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Changes of Clastic Provenance of Yunnan-Guizhou-Guangxi Basin in SW China and Implications for evolution history of Paleo-tethys

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Abstract: *Tectonic evolution of the Paleo-tethys has been the focus of many studies, especiallyon the timing of opening, expansion, subduction and closure, there has been controversy. The predecessors of the Paleo-Tethys evolution mostly concentrated in the traditional direction, such as ophiolite, granite, metamorphic rocks and paleomagnetic. In this study, we carried out LA-ICP-MS U–Pb dating to analyze the detrital zircon from the Devonian Posongchong formation and the Upper Triassic Luolou formation in the Yunnan-Guizhou-Guangxi Basin, and to limit evolution history of the Paleo-Tethys by studying the changes of the Paleozoic clastic provenance in the basin. The results show that most of the zircons in these two places have magmatic zones with Th/U values > 0.4. And the test results showed that the ages of the zircons from the Luolou formation in the Zhesang area ranged from 308-396 Ma, 440-680 Ma, 727-930 Ma, 1004-1266 Ma, 1400-1880 Ma and 2360-2724 Ma, respectively, while the ages of the zircons from the Posongchong formation in Laozhaiwan area were mostly 657-460 Ma and 998-798Ma. By comparing the age distribution characteristics of detrital zircons between the study area and the surrounding blocks, and combining with lithofacies palaeogeography, palaeo-ocean current and palaeo-current, the comprehensive analysis shows that the Palaeozoic clastic provenance of the Yunnan-Guizhou-Guangxi Basin has changed around 460 Ma. Before 460 Ma, the clastic provenance was mainly from the Northern India、Himalaya、Lhasa、Qiangtang terrane、Hainan Island 、western Australia and Jiangnan Orogen; After 460Ma, the provenance of the study area is mainly from the northern Vietnam palaeo-continent, and that the tectonic mountain system of Hunan, Guangdong and Guangxi and Yunkai area may also provide some provenances. This provenance change confirms that the Paleo-Tethys opened around 460 Ma and closed in the Upper Triassic, and the South China Block collided with the Indosinian Block along the Songma suture zone.*

Keywords: *Paleo-tethys, Yunnan-Guizhou-Guangxi Basin, LA-ICP-MS, Detrital zircon, Paleozoic, Provenance, Northern India, Himalaya, Northern Vietnam.*

1. INTRODUCTION

The Paleo-Tethys Ocean is one of the largest oceans in geological history and is generally considered to be a Paleozoic ocean basin between the Laurasia and Gondwana supercontinents[1,2]. Generally speaking, the tectonic evolution of the northern edge of Gondwana is interpreted as the evolutionary relationship (open and closed) between the Paleo-Tethys, Meso-Tethys and Ceno-Tethys [3]. At present, it is more common that Paleo-Tethys has experienced four stages of formation, expansion, subduction and closure, but there has been much controversy about the opening and closing time of the Paleo-Tethys. Preliminary studies have shown that the Paleo-Tethys Ocean opened at the end of Silurian, began to expand in Devonian, formed an ocean in Carboniferous, developed to the limit in Early Permian, then began to decline until the end of Late Triassic closed. There has been a lot of research on the specific time when Paleo-Tethys opened and closed, but there is still no widely accepted research conclusion. For instance, Liu et al.[4]and Chen et al.[5] believed that the opening time of the Paleo-Tethys Ocean was 345-333 Ma based on the late Devonian-early Carboniferous ophiolites discovered in the East Kunlun Orogen. Through the discovery and study of Cambrian ophiolites, some scholars have shown that the Paleo-Tethyas Ocean was first opened in Cambrian[6,7]. Besides, based on the late Triassic high-pressure metamorphic belt, the collisional to post-collisional magmatism of the Late Triassic and the Late Triassic oceanic island arc discovered in the Qiangtang terrane, the closure time of the Paleo-Tethys Ocean was constrained to the Late Triassic[8]. However, other scholars believe that the Paleo-Tethys Ocean was closed in the Middle Triassic.

2. GEOLOGICAL SETTING

The South China Block in the southeastern part of the Eurasian consists of the Yangtze Block to the northwest and the Cathaysia Block to the southeastby the Qin Hang Suture zone, at around 830 Ma[9]. In the Triassic, due to Indosinian subduction of Indochina beneath the South China Craton, the South China Craton was connected to the Indosinian block in the south by the Song Ma Suture zone and Adjacent to the North China Craton along the Qinling-Dabie orogenic belt in the north[10,11,12,13]. controlled by ore-bearing formations and strata, resulting in various shapes of ore bodies, which are layered, layered and lenticular, mainly occurring in the phase-changing areas of the basin[14]. Faults and several primary structures in the study area controlled basin subsidence during the crustal movement and early Devonian rifts.

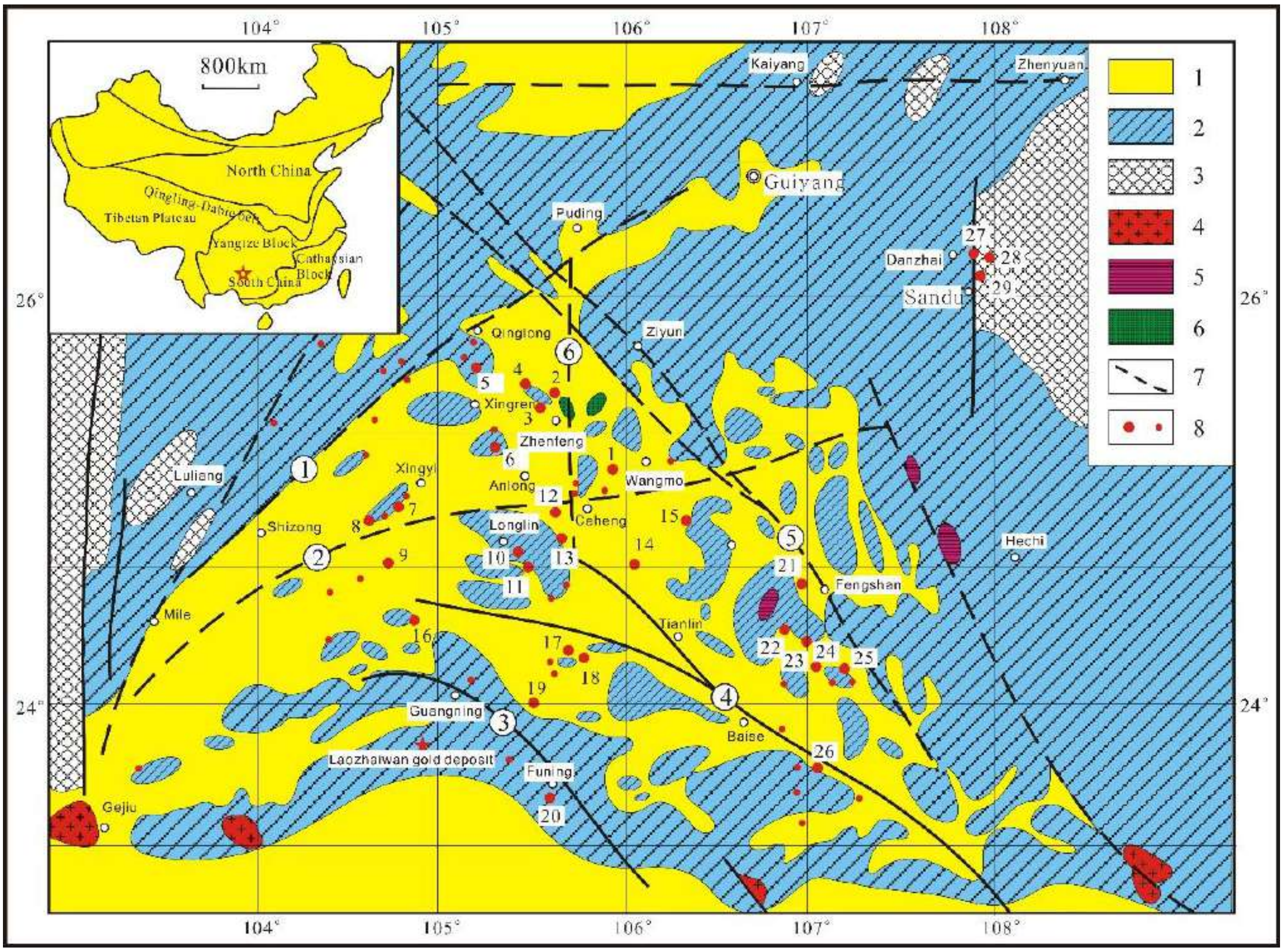

Fig -1. Regional Geological Map of Yunnan-Guizhou-Guizhou Basin

The micro-disseminated gold deposits in the area are mainly distributed in the sedimentary rocks of the Permian and Triassic, and the Triassic strata are the most widely distributed rock series in the area. The center of the rock series is mainly turbidite sedimentary rocks and pyroclastic rocks, surrounded by mesocarbonate carbonates, and the two are called interbedded phases or transitional slopes. The main facies of the Triassic stratum and the platform facies are the same-minded manganese deposits, in the Latino period, while the transitional facies are the ore-bearing horizons of various low-temperature minerals, such as Carlin-type gold, antimony, mercury, etc [15,16,17,18,19,20].The "Golden Triangle" area of Yunnan, Guizhou and Guangxi formed a continental margin rift basin in the early Paleozoic. During the long geological history from the Early Devonian to the Middle Triassic, it underwent complex transgression, developed huge marine sedimentary stratum from the Devonian to the Triassic, and evolved into a unified turbidite sedimentary basin in the Triassic, which underwent denudation and uplift in the Caledonian. After the Indosinian movement, the Cretaceous terrigenous clastic strata were formed in the Yanshanian Period[21]. The oldest stratum in the area are Cambrian–Ordovician shales and calcareous rocks, and these crop out on the anticlines of superimposed folds[22,23]. From the Late Proterozoic to Middle Triassic, marine sediments with a thickness of 7 km accumulated within the study area. After this protracted marine history, the area was overthrust by Palaeozoic sedimentary rocks[24,25,26]. The lower part of the "Golden Triangle" area in Yunnan, Guizhou and Guangxi is a Youjiang block with strong activity. The activity of the block causes frequent and intense magmatic activity in the study area. From Caledonian to Himalayan magmatic activities occur to varying degrees, mostly basic and intermediate-acid magmatic activities, of which the Hercynian-Indosinian basic magmatic intrusion is the most magnificent. The sedimentation in study area is controlled by paleotectonic basins which evolved into the tidal flat of the lower Triassic along the broad restricted platform [27,28,29,30].

3. SAMPLES AND METHODS

The samples are from Zhesang gold deposit and Laozhaiwan gold deposit in the "Golden Triangle" area of Yunnan, Guizhou and Guangxi. The samples from Zhesang and Laozhaiwan deposits are numbered ZS and LZW respectively. The sample was taken from the Laozhaiwan area in southeastern Yunnan. The geographical coordinates are: east longitude 104°51′30″～104°55′00″, north latitude 23°48′01″～23°51′00″. The specific sampling location is the Lower Devonian Posongchong Formation in Laozhaiwan area and the stratigraphic lithology is thin-bedded mudstone silty mudstone and siltstone respectively. Generally speaking, the Posongchong Formation is angular unconformity overlying carbonate rocks of the Lower Ordovician Shanpianshan Formation. Another group of samples from Zhesang Mining Area, Funing County, Yunnan Province, were collected from Baifeng Formation of Middle Triassic. Sampling positions of two groups of samples are shown in Fig.2.

Zircon is a very stable mineral, which often exists in magmatic rocks as a by-mineral. Its U-Pb isotope system can be kept closed during weathering and denudation, transport and deposition of rocks, and middle and low-grade metamorphism. Even if the rocks are affected by other external forces, the source information in zircon will not be completely lost. Therefore, according to the agglomeration of its clastic zircon grains in middle and low-grade metamorphic rocks. The age characteristics of the protolith are obtained from the information of crystal morphology, zonal characteristics and so on.

The sample crushing and zircon selection were completed by Langfang Chengxin Geological Service Co., Ltd., and the sample target work was completed in Beijing Zirconium Leading Technology Co., Ltd. The zircon cathode luminescence image was taken in the scanning electron microscope room of Beijing Zirconium Leading Technology Co., Ltd. The instrument model was an electronic JSM6510 scanning electron microscope from Japan equipped with a Gantan cathode fluorescent probe. The trace element test was carried out at the State Key Laboratory of Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, using a quadrupole Inductively Coupled Plasma Mass Spectrometer = Q-ICP-MS. Thezircon U-Pb isotopic dating test was performed by LA-ICP-MS analysis at the State Key Laboratory of Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences. The U-Th-Pb isotope ratio drift related to the analysis time was corrected by linear interpolation[31]. The recommended U-Th-Pb isotope ratio of zircon standard 91500 was calculated by Wiedenbeck et al.[32]. The samples were analyzed once every 10 sample points.Isoplot/Ex_ver3[33] was used to plot U-Pb age harmonics and to calculate the average age weight. SQUID11.03d and ISOPLOT[33] are used for data processing. Single data error is 1σ and the reported results have a 95% confidence level in accuracy.

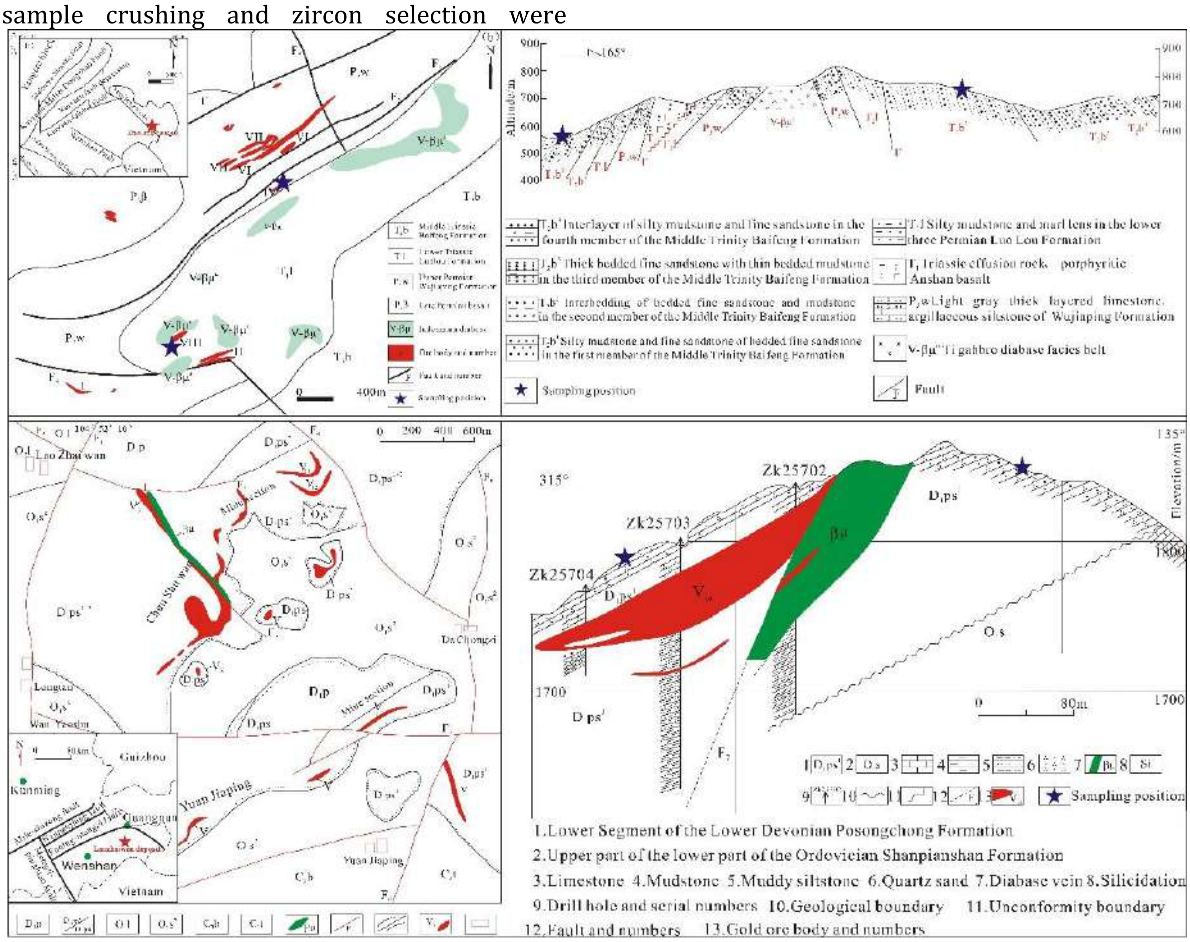

Fig -2. Sampling position and sampling profile

4. RESULTS

The cathodoluminescence image of the detrital zircon (ZS represents samples from Zhesang gold deposit and LZW represents samples from Laozhaiwan gold deposit) shows that the zircon particles are mainly divided into two categories: most of the zircon particles are grayish white to taupe, a small part is colorless and transparent, and the crystal form is mostly long columnar, sub-angular, The particle size is 50~150μm, the crystal form is complete, suggesting that the source may be nearby; the other type is grayish white, the transparency is higher, the secondary rolling is granular, the surface is smooth, the roundness and sorting are better, and the handling trace is obvious. This type of zircon is derived from younger rocks and has been preserved for long distance handling. The degree of CL luminescence of zircon particles is significantly different. Some zircons have poor luminescence and darker colors, indicating that the formation of their parent rocks is earlier. Secondly, the zircons in the samples are different in morphology but from CL. Obvious oscillations of the annulus and prosodic structure can be seen in the image, and the Th/U value is greater than 0.4, indicating that the zircon is mostly magma,The selection of age data in this study is bounded by 1000 Ma. This is because $^{207}Pb/^{206}Pb$ ages are more reliable for zircons older than 1000 Ma, as they have large amounts of radiogenic Pb. In contrast, $^{206}Pb/^{238}U$ ages are more reliable for zircons younger than1000 Ma because of low amount of radiogenic Pb and common Pb correction. Complete U-Pb zircon age results of Zhesangare shown inFig.3. For the detrital zircon from Laozhaiwan area, after processing and analysis, the data with less than 90% harmonic degree are eliminated, and the remaining data and U-Pb Concordia diagram and age Histogram for detrital zircon are shown in Fig.4. The age span of detrital zircon in this test is large, but it mainly concentrates on 350-1000 Ma.

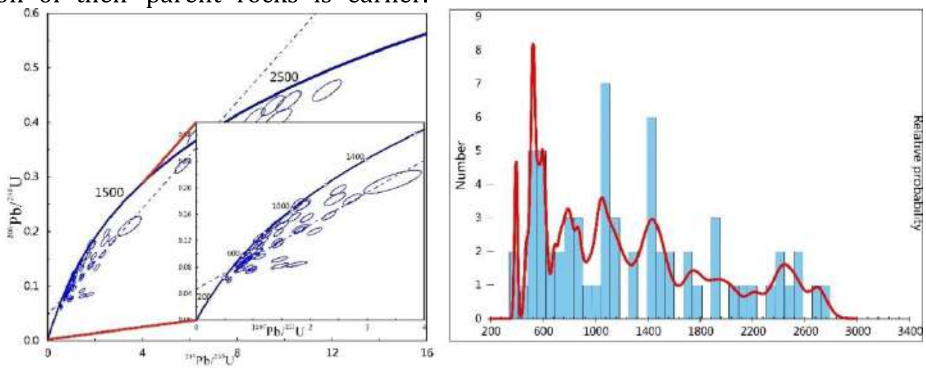

Fig -3.U-Pb Concordia diagram and age Histogram of detrital zircon from the Zhesang area

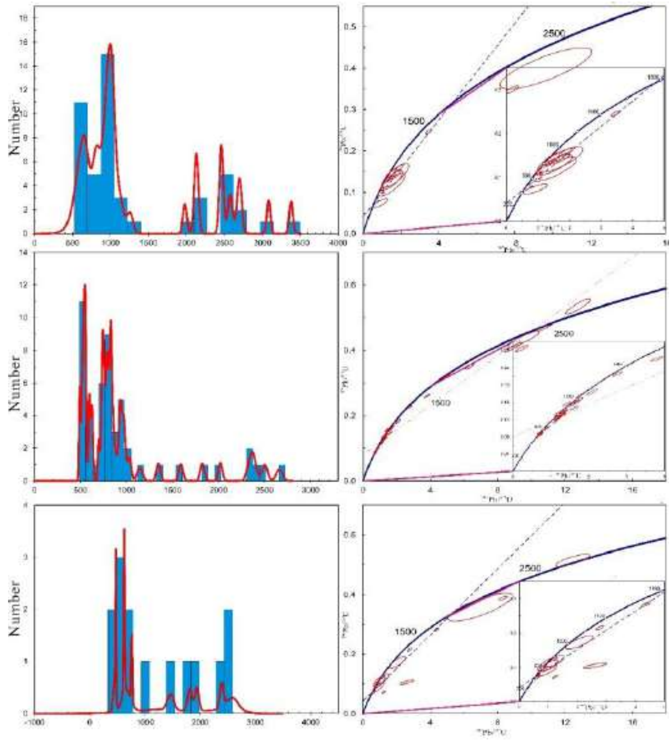

Fig -4.U-Pb Concordia diagram and age Histogram for detrital zircon from the Laozhaiwan area

5. DISCUSSION

5.1 Changes of Provenance of Yunnan-Guizhou-Guangxi Basin

The detrital provenance of Yunnan-Guizhou-Guangxi Basin has been studied extensively by predecessors, but mainly in the Early and Middle Triassic, and different scholars hold different opinions. In the study of the provenance of the Middle Triassic turbidite in Yunnan-Guizhou-Guangxi Basin, some scholars believe that the provenance of the basin comes from the Hunan-Guangdong-Guangxi tectonic mountain system in the eastern part of the basin. In addition, others believe that the provenance comes from the north of Vietnam and is closely related to the Indosinian movement. In this study, based on previous work results, lithofacies palaeogeographic pattern, zircon U-Pb age and the paleocurrent direction, the authors preliminarily believe that the Devonian to Late Triassic detrital provenances in the study area can be divided into two stages:⑴ The detrital provenance from the Devonian to Carboniferous in Yunnan-Guizhou-Guangxi Basin is mainly from the southwest of the Cathaysian Block.⑵ The detrital provenance from the Permian to Triassic in Yunnan-Guizhou-Guangxi Basin is mainly from the North Vietnam Block and is closely related to the evolution of Paleo-Tethys.

The Cathaysia block is one of the important components of the eastern part of China. It consists mainly of Early Paleozoic metamorphic rocks and Mesozoic granitoids and volcanic-sedimentary rocks, with a small amount of Precambrian rocks exposed (including Neoproterozoic volcanic-sedimentary rocks and a very small amount of Paleoproterozoic gneiss). Since its amalgamation with the Yangtze Block in early Neoproterozoic time, the Cathaysia Block has suffered intensive polyphaser tectonic-magmatic events, and rich age information left in the stratum. The Cathaysia block can be further divided into the West Cathaysia block and the East Cathaysia block roughly along the Zhenghe–Dapu fault zone [34,35]. Western Cathaysia is composed mainly of Neoproterozoic crust with Archean (3.5–2.5 Ga) to Mesoproterozoic components and it was strongly reworked by the Indosinian (~240 Ma) and Caledonian (~450 Ma). Previous studies on the Cathaysian Block are very rich, and enough detrital zircon ages have been published. By comparing the detrital zircon ages of the Cathaysian Block with the (A/CNK = 1.05–1.10), Granodiorites (429 ± 3 Ma) from Enping and granodiorite xenolith (442 ± 4 Ma) from Baoxu.Biotite monzogranite samples collected from the Dajin, Boquan, and Lingzu in the Guangxi plutons yield zircon SHRIMP $^{206}Pb/^{238}U$ ages of 419±5Ma, 436±4Ma, and446±8 Ma, respectively, indicating that the plutons were emplaced during the Caledonian time[39].According to previous published data, some potassic and ultrapotassic rocks in the Southwest of Cathaysia Block have been recognized, Combining with test data, it is obvious that there is a great correlation between the Cathaysian Block and Yunnan-Guizhou-Guangxi basin.

For instance, Three amphibolites, two biotite–bearing amphibolites, norite and mafic granulite were collected from the Chencai terrane in the Cathaysia Block. And SIMS zircon U–Pb results suggest that protoliths of meta–mafic rocks were emplaced at 434–445 Ma and have experienced metamorphism at 428–439 Ma. Wang et al.[36] present a new set of zircon U-Pb geochronological, Lu-Hf isotopic data and whole-rock geochemistry for basicintermediate from the southwestern Fujian. And yielded zircon U-Pb ages of 315Ma. Most Devonian granites in Cathaysia Block are S- or I-type granites, which are suggested to be related to the Wuyi-Yunkai orogeny. Cai et al.[37] present the detailed LA-ICP-MS zircon U-Pb dating, major and trace element geochemical for Xiqin A-type granites in the northeastern Cathaysia Block, SE China. Zircon U-Pb dating results show that the granites were emplaced at 410 Ma. The tectonic evolution of the Early Paleozoic Cathaysian Block is very active, leaving a large amount of evidence of detrital zircon age in the stratum. At Jianning area, in the eastern Cathaysia Block, Proterozoic rock include migmatized paragneiss of the Wanyuan Group is intruded by Paleozoic and Mesozoic igneous rocks. Characteristics of detrital zircon age populations indicate accumulation of the Wanyuan Group in a convergent and/or collisional setting. Detrital zircon grains from the Wanyuan paragneiss display metamorphic rims that yield concordant weighted average $^{206}Pb/^{238}U$ ages of 435±5Ma and 860±6Ma, along with variably disconcordant ages with lower intercept ages of 442 ±41 Ma[38]. The Nanping pegmatite deposit is located in the northeastern Cathaysian block, SE China. The compositions and texture features of zircon grains from pegmatite deposit identify their magmatic origin. And these U-Pb age data constrain the absolute formation timing of this zircon to approximately 387 Ma .In addition, The Early Paleozoic Wuyi-Yunkai orogenic belt was associated with extensive felsic magmatism and orogenic nucleus was mainly distributed in the Yunkai and Wugong domains in the western part of the Cathaysia block, and the Wuyi domain in the central part of the Cathaysia block. The zircon U/Pb ages show that Biotite granites (441 ± 5 Ma) and gneissic granite xenolith (443 ± 4 Ma) of the Baoxu pluton are all weakly peraluminous

new geochronological, geochemical and Sr-Nd isotopic data. Zircon U-Pb dating from six plutons yield concordant crystallization ages of 424~445 Ma[40]. Combined with previous studies, we consider that the Cathaysia block was an early Paleozoic collisional orogeny, and speculate the possible linkage of South China with the Gondwana supercontinent. The monazite and zircon U–Pb data presented ages of the rocks in the Gaozhou complex in Yunkai massif, theWanquan Group, the Longyou Group in central

Wuyi massif show ages ranging from 447 ~430 Ma, respectively. Gabbroic intrusions was emplaced at 425 Ma in the Longyou Group, Furthermore, the 470 Ma pyroxenite was overprinted by hydrothermal alteration at 400 Ma[41].And Amphibolites–facies metamorphism activity in Wuyi area occurred between 445~460Ma, and the peak of tectonic thermal events may be between 423~446Ma[42], indicating that the orogeny occurred approximately 460 Ma[43]. Moreover, a large amount of Neoproterozoic detrital zircon information is retained in the Cathaysian block, and a small amount of older age information is also retained. The exposed metamorphic rocks and xenolithic metamorphic rocks in the Xiangshan-Yuhuashan area in Jiangxi Province, were studied in order to reveal the compositions of the basement rocks and their tectonic implications. Geochemistry and zircon U-Pb-Hf isotopic compositions suggest that the basement metamorphic rocks in the study area are mainly composed of 683~822Ma meta-sedimentary rocks. Li et al.[44] conduct a comprehensive study of zircon U-Pb geochronology, geochemistry and Nd-Hf isotopes for rhyolite and rhyolite tuff in the region. The SIMS zircon U-Pb dating of two samples from the Jingtan Formation in the eastern part of the Jiangnan orogeny yielded weighted mean $^{206}Pb/^{238}U$ ages of 784 ± 6 Ma and 788 ± 6 Ma, respectively. And Xin et al.[45]present geochemical and Lu-Hf isotopic data of a suite of granitoids and diorites from the Jiuling and Meixian plutons of the central Jiangnan Orogen. The zircons from the Jiuling and Meixian granitoids yield concordant weighted average U-Pb ages of 822Ma and 816Ma, respectively. Pre-Palaeozoic metasedimentary rocks are widespread in the Cathaysia Block. Recent reports a study on U–Pb dating for zircons from the metasedimentary rocks from NW Fujian Province, Their age spectra are characterized by two prominent age groups of 900~1300Ma and 700~900Ma, and two minor age groups of 500~700 Ma and 2400~2700Ma [46]. in addition, Detrital zircons from the Minjiang and Zhujiang Rivers have been analyzed for U/Pb ages to constrain the growth history of the continental crust of the Cathaysia Block. Zircon U/Pb ages show five major populations at 90~250Ma, 400 ~500 Ma,700~1200Ma, 1600~2000Ma and 2300~2600Ma[47]. Daoxian basalts from the western Cathaysia block (South China) entrained a suite of deepseated crustal xenoliths, including gneiss, felsic schist and granulite, and mafic two-pyroxene granulite and metagabbro. Detrital zircons from the garnet-biotite schists indicate several populations of ages at 500~650Ma, 750~1100Ma, 1400~1600Ma, 1700~1800Ma, 2400~2500Ma, ~2800Ma, and ~300 Ma.

The increasingly accepted scenario that Hainan Island was the southern extension of the Cathaysia Block [48,49,50,51].Yao et al.,[51] report geochronological and Hf–O isotopic results for Mesoproterozoic gneisses , metasedimentary rocks and quartz sandstones from Hainan Island. The amphibolite-facies Baoban Complex, consisting mainly of 1430Ma volcanic/plutonic rocks and subsequently experienced high-grade metamorphism during 1000~1300Ma; It follows that Hainan Island in southwestern south China has 1430Ma crystalline rocks as part of the Proterozoic basement rocks for the Cathaysia Block. Hainan Island is situated at the southern margin of the South China Block. Tectonically, it is regarded as part of the Cathaysia Block, located at the intersection of the Indochina Block, the southern margin of the South China Block and the Pacific oceanic plate[52]. Due to its special tectonic position, Hainan Island has a complex history of tectonic evolution. Predecessors have studied the detrital zircons in Hainan, and the zircon age data obtained is rich. Firstly, the predecessors believed that Mafic-intermediate igneous rocks in the Bangxi-Chenxing tectonic zone of Hainan Island can be used to constrain the tectonic evolution of the Cathaysia Block. Zircon grains fromrocks yielded U-Pb ages of ~330 Ma. And the ~330 Ma basalts contain 1400 Ma captured zircon grains. Zhou et al.[14] conducted in situ U–Pb dating and Hf-isotope analysis on detrital zircons from sandstone samples from Hainan Island to indicate regional magmatism activity and crustal evolution processes. The U–Pb zircon analyses of the sample define five major populations of ages at 2598–2320 Ma, 1944–1606 Ma, 1600–1406 Ma,1288–902 Ma, 470–427 Ma and two subordinate populations at 898–710 Ma and 618–513 Ma. Besides, new U-Pb geochronological and Nd-Hf isotopic data for the metamorphic mafic rocks from the Baoban Complex in southwest Hainan provide new constraints on crystallization ages. Magmatic zircons from the representative samples yielded weighted mean $^{207}Pb/^{206}Pb$ ages of 1424~1441 Ma, representing their crystallization ages[53]. And Metasedimentary rocks in the Baoban Complex from southwest Hainan are intruded by Mesoproterozoic gneissic granites and mafic rocks. New geochemical data show that these gneissic granites are monzogranites and granodiorites and crystallized at ~1430Ma[53]. A large number of statistics have been made on the age records of detrital zircons in the Cathaysian block. The following is a comparative map of the age of detrital zircons in the Cathaysian block and Yunnan-Guizhou-Guangxi basin(Fig.5). It is not difficult to see that there is a great correlation between the two areas.

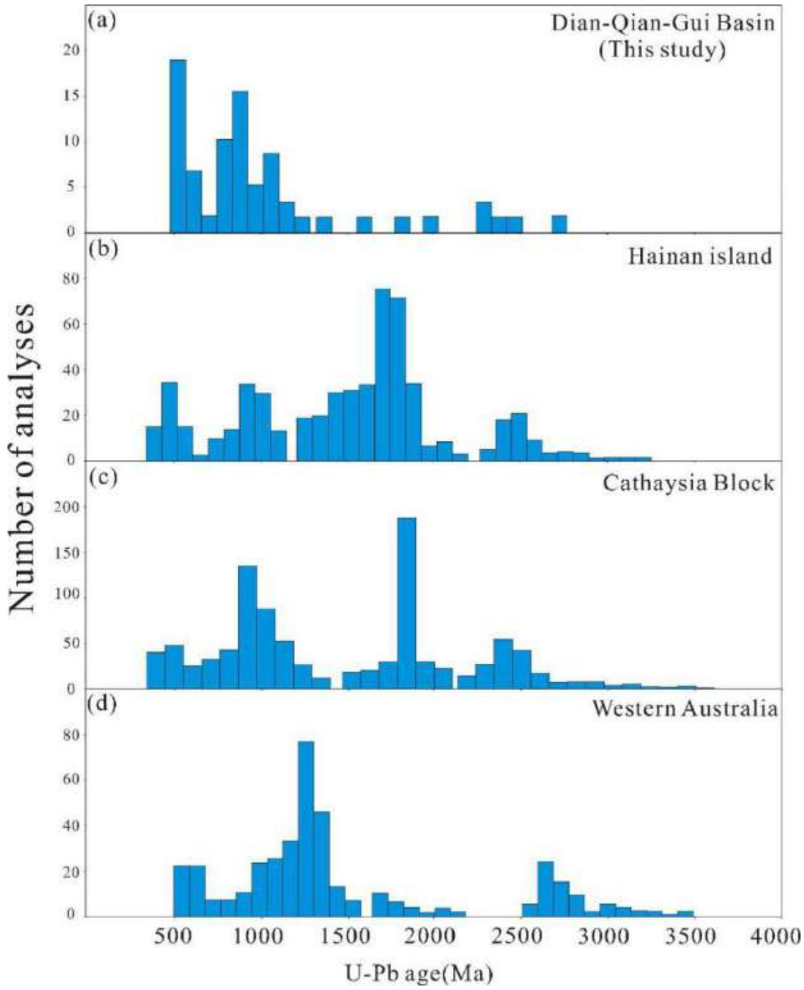

Fig -5. Relative probability plots comparing U–Pb ages for detrital zircons in this study with rock ages in Hainan island[14], Cathaysia [54,55,56] Western Australia[57,58]

5.2Implications for evolution of Paleo-Tethys

The evolution of Paleo-Tethys has been one of the hotspots of geologists all over the world. A large number of studies have shown that the convergence, dispersion and reunification of Gondwana and Paleo-Asian continents have undergone a long process of evolution. At the end of the Early Paleozoic, the Yangtze Block and other blocks converged from south to north near the equator, forming part of the Tongwana Supercontinent. Since the Early Devonian, these Gondwana-friendly blocks (Yangtze, North China, Indosinian, Tarim, etc.) have split up successively from the northeastern part of Gondwana continent and formed the Paleo-Tethyan Ocean between the Yangtze block groups near the equator[59].Among them, the Changning-Menglian tectonic belt is considered to be the main suture zone separating Yangtze block from Gondwana continent. Its ophiolite represents the main branch of the Paleo-Tethyan Ocean and separates the Yunnan-Burma-Matai block with the late Paleozoic Gondwana-type bio-sedimentary assemblage from the Simao block with the South China-type bio-sedimentary assemblage[60,61]. The Jinshajiang-Ailaoshan suture zone between Simao Block and South China Continent is the representative branch oceanic basin. The Jinshajiang-Ailaoshan oceanic basin underwent Silurian-Devonian initial rift, Carboniferous oceanic basin expansion, Carboniferous-Permian oceanic crust subduction-arc magmatism and Triassic closed mountain-building complete Wilson cycle. The branch oceanic basin is generally considered to extend southward into Vietnam, forming the Songma suture zone separating the Indosinian block from the South China continent[60,62,63,64,65,66].

Babu basic and ultrabasic intrusions in southeastern Yunnan are considered to represent oceanic crust debris, and together with Ophiolites in the North Vietnam Song Hien tectonic belt, they constitute an important record of the Babu-Song Hien Paleotethys suture zone, which is an important window for understanding the evolution of the Paleotethys tectonics in the southwestern margin of South China. Rock records are believed to indicate the extension of the Paleo-Tethys branch oceanic basin in Ailaoshan in the Yunnan-Guangxi-Vietnam border area (Babu-SongHien suture zone), and to form part of the Paleo-Tethys suture zone (Yunnan-Qiong suture zone) between the South China and Indosinian blocks

[67].From Late Paleozoic to Triassic, the Nanpan River Sea developed in Yunnan, Guizhou and Guizhou provinces and Northern Vietnam for a long time. Geologically, there are Yangtze Block in the north, Yunkai Block in the southeast and Damingshan Block in the south, and North Vietnam Block in the southwest. The opening of Nanpanjiang Sea in the late Early Devonian may be the result of anticlockwise rotation of the Gondwana Plate and northward movement of the Yangtze Plate, which resulted in the splitting of the Yunnan-Guangxi-Vietnam Plate. Further seafloor expansion resulted in the occurrence of oceanic crust in the Babu Basin during the Early Carboniferous.Palaeogeographic reconstruction shows that the spreading ridge of the Babu Basin may connect the oceanic ridge of the Ailaoshan Sea to the west. The Yunkai Block moved northward in the Late Permian, collided with the Damingshan micro-block, the Indosinian Block moved northward in the Early Triassic, and converged with the Vietnam Block. The active continental margin appeared in the southern margin of the Nanpanjiang Sea in the Late Permian-Middle Triassic, and the Indosinian-Vietnam Block converged with the Yangtze Block in the Late Triassic. The occurrence, development and extinction of Nanpan River Sea, Ailaoshan Sea and Changning-Menglian Sea are basically synchronized, which are controlled by the same oceanic ridge system of Paleo-Tethys. The early Triassic tectonic metamorphic events in the Majiang belt in Vietnam indicate that the Indosinian and Vietnamese blocks collided before the Middle Triassic, and the Nanpanjiang and Ailaoshan seas were greatly reduced. The Middle Triassic volcaniclastic turbidite deposited in Nanpanjiang Sea is very thick, and its provenance mainly comes from the Yuebei Mountains in the south. With the extension and deepening of the basin, siliceous deposits were the main deposits in the Nanpanjiang Sea during the Late Devonian. During the Early Carboniferous, the oceanic crust appeared in the South and the Babu oceanic basin was formed.The Ailaoshan Sea and the Changning-Menglian oceanic crust appeared at roughly the same time, indicating that they belong to the same ridge system. From palaeogeographic reconstruction, the western Babu Ocean Basin is connected with the Ailaoshan Ocean Basin, and may even have the same east-west extension ridge. Therefore, the Babu Ocean Basin can also be regarded as a branch of the Ailaoshan Ocean Basin. Its remnants are also part of the suture zone between the Indosinian Yangtze Block and the Indosinian Block. From Late Carboniferous to Early-Middle Permian, the Nanpanjiang Sea was in a relatively stable state. During the late Early Permian to Middle Permian, carbonate breccia deposits were widely distributed in deep-water basins, indicating further development of the tensional fracture system, intensified syngenetic faults in the margins of carbonate platforms in the basin, and a large number of volcanic debris and Permian-Triassic magmatic arc/orogenic clastic zircons appeared in the sandstones of Youjiang basin during the Early-Middle Triassic, indicating that the basin occurred in the Early Triassic. The transition from passive continental margin to peripheral foreland basin is the result of Indosinian Subduction-Collision orogeny in the southwestern margin of South China. In addition, the Babu oceanic basin subducted southward, and the Damingshan microcontinent experienced intense volcanic activity. The frequent supply of volcanic materials and crustal activities intensified the topographic cutting, and the volcanic clastic turbidity deposits developed very well, and finally filled the basin. In the Late Triassic, the Indosinian-Vietnam Block continued to move northward, the Babu Ocean Basin closed, then converged with the Yangtze Block, and the Tianlin Basin closed. The closure of the Nanpanjiang Sea in the Late Triassic is a part of the overall closure of the Paleo-Tethys, and the Ailaoshan and Changning-Menglian oceanic basins are also closed at the same time. From the above-mentioned evolution process of Nanpan River and Sea, it can be seen that the disintegration of the Guizhou-Yunnan- Vietnam block and the formation of the Babu Ocean Basin changed the tectonic framework of the Yunnan-Guizhou-Guangxi Basin in the Early Paleozoic. When the Nanpanjiang Sea closed in the Late Triassic, the suture zone was located in the Babu Ocean Basin. The northern part of the Guizhou-Yunnan-Vietnam Block belongs to the new Yangtze or South China Block, while the southern part belongs to the new Indosinian Block. This process of continental crust transformation is controlled by the development of the Paleo-Tethyan ridge system. The occurrence, development and extinction of Nanpanjiang Sea, Ailaoshan Sea and Changning-Menglian Sea are basically synchronous, representing the Late Devonian rift-Carboniferous-Permian ocean basin expansion, subduction-Triassic closed Paleo-tethyan Branch Ocean basin. Thus, the southeastern Yunnan-North Vietnam terrane had the continental property of South China in the Precambrian-Early Paleozoic, and was later separated by the Babu-Song Hien Paleo-Tethys Ocean.The provenance of the Devonian-Triassic sedimentary units in the Yunnan-Guizhou-Guangxi Basin helps constrain the paleogeographic evolution of South China and the confirmation of the evolution of Tethys. During the Late Permian, Paleotethyan's northward rapids drifted into a rift system in the southern margin of South China, such as the Song Rift Valley. In turn, this ever-expanding rift system caused a southward subduction of the oceanic crust beneath Indochina. To the Middle Triassic, the uplifted active margin of Indochina was eroded to source voluminous siliciclastic turbidites in the Youjiang basin during the Middle Triassic. In addition, Abundant syn-orogenic detrital zircons of 300-240Ma of are preserved in the Middle Triassic stratum, indicateing widespread uplift and exhumation of the basin hinterland during the Indosinian orogeny.

Sedimentary facies in the Yannan-Guizhou-Guangxi Basin record significant changes in the setting of South China over time. The Devonian to Triassic stratum of the basin record the rift and drift history of South China from northern Gondwana during opening of the Paleo-Tethys[68,69].During the Late Paleozoic and Early Triassic, the ocean was consumed through south-directed oceanic subduction underneath Indochina.Sequent Indochina-South China continental collision led to elevation of the active North Vietnam margin, possibly during the Middle Triassic, a large amount of debris shed into the Yunnan-Guizhou-Guangxi basin.

The eastern Cambrian East margin from the Precambrian-early Mesozoic (570~230Ma, Terra Australis orogenic belt) has long been in the context of the proliferative orogeny caused by the reduction of the original Pacific plate to the east of Gondwana, and the continuous tectonic activity makes the structure The stress was transmitted to the interior of East Gondwana and eventually gathered in central Australia and the Cathaysian block that was assembled with Australia. With the further concentration of stress, the crust rises from south to north and continues to the Middle Silurian (435Ma), which also leads to large-scale granite magma emplacement and a small amount of meso-basic magmatism in south China and Cathaysia Block. The types are mainly S-type granites with ramie and block and a small number of Type I and A-type granites, aged from 380 to 460 Ma. After that, the extension mechanism was converted and the orogenic belt was denuded. In the early Devonian, new transgressions advanced from south to north, and a large amount of detrital material from denudation of orogenic belts was deposited in the Yunnan-Guizhou-Guangxi basin. During Permian to Triassic, a confined small ocean basin or deep sea basin associated with the ancient Tethys Ocean appears between the Carboniferous and the North Vietnam. By the Permian, the ocean basin began to subduct southwest of the northwest block to form the active continental margin. Since the Late Permian, the Yunkai Massif likely acted as a topographic barrier , preventing transport of detritus from the southeast Hainan Island. After the late Early Triassic, with the closure and collisional orogeny of the ocean basin, a large number of siliciclastic turbidites from North Vietnam were deposited in the Nanpanjiang Basin.

6. CONCLUSION

(1) In this study, based on previous work results, lithofacies palaeogeographic pattern, zircon U-Pb age and the paleocurrent direction, the authors preliminarily believe that the Devonian to Late Triassic detrital provenances in the study area can be divided into two stages:①The detrital provenance from the Devonian to Carboniferous in Yunnan-Guizhou-Guangxi Basin is mainly from the southwest of the Cathaysian Block.②The detrital provenance from the Permian to Triassic in Yunnan-Guizhou-Guangxi Basin is mainly from the North Vietnam Block and is closely related to the evolution of Paleo-Tethys.

(2) Evolution of provenance in Yunnan-Guizhou-Guizhou Basin confirms the opening and closing of Paleo-Tethys.

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