年龄组合(253 Ma和430 Ma),中三叠统百逢组(样品PY81、PY88、PY97、19PK-1和19TY-1)以单峰(250~273 Ma)为主,仅个别样品(样品TZ21、19BN-4)保留双峰特征;兰木组(样品TZ19)和河口组样品(样品19BN-5、19BN-4)主要年龄组略年轻(263~245 Ma),可能与南部更接近同时代岩浆岩源区有关。

此外,上述样品的次要年龄组多集中于中—新元古代(1000~900 Ma)和古元古代(1800 Ma),其中北部和东部样品次要峰值年龄以~975 Ma为特征(样品TZ02、TZ06),中部田林(样品LCG1)则记录更古老的1858 Ma峰值。零散分布的古老锆石以中—

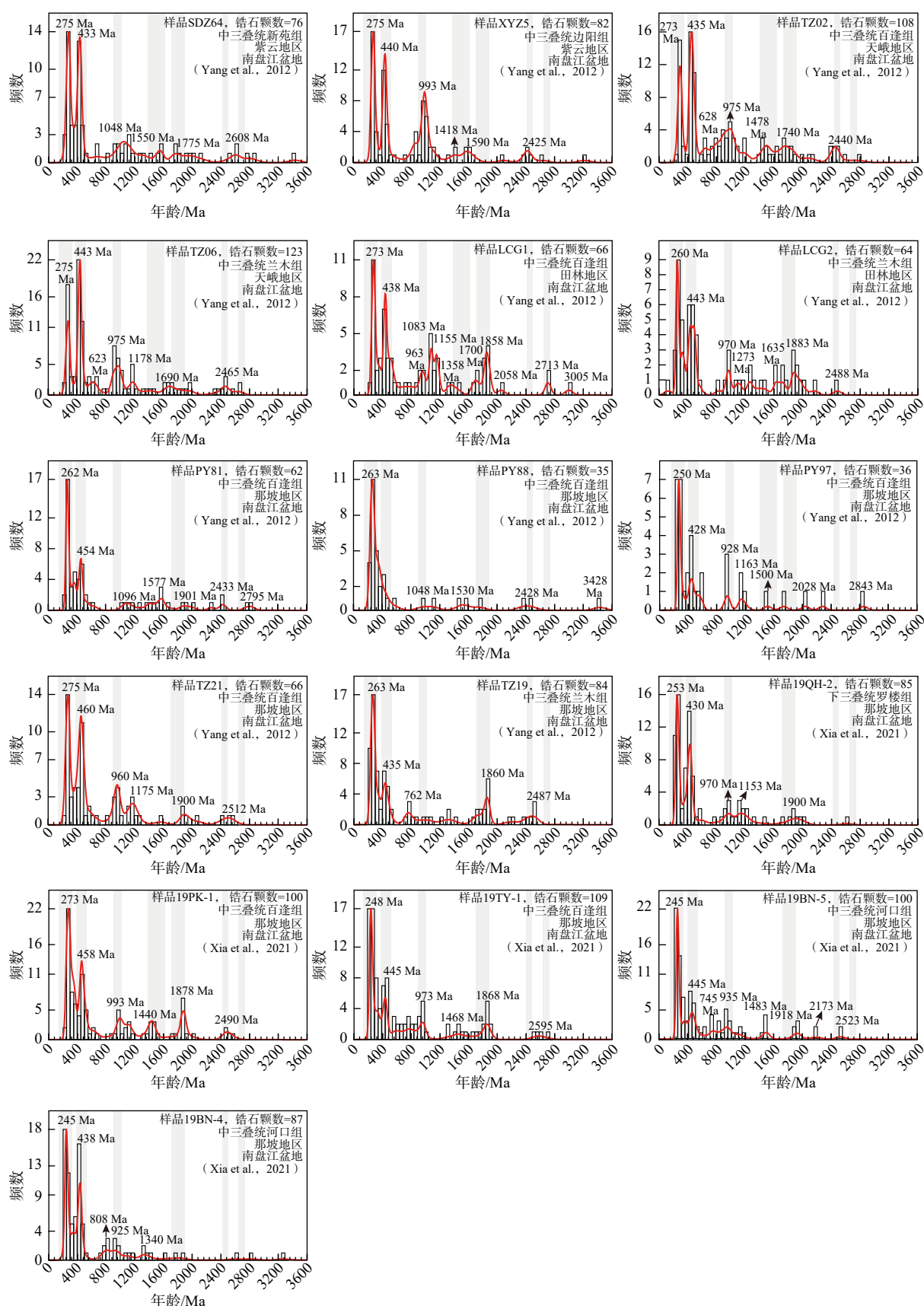


图3 南盘江盆地碎屑锆石年龄谱图

Fig. 3 Detrital zircon age spectra for the samples from the Nanpanjiang basin

新元古代(1880~970 Ma)为主,太古代锆石仅少量出现于田林样品(样品 LCG1)。南部那坡地区次要峰较弱,但部分样品(如样品 TZ21)仍保留~960 Ma 的次要峰值年龄,反映局部物源差异。

整体上,南盘江盆地下一中三叠统砂岩样品普遍具有2个显著的主要年龄组(主要集中在270~250 Ma 和460~420 Ma),以及1个次要年龄组(1000~900 Ma)。

2.2 八布-高平构造带

八布-高平构造带8件碎屑锆石样品主要采自西段八布地区的中三叠统兰木组 and 东段越南高平

地区的下三叠统 Song Hien 组,采样位置见图2。碎屑锆石年龄谱(图4)分析表明,其西段和东段碎屑锆石年龄分布具有些许差异,其中西段八布地区的样品 19FD-5、19FD-23 和 19TC-4 主要年龄组多集中在晚二叠世—早三叠世(253~242 Ma)与新元古代(963~938 Ma),而样品 19MLP-10 的主要年龄组则出现在志留纪(425 Ma)和新元古代(943 Ma),表现出双峰分布特征。样品 19BB-7 则具有单峰分布特征,主要年龄组集中在晚奥陶世(455 Ma),其余锆石为元古代,多呈零散分布。

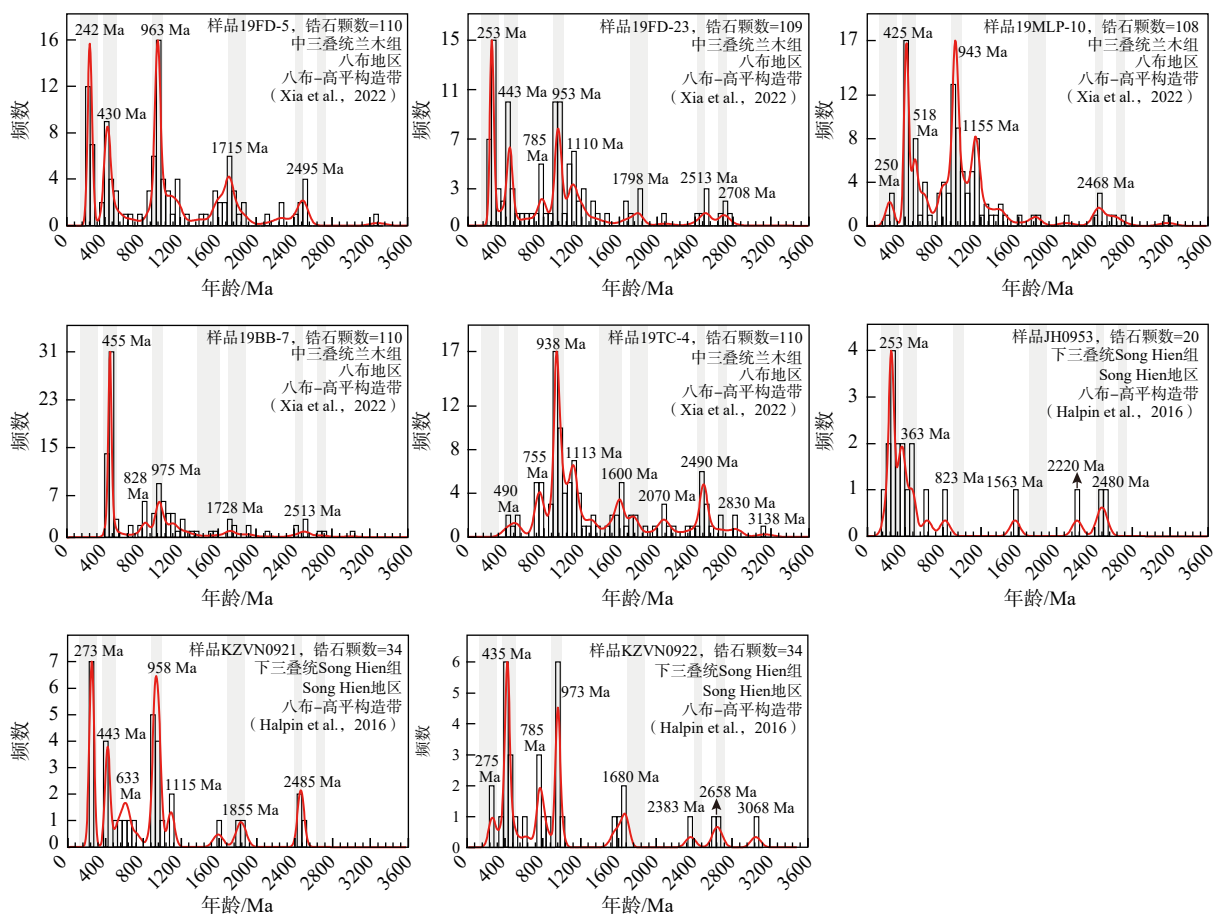


图4 八布-高平构造带碎屑锆石年龄谱图

Fig. 4 Detrital zircon age spectra for the samples from the Babu-Cao Bang tectonic belt

东段高平地区样品 JH0953 和 KZVN0921 的最年轻峰值年龄出现在中—晚二叠世(273~253 Ma),后者还具有1个新元古代(858 Ma)的主要年龄组。样品 KZVN0922 具有晚奥陶世(435 Ma)和新元古代(973 Ma)2个主要年龄组,与西段八布地区的样品 19MLP-10 较为一致。此外,样品 KZVN0922 还具有1个新元古代(785 Ma)次要年龄组。

综合分析得出,八布-高平构造带样品均不同程度地表现出270~240 Ma、460~430 Ma、980~780 Ma 的年龄集中,整体上与南盘江盆地较为一致。

2.3 越北地块

在越北地块南缘的斋江混杂岩中搜集了7个碎屑锆石样品的数据,样品位置见图2。另外,越北地块内部的斋江岩体锆石年龄数据参考 Zhou et

al.(2017)。由于岩浆在向上侵位的过程中,也会捕掳侵位路径中沉积岩围岩中的碎屑锆石,因此岩体中的继承锆石的分布也可以进行对比,作为地块归属的参考。

斋江岩体共搜集到了104粒锆石的数据,年龄谱图共表现出2个主要年龄组,峰值年龄分别为535 Ma和823 Ma,岩体的结晶年龄为436~423 Ma,其余多为中元古代锆石,年龄值零散波动分布(Zhou et al., 2017)。

斋江混杂岩中的7件样品的碎屑锆石主要年

龄组以早古生代(550~463 Ma)和新元古代(935~725 Ma)为主(图5),除样品SM209以外,绝大多数样品缺失270~250 Ma的锆石记录,年龄谱整体表现为单峰或双峰分布特征。此外,1800 Ma左右和2500 Ma左右的锆石同样普遍存在。由此可知,斋江混杂岩样品的碎屑锆石与南盘江盆地以及八布-高平构造带存在一定的差异。但样品SM209中晚二叠世的锆石暗示存在华南地块陆源碎屑物质的加入。

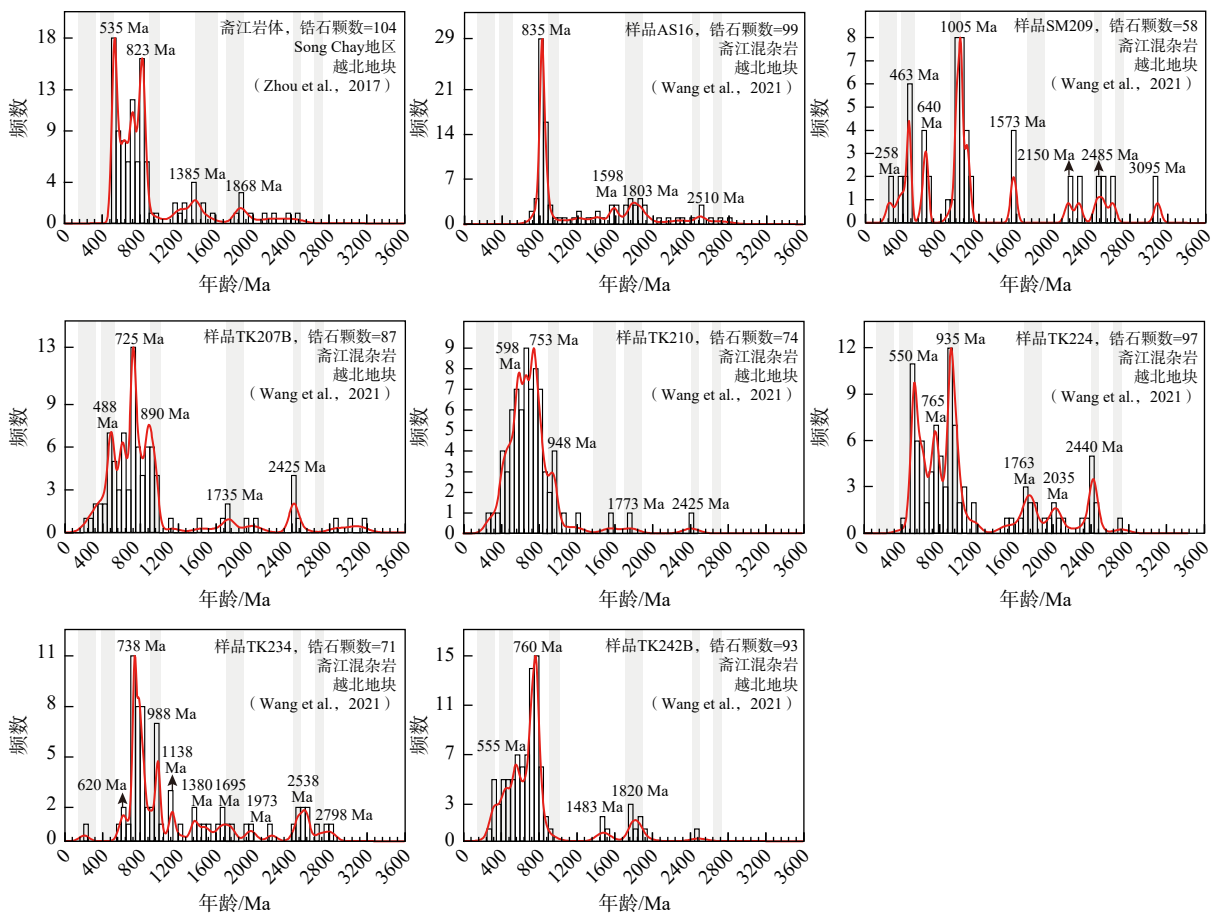


图5 越北地块斋江岩体和碎屑锆石年龄谱图

Fig. 5 Detrital zircon age spectra for the samples from the Song Chay massif in the North Vietnam terrane

3 讨论

3.1 碎屑锆石年龄对比

自北向南,南盘江盆地内的碎屑锆石样品均表现出2个极其明显的主要年龄组,其峰值主要集中在270~250 Ma和460~420 Ma范围内,反映其物源与二叠纪和早古生代晚期(晚奥陶世和志留纪)发

生的重要地质事件密切相关。在二叠纪,最显著的岩浆事件莫过于260 Ma左右峨眉山大火山岩省的形成,其核心地带位于南盘江盆地邻近的四川、云南和贵州(Fu et al., 2021);南盘江盆地内部也有大量的260 Ma左右的基性岩墙及玄武岩的发育,被认为形成于峨眉山大火山岩省的外带(Liu et al., 2017; Huang et al., 2019; Zhang et al., 2021; Hu et al., 2024)。另外,峨眉山大火山岩省活动结束后的三叠纪,南

缘山罗地区腕足动物可以同华南地区进行很好的对比(Shi and Shen, 1998),这也说明二叠纪时期持续的伸展作用虽然导致八布-高平构造带发育裂谷,但扩张幅度有限,并未出现广阔的大洋,裂谷两岸的物种仍存在联系。

从构造变形方面来看,越北地块以变形变质的斋岩岩体为核心,发育高级变质岩,并发育顶部指向北东方向的逆冲岩席,扩展到中国境内,且变质级别向北东方向逐渐降低(Lepvrier et al., 2011),这与南盘江盆地极低的变质程度是一致的(陈暑荣等, 2007)。变形变质的连续性说明南盘江盆地和越北地块之间并没有可以改变构造格架的重大构造边界。这也印证了上文得出的结论,即晚古生代八布-高平构造带并非开阔洋盆,而是裂谷盆地,或是类似于现今红海一般的初始洋盆;越北地块和南盘江盆地同属于华南地块的重要组成部分。

4 结论

(1) 华南西南缘的南盘江盆地、中越边境地区的八布-高平构造带、越北地块 3 个构造单元中的碎屑岩锆石多具有 270~250 Ma、460~420 Ma、1000~900 Ma 的年龄谱峰,另外年龄数据在 1800 Ma 左右以及 2500 Ma 左右也相对集中。这体现了 3 个构造单元的沉积物源具有统一性。

(2) 结合南盘江盆地和越北地块晚古生代—早中生代地层对比结果以及同时期动物区系的相似性,推测自泥盆纪以来的伸展作用导致了八布-高平构造带在二叠纪时期发育裂谷、深水沉积,甚至演化至初始洋盆,然而其扩张幅度有限,未发育成广阔的大洋,也未阻断越北地块和南盘江盆地的联系。越北地块是华南地块的重要组成部分。

References

- CAI J X, ZHANG K J, 2009. A new model for the Indochina and South China collision during the Late Permian to the Middle Triassic[J]. *Tectonophysics*, 467(1-4): 35-43.
- CHEN S R, LU G, ZHANG N, et al., 2007. Low metamorphism and deformation tectonics of Triassic system in Youjiang Basin: take Tian'e area as an example[J]. *Journal of Guilin University of Technology*, 27(3): 304-309. (in Chinese with English abstract)
- CHEN Z C, LIN W, FAURE M, et al., 2014. Geochronology and isotope analysis of the Late Paleozoic to Mesozoic granitoids from northeastern Vietnam and implications for the evolution of the South China block[J]. *Journal of Asian Earth Sciences*, 86: 131-150.
- DU Y S, HUANG H W, HUANG Z Q, et al., 2009. Basin translation from Late Palaeozoic to Triassic of Youjiang basin and its tectonic significance[J]. *Bulletin of Geological Science and Technology*, 28(6): 10-15. (in Chinese with English abstract)
- DUAN L, CHRISTIE-BLICK N, MENG Q R, et al., 2023. A back-arc transtensional origin for the Nanpanjiang basin in the pre-Norian Triassic, with implications for the broader intracontinental development of South China[J]. *Basin Research*, 35(2): 551-571.
- FAURE M, LEPVRIER C, VAN NGUYEN V, et al., 2014. The South China block-Indochina collision: where, when, and how?[J]. *Journal of Asian Earth Sciences*, 79: 260-274.
- FAURE M, LIN W, CHU Y, et al., 2016a. Triassic tectonics of the southern margin of the South China Block[J]. *Comptes Rendus Geoscience*, 348(1): 5-14.
- FAURE M, LIN W, CHU Y, et al., 2016b. Triassic tectonics of the Ailaoshan Belt (SW China): early Triassic collision between the South China and Indochina Blocks, and Middle Triassic intracontinental shearing[J]. *Tectonophysics*, 683: 27-42.
- FENG Q L, LIU B P, 2002. Early Permian radiolarians from Babu ophiolitic mélange in southeastern Yunnan[J]. *Earth Science—Journal of China University of Geosciences*, 27(1): 1-3. (in Chinese with English abstract)
- FU J N, PIRAJNO F, YANG F, et al., 2021. Integration of zircon and apatite U-Pb geochronology and geochemical mapping of the Wude basalts (Emeishan large igneous province): a tool for a better understanding of the tectonothermal and geodynamic evolution of the Emeishan LIP[J]. *Geoscience Frontiers*, 12(2): 573-585.
- GAO J B, YANG R D, ZHENG L L, et al., 2017. Depositional environments and tectonic background of the Middle-Late Devonian siliceous sediments in Luodian, South Guizhou[J]. *Acta Geologica Sinica*, 91(9): 2004-2020. (in Chinese with English abstract)
- GUO W, NIE T, SUN Y L, 2019. New data on the biostratigraphy of the Early Devonian "*Spirifer*" tonkinensis brachiopod fauna in South China and adjacent region[J]. *Palaeobiodiversity and Palaeoenvironments*, 99(1): 29-43.
- HALPIN J A, TRAN H T, LAI C K, et al., 2016. U-Pb zircon geochronology and geochemistry from NE Vietnam: a 'tectonically disputed' territory between the Indochina and South China blocks[J]. *Gondwana Research*, 34: 254-273.
- HOA T T, ANH T T, PHUONG N T, et al., 2008. Permo-Triassic intermediate-felsic magmatism of the Truong Son belt, eastern margin of Indochina[J]. *Comptes Rendus Géoscience*, 340(2-3): 112-126.
- HU L S, CAWOOD P A, DU Y S, et al., 2024. OIB-type mafic-ultramafic rocks in South Guangxi, South China: a record of interaction between Paleozoic Tethys subduction and Emeishan large Igneous Province[J]. *Lithos*, 468-469: 107497.
- HUANG Y, HE C, CHEN N S, et al., 2019. Diabase sills in the outer zone of the Emeishan Large Igneous Province, Southwest China: petrogenesis and tectonic implications[J]. *Journal of Earth Science*, 30(4): 739-753.
- HUANG Z Q, HUANG H, DU Y S, et al., 2013. Depositional chemistry of cherts of the Late Paleozoic in Napo rift basin, Guangxi and its implication for the tectonic evolution[J]. *Earth Science—Journal of China Uni-*

- versity of Geosciences, 38(2): 253-265. (in Chinese with English abstract)
- JIANG W, YAN Q R, XIA W J, et al., 2021. Geochronology and petrogenesis of Triassic low-Ti mafic intrusions in Funing: implications for the tectonic evolution of Nanpanjiang Basin, SW China[J]. *Geological Journal*, 56(10): 5235-5254.
- LEPVRIER C, FAURE M, VAN V N, et al., 2011. North-directed Triassic nappes in Northeastern Vietnam (East Bac Bo)[J]. *Journal of Asian Earth Sciences*, 41(1): 56-68.
- LI Q L, LIN W, WANG Y, et al., 2021. Detrital zircon U-Pb age distributions and Hf isotopic constraints of the Ailaoshan-Song Ma Suture Zone and their paleogeographic implications for the Eastern Paleo-Tethys evolution[J]. *Earth-Science Reviews*, 221: 103789.
- LIN W, LIU F, WANG Y, et al., 2024. Temporal and spatial heterogeneity of the Ailaoshan-Song Ma-Song Chay ophiolitic mélange, and its significance on the evolution of Paleo-Tethys[J]. *Comptes Rendus Géoscience*, 356(S2): 115-136.
- LIN W, WANG Y, LIU F, et al., 2024. Indosinian orogenic belt: Song Chay tectonic belt[J]. *Acta Petrologica Sinica*, 40(1): 1-28. (in Chinese with English abstract)
- LIU B P, FENG Q L, FANG N Q, et al., 1993. Tectonic evolution of Palaeo-Tethys poly-island-ocean in Changning-Menglian and Lancangjiang belts, southwestern Yunnan, China[J]. *Earth Science—Journal of China University of Geosciences*, 18(5): 529-539. (in Chinese with English abstract)
- LIU C, 2017. Sedimentary features and evolution of the Late Paleozoic isolated Bama Platform in the Youjiang Basin: responses to and implications for the deep-time climate change[D]. Wuhan: China University of Geosciences: 1-214. (in Chinese with English abstract)
- LIU J L, TRAN M D, TANG Y, et al., 2012. Permo-Triassic granitoids in the northern part of the Truong Son belt, NW Vietnam: geochronology, geochemistry and tectonic implications[J]. *Gondwana Research*, 22(2): 628-644.
- LIU X J, LIANG Q D, LI Z L, et al., 2017. Origin of Permian extremely high Ti/Y mafic lavas and dykes from Western Guangxi, SW China: implications for the Emeishan mantle plume magmatism[J]. *Journal of Asian Earth Sciences*, 141: 97-111.
- METCALFE I, 2021. Multiple Tethyan ocean basins and orogenic belts in Asia[J]. *Gondwana Research*, 100: 87-130.
- QIU L, YAN D P, TANG S L, et al., 2016. Mesozoic geology of southwestern China: indosinian foreland overthrusting and subsequent deformation[J]. *Journal of Asian Earth Sciences*, 122: 91-105.
- ROGER F, MALUSKI H, LEPVRIER C, et al., 2012. LA-ICPMS zircons U/Pb dating of Permo-Triassic and Cretaceous magmatisms in Northern Vietnam-Geodynamical implications[J]. *Journal of Asian Earth Sciences*, 48: 72-82.
- SHI G R, SHEN S Z, 1998. A Changhsingian (Late Permian) brachiopod fauna from Son La, northwest Vietnam[J]. *Journal of Asian Earth Sciences*, 16(5-6): 501-511.
- SHU L S, YAO J L, WANG B, et al., 2021. Neoproterozoic plate tectonic process and Phanerozoic geodynamic evolution of the South China Block[J]. *Earth-Science Reviews*, 216: 103596.
- SONE M, METCALFE I, 2008. Parallel Tethyan sutures in mainland Southeast Asia: new insights for Palaeo-Tethys closure and implications for the Indosinian orogeny[J]. *Comptes Rendus Géoscience*, 340(2-3): 166-179.
- THANH N X, HAI T T, HOANG N, et al., 2014. Backarc mafic-ultramafic magmatism in Northeastern Vietnam and its regional tectonic significance[J]. *Journal of Asian Earth Sciences*, 90: 45-60.
- THANH T D, KHUC V, 2006. Stratigraphic units of Vietnam[M]. Hanoi: Vietnam National University Publishing House: 1-526.
- TRAN H T, DANG B V, DO T D, et al., 2007. The occurrence of pillow basalts in Cao Bang-Lang Son area and their implication to the tectonic setting of East Bac Bo region[J]. *Journal of Geology, Department of Geology and Minerals of Vietnam*, 299: 10-24. (in Vietnamese)
- TRAN H T, POLYAKOV G V, TRAN A T, et al., 2016. Intraplate magmatism and metallogeny of North Vietnam[M]. Cham: Springer: 103-152.
- WAN B, WU F Y, ZHU R X, 2023. The influence of Tethyan evolution on changes of the Earth's past environment[J]. *Science China Earth Sciences*, 66(12): 2653-2665. (in Chinese with English abstract)
- WANG Y, LIN W, FAURE M, et al., 2021. Detrital zircon U-Pb age distribution and Hf isotopic constraints from the terrigenous sediments of the Song Chay suture Zone (NE Vietnam) and their paleogeographic implications on the eastern Paleo-Tethys evolution[J]. *Tectonics*, 40(8): e2020TC006611.
- WU F Y, WAN B, ZHAO L, et al., 2020. Tethyan geodynamics[J]. *Acta Petrologica Sinica*, 36(6): 1627-1674. (in Chinese with English abstract)
- XIA L, YAN Q R, XIANG Z J, et al., 2018. Olistotromes in the northern margin of the Napo forearc basin (Guangxi, South China): a special indicator for discriminating forearc domain[J]. *Acta Petrologica Sinica*, 34(3): 685-700. (in Chinese with English abstract)
- XIA L, YAN Q R, XIANG Z J, et al., 2021. Provenance and tectonic setting of the Triassic clastic deposits in the Napo basin, South China: evidence from petrography, whole-rock geochemistry and detrital zircon U-Pb geochronology[J]. *Geological Magazine*, 158(12): 2095-2114.
- XIA L, YAN Q R, XIANG Z J, et al., 2022. Triassic detrital records in the western Dian-Qiong suture, South China: implications for the eastern Paleozoic-Tethys evolution[J]. *Terra Nova*, 34(6): 561-571.
- XIA W J, YAN Q R, XIANG Z J, et al., 2018. Sedimentary characteristics of the Early-Middle Triassic on the south flank of the the Xilin faulted block in the Nanpanjiang basin and its tectonic implications[J]. *Acta Petrologica Sinica*, 34(7): 2119-2139. (in Chinese with English abstract)
- XIA W J, YAN Q R, XIANG Z J, et al., 2019. Baddeleyite and zircon U-Pb dating of Badu diabase in the Nanpanjiang basin and its tectonic significance[J]. *Acta Geoscientia Sinica*, 40(2): 265-278. (in Chinese with English abstract)
- XIANG Z J, YAN Q R, XIA L, et al., 2021. The tectonic setting of the Early-Middle Triassic volcanic-sedimentary succession in Funing-Napo area, the south margin of Nanpanjiang Basin, South China[J]. *Geological Bulletin of China*, 40(1): 138-151. (in Chinese with English abstract)
- XIANG Z J, YANG J H, YAN Q R, et al., 2022. Petrogenesis of the Early-Middle Triassic high-Mg andesitic rocks in the southern margin of the South China Block: implications for the convergence between the South China and Indochina Blocks[J]. *Journal of Asian Earth Sciences*, 232: 104994.
- YANG J H, CAWOOD P A, DU Y S, et al., 2012. Detrital record of Indosinian mountain building in SW China: provenance of the Middle Triassic

- turbidites in the Youjiang Basin[J]. *Tectonophysics*, 574-575: 105-117.
- YAO S X, ZHOU K H, YU H M, et al., 2018. Extension of the Devonian Danchi sequence in western Guangxi province[J]. *Journal of Stratigraphy*, 42(2): 238-242. (in Chinese with English abstract)
- ZHANG B H, DING J, ZHANG L K, et al., 2013. SHRIMP zircon U-Pb chronology of the Babu ophiolite in southeastern Yunnan province[J]. *Acta Geologica Sinica*, 87(10): 1498-1509. (in Chinese with English abstract)
- ZHANG C G, ZENG R Y, LI C M, et al., 2021. Late Permian High-Ti basalt in Western Guangxi, SW China and its link with the Emeishan Large Igneous Province: geochronological and geochemical perspectives[J]. *Frontiers in Earth Science*, 9: 729955.
- ZHANG Q, ZHANG K W, LI D Z, et al., 1988. A preliminary study of Shuanggou ophiolite in Xiping county, Yunnan province[J]. *Acta Petrologica Sinica*(4): 37-48. (in Chinese with English abstract)
- ZHONG D L, WU G Y, JI J Q, et al., 1999. Discovery of ophiolite in Southeast Yunnan, China[J]. *Chinese Science Bulletin*, 44(1): 36-41.
- ZHOU X Y, YU J H, O'REILLY S Y, et al., 2017. Sources of the Nanwenhe-Song Chay granitic complex (SW China - NE Vietnam) and its tectonic significance[J]. *Lithos*, 290-291: 76-93.
- 黄志强, 黄虎, 杜远生, 等, 2013. 广西那坡裂陷盆地晚古生代硅质岩地球化学特征及其地质意义[J]. *地球科学——中国地质大学学报*, 38(2): 253-265.
- 林伟, 王印, 刘飞, 等, 2024. 印支造山带: Song Chay 构造带[J]. *岩石学报*, 40(1): 1-28.
- 刘本培, 冯庆来, 方念乔, 等, 1993. 滇西南昌宁—孟连带和澜沧江带古特提斯多岛洋构造演化[J]. *地球科学——中国地质大学学报*, 18(5): 529-539.
- 刘超, 2017. 华南右江盆地晚古生代巴马孤立台地沉积特征与演化: 对深时古气候演变的响应和启示[D]. 武汉: 中国地质大学: 1-214.
- 万博, 吴福元, 朱日祥, 2023. 特提斯演化对地球环境演变的影响[J]. *中国科学: 地球科学*, 53(12): 2687-2700.
- 吴福元, 万博, 赵亮, 等, 2020. 特提斯地球动力学[J]. *岩石学报*, 36(6): 1627-1674.
- 夏磊, 闫全人, 向忠金, 等, 2018. 广西那坡盆地火山岩-碳酸盐岩混杂型滑塌堆积: 特殊的弧前域构造指相标志及其大地构造意义[J]. *岩石学报*, 34(3): 685-700.
- 夏文静, 闫全人, 向忠金, 等, 2018. 南盘江盆地中部西林断隆南翼中一下三叠统沉积学特征及其大地构造意义[J]. *岩石学报*, 34(7): 2119-2139.
- 夏文静, 闫全人, 向忠金, 等, 2019. 南盘江盆地八渡辉绿岩斜锆石和锆石 U-Pb 年龄及其地质意义[J]. *地球学报*, 40(2): 265-278.
- 向忠金, 闫全人, 夏磊, 等, 2021. 南盘江盆地南缘富宁—那坡地区早一中三叠世火山-沉积组合形成环境[J]. *地质通报*, 40(1): 138-151.
- 姚仕祥, 周开华, 庾慧敏, 等, 2018. 丹池地区泥盆纪地层序列在右江裂陷盆地的延伸[J]. *地层学杂志*, 42(2): 238-242.
- 张斌辉, 丁俊, 张林奎, 等, 2013. 滇东南八布蛇绿岩的 SHRIMP 锆石 U-Pb 年代学研究[J]. *地质学报*, 87(10): 1498-1509.
- 张旗, 张魁武, 李达周, 等, 1988. 云南新平县双沟蛇绿岩的初步研究[J]. *岩石学报*(4): 37-48.

附中文参考文献

- 陈暑荣, 陆刚, 张能, 等, 2007. 右江盆地三叠系的极低级变质作用与变形构造: 以天峨地区为例[J]. *桂林工学院学报*, 27(3): 304-309.
- 杜远生, 黄宏伟, 黄志强, 等, 2009. 右江盆地晚古生代—三叠纪盆地转换及其构造意义[J]. *地质科技情报*, 28(6): 10-15.
- 冯庆来, 刘本培, 2002. 滇东南八布蛇绿混杂岩中的早二叠世放射虫化石[J]. *地球科学——中国地质大学学报*, 27(1): 1-3.
- 高军波, 杨瑞东, 郑禄林, 等, 2017. 黔南罗甸中晚泥盆世硅质岩类沉积环境及其形成的大地构造背景[J]. *地质学报*, 91(9): 2004-2020.