Petrogenesis of the Jurassic Guiping Complex in the Southwestern South China Block: Insights into the Subduction Processes of the Paleo-Pacific Slab

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Abstract: Late Jurassic NE-trending A-type granitoids are widespread in the Shihang belt, South China, though their petrogenesis and geodynamic settings remain controversial. The Guiping complex is located on the southwest margin of the Shihang belt. In this study, the petrography, major and trace element geochemistry, whole-rock Sr–Nd isotopes, and zircon U–Pb geochronology of the Guiping complex were investigated. The Guiping complex is composed of the Fenghuangling and Xishan plutons; both plutons yielded zircon U–Pb ages of ca. 160 Ma. The Fenghuangling pluton has low SiO2 content of 54.26% to 60.31%, whereas the Xishan pluton exhibits high SiO2 content of 65.19% to 71.18%. Both of them are metaluminous and belong to the high-K calc-alkaline series and are enriched in large-ion lithophile elements (LILEs) such as Rb, Th, U, and Pb. The Fenghuangling and Xishan plutons showed enrichment in light rare earth elements (LREEs) and high-field strength elements (Nb, Ta, Zr, and Hf) and depletion in heavy rare earth elements (HREEs). Marked Nb and Ta negative anomalies were not observed. Due to the high contents of Zr + Ce + Nb + Y and high Ga/Al ratios, all the samples belonged to the group of A-type granites. The Fenghuangling and Xishan plutons had low Iε (mainly in the range of 0.7046–0.7058) and high εNd(t) (~0.60 to 1.94) values, though obviously different from those of the Precambrian basement in South China. Furthermore, they lie between the ocean island basalt (OIB) of the asthenosphere and the arc basaltic rocks of the enriched lithospheric mantle. Therefore, we proposed that the basaltic parental magma of the Guiping complex originated from partial melting of the enriched lithospheric mantle, which was metasomatized by asthenosphere-related OIB-type basaltic magma. Mafic microgranular enclaves in the Xishan pluton displayed positive Nb and Ta anomalies, which is consistent with OIB-type basalts. The enclaves also had similar Sr-Nd isotopic compositions to the Xishan pluton. That indicated that the enclaves were probably formed by mixing of the OIB-type basaltic magma and the Xishan pluton. In conclusion, the formation of the Late Jurassic NE-trending A-type granite belt was attributed to back-arc extension as a result of the rollback of the Paleo-Pacific Plate.

Keywords: Shihang belt; Guiping complex; A-type granites; back-arc extension; Paleo-Pacific Plate
1. Introduction

Granitoids are widespread in South China and have received significant attention from researchers. In particular, the Yanshanian (late Mesozoic) magmatic activities and related mineralization are the most developed (Figure 1) [1–8]. However, no consensus has been reached regarding the geodynamic mechanisms of large-scale magmatism and mineralization [9–15]. There is also considerable controversy about the role of the Paleo-Pacific Plate during this period [10,12,13,16,17].

Figure 1. (a) A structural outline of Southeast Asia showing the distribution of principal continental blocks. (b) The distribution of Yanshanian granites in southeastern China (based on the map from [2,18]). (c) The distribution of Jurassic A-type granites in the southwest of the Shihang belt.
Gilder et al. (1996) [18] identified a granite belt with a relatively young Nd model age (<1.5 Ga) in the inland area of South China, namely, the Shihang belt. Since then, an NE-trending A-type granite belt has been gradually delineated in the southwest of the Shihang belt, which is closely related to the Jurassic W-Sn mineralization [19–27]. This NE-trending A-type granite belt extends from the Qianlishan and Qitianling plutons in the north, through the Jiuyishan pluton in the middle section, to the Huashan–Guposhan pluton in the south (Figure 1c). The young T ox granite belt continues to extend towards the southwest until it reaches the southeast of Guangxi Province [28–30]. However, controversies still exist about the genesis of the Jurassic NE-trending A-type granites and their geodynamic settings [31–33].

In the Guiping area in Guangxi, the Guiping pluton was identified in this study: on the southwest margin of the Shihang belt. It was classified as A-type granite according to its geochemical characteristics. The petrography, major and trace element geochemistry, whole-rock Sr-Nd isotopes, and zircon U-Pb geochronology of the Guiping pluton are reported in this study. The goal of this study was to constrain the petrogenesis of the Guiping pluton and to better understand the geodynamic significance of the A-type granite belt in the southwest part of the Shihang belt.

2. Geological Setting

The South China Block was formed by the merging of the Yangtze and Cathaysia Blocks in the Neoproterozoic [34–37] and was then intensely modified during three periods of orogeny, including the early Paleozoic, Indosinian, and Yanshanian. The Yanshanian orogeny was the most intense orogeny [13,38,39]. The Shihang belt, referring to a Yanshanian granite belt of young model age, was defined by Gilder et al. (1996) [18]. Jurassic A-type granites and basaltic rocks were discovered in the southwest of the Shihang belt (Figure 1c). Basaltic rocks from Ningyuan area display similar geochemical characteristics of oceanic island basalts with positive Nb anomalies and relatively depleted Sr-Nd isotope compositions. Mafic rocks from Daoxian, Guiyang, and Changchengling areas have typical arc signatures with negative Nb anomalies and relatively enriched Sr-Nd isotope compositions [31,40,41]. The Guiping complex is located on the southwest margin of the “Shihang Belt” (Figure 1) in Guiping City, Guangxi Province of China. It is composed of the Fenghuangling and Xishan plutons. The main body of the Xishan pluton consists of elliptical concentric rings, striking 20° NE with a long axis of about 9.5 km, a short axis of about 7.3 km, and a total area of 64 km². The Fenghuangling pluton is located on the east boundary of the Xishan pluton. It is recognized as a small dioritic stock covering an area of about 1.5 km². The Guiping complex intruded into Devonian dolomite and sandy shale and is unconformably overlain by quaternary sediments. Its formation age was estimated to be 199–150 Ma according to the K-Ar dating of biotite and K-Feldspar by previous researchers [42].

The main body of the Guiping complex is the Xishan granite (Figure 2a), with both porphyroid and fine-grained textures (Figure 2b). Primary minerals include alkali feldspar (30–40%), plagioclase (20–35%), quartz (20–30%), hornblende (2–8%), and biotite (4–7%); accessory minerals include zircon, apatite, and titanite. Mafic microgranular enclaves, widely developed in the Xishan pluton, are mostly dioritic and vary in morphology from lenticular, elliptical, and flame-like to irregular shapes (Figure 2c,d). They consist mainly of plagioclase (55–70%), alkali feldspar (10–20%), hornblende (6–10%), biotite (3–5%), and quartz (2–3%) and include accessory minerals zircon and apatite. Their diameters vary broadly from 2 cm to 1 m. Granitic back veins can be seen in a few enclaves. Some potassium-feldspar phenocrysts in the host rock can be found traversing the boundaries between the enclaves and host rock, and some phenocrysts are resorbed to form elliptical shapes (Figure 2e). In some areas, the contact between enclaves and host rock is either obscure or gradational (Figure 2f). Furthermore, acicular apatites are also very well developed in the mafic microgranular enclaves, indicating their quenching affinity (Figure 2g). The Fenghuangling pluton is composed of diorite (Figure 2h,i) with a fine-grained texture, consisting mainly of plagioclase (50–60%), alkali feldspar (15–30%), hornblende
(5–10%), biotite (4–6%), and a small amount of quartz, along with accessory minerals zircon and apatite.

Figure 2. (a) An outcrop of the Xishan pluton. (b) Granite of the Xishan pluton under a microscope (cross-polarized light) with euhedral hornblende. (c) Flame-like mafic microgranular enclaves in the Xishan pluton. (d) Mafic microgranular enclaves in the Xishan pluton under a microscope (cross-polarized light), where dark minerals are biotite occurring as small and thin flakes, and light-colored minerals are euhedral columnar plagioclase and a small amount of columnar hornblende. (e) Mafic microgranular enclaves in the Xishan pluton and potassium-feldspar phenocrysts traversing the boundaries between the enclaves and host rock; some elliptical phenocrysts are visible within the enclaves. (f) An outcrop of Xishan pluton; the contact between enclaves and host rock is either obscure or gradational. (g) Acicular apatites are developed in the mafic microgranular enclave under the microscope (cross-polarized light). (h) An outcrop of the Fenghuangling pluton. (i) Fenghuangling diorite under the microscope (cross-polarized light) with columnar plagioclase (Kfs: alkali feldspar; Pl: plagioclase; Bt: biotite; Hb: hornblende; Q: quartz).

3. Materials and Methods

Samples were collected from fresh outcrops in the field to ensure that they were not subject to weathering or alteration. The samples used for zircon U-Pb dating were ground with 40–60 mesh and then processed with techniques such as elutriation, magnetic separation, electromagnetic separation, and heavy liquid beneficiation. Then, the samples were placed under a microscope such that pure zircon grains could be distinguished. For petrochemical experiments, samples were ground through 200 mesh in an agate mortar, and the powder was separated into three parts for analyses of major elements, rare earth elements and trace elements, and Sr-Nd isotopes, respectively.

3.1. Zircon U-Pb Dating

The cathodoluminescence (CL) imaging for zircons was conducted using a JEOL JXA 8900 RL electron microprobe at the Institute of Mineral Resources, Chinese Academy of Geological Sciences (Beijing, China), and the LA-ICP-MS zircon U-Pb dating was conducted at the
State Key Laboratory of Geological Processes and Mineral Resources (GPMR), China University of Geosciences (Wuhan, China). Samples were processed in the following steps: (1) Zircon grains with different crystalline forms and colors were carefully selected under binoculars and then were glued to a double-sided adhesive and fixed with epoxy resin. After the epoxy resin was fully solidified, the surface of the zircon was polished, and then, the transmitted and reflected light photography was used. Zircon was observed under the microscope, and it was subjected to CL imaging in advance to properly select domains and to avoid inclusions during the microprobe analyses. (2) LA-ICP-MS zircon U-Pb dating was conducted using an Agilent 7500a ICP-MS instrument and a GeoLas 2005 laser ablation system equipped with a 193 nm excimer laser. In the experiment, samples were ablated in helium gas, and the laser spot size was 32 μm. The external reference material GJ-1 was utilized for correcting the effects of isotopic fractionation, and the reference material zircon 91,500 calibration method was employed for zircon analysis. (3) Isotopic data were processed by using ICP-MS-DataCal program [43]. The Isoplot 4.15 program was used to calculate the weighted mean age. The uncertainties of the measured zircon analysis points were 1σ, and the confidence level of the weighted mean age was 95%. The detailed analysis procedure can be found in [44].

3.2. Element Geochemistry

The whole-rock analysis (major elements) was conducted by using X-ray fluorescence (XRF) with a Regaku 3080E1 spectrometer at the Wuhan Comprehensive Rock and Mineral Testing Center of Hubei Provincial Institute of Geological Experiments (Wuhan, China). The content of H2O was measured by a gravimetric method. The content of CO2 was determined by non-aqueous titration. The content of FeO was obtained using a chemistry method. The relative standard deviations of the experimental data were smaller than 5%, and the precision of the sample analysis was better than 5%.

The whole-rock analyses of rare earth and trace elements were conducted using the Agilet 7500a ICP-MS at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan, China). Samples were prepared and tested as follows: (1) The 200 mesh rock powder was dried, and 50 mg of the sample was weighed out and placed in a washed Teflon crucible for digestion. (2) After 1 mL HNO3 and 1 mL HF were added to the Teflon crucible in order, the sample was placed in a stainless steel sleeve, and then, the sleeve was transferred to an oven; the oven temperature was raised to 190 ± 5 °C and maintained for 48 h for sample digestion. (3) After the sleeve cooled down, the sample was placed on an electrical hot plate at 115 °C to dry (to remove Si); then, 1 mL HNO3 was added, and the sample was dried again; afterward, 1 mL HNO3 and 1 mL IN were added to the sample, and the sample was placed into the steel sleeve again and transferred to the oven (heated at 190 ± 5 °C for >12 h). (4) The completely digested sample was transferred into a polyester bottle and diluted to about 100 mL with 2% HNO3 and stored in a sealed container for ICP-MS testing.

3.3. Isotope Geochemistry

The Sr-Nd isotopic analysis was carried out at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Wuhan, China). The experimental procedure was as follows: (1) 50 mg powder sample was weighed and placed into a Teflon vessel, and then, 1 mL high-purity water, 1 mL HNO3, and 1 mL HF were added in turn. (2) After being placed in a steel sleeve and sealed, the sample was transferred into an oven (heated at 190 °C for >48 h). (3) The sample was taken out, and the sample was placed on an electric hot plate at 120 °C to turn into wet salt; then, 1 mL HNO3 was added, and the sample was steamed again until it became wet salt; then, 1 mL HNO3 was added, and the sample was transferred to a centrifuge tube for centrifugation in a high-speed centrifuge. (4) The supernatant liquor of the sample after centrifugation was added into AG50X8 cation exchange resin to separate Sr (two times) and REE, and then, the LN special resin was used to separate REE.
and to purify Nd. (5) The samples were analyzed using the MAT261 isotope mass spectrometer; the internal standards BS987 and LaJolla were monitored during the test. The details of the sample digestion process and its analytical precision can be found in [45].

4. Results

4.1. Zircon U-Pb Geochronology

Zircon U-Pb geochronological studies were performed for three granites samples (11XS01-1, 11XS03-1, 11XS04-2-2), one mafic microgranular enclave (11XS04-2-1) in the Xishan pluton, and one diorite (11XS05-1) from the Fenghuangling pluton. The results are shown in Table 1.

Zircons from the Guiping complex are generally colorless and transparent or pale yellow. Except for grains in sample 11XS05-1 from the Fenghuangling pluton with lengths of 50–100 μm and length/width ratios of 2:1–3:1, most of the grains were euhedral, which had lengths of 100–450 μm and length/width ratios of 1:1–4:1. Cathodoluminescence (CL) images of these zircons clearly show oscillatory zoning (Figure 3) indicative of typical magmatic origin.

4.1.1. Xishan Pluton

The zircons of the four samples from the Xishan pluton, i.e., 11XS01-1, 11XS03-1, 11XS04-2-2, and 11XS04-5-1, had high contents of Th and U and high Th/U ratios, indicating their magmatic origin [46]. For sample 11XS01-1, the weighted mean \(^{206}\text{Pb}^{238}\text{U}\) age of 15 ablation points was 159.7 ± 0.9 Ma (MSWD = 0.8) (Figure 4a), representing the crystallization age. The weighted mean \(^{206}\text{Pb}^{238}\text{U}\) age of 17 ablation points in sample 11XS03-1 was 160.8 ± 0.9 Ma (MSWD = 0.5) (Figure 4b), representing its crystallization age. The weighted mean \(^{206}\text{Pb}^{238}\text{U}\) age of 15 ablation points in sample 11XS04-2-2 was 159.6 ± 1.1 Ma (MSWD = 1.0) (Figure 4c), representing the crystallization age. For sample 11XS04-5-1, the weighted mean \(^{206}\text{Pb}^{238}\text{U}\) age of 12 ablation points was 159.1 ± 1.2 Ma (MSWD = 0.7) (Figure 4d), which was consistent with the age of its host rock (159.6 ± 1.1 Ma) within the margin of error.

![Figure 3](image-url)  
Figure 3. Cathodoluminescence images for typical zircons from the Guiping complex: (a) sample 11XS01-1, (b) sample 11XS03-1, (c) sample 11XS04-2-2, (d) sample 11XS04-5-1, and (e) sample 11XS05-1. Analyzed spot on zircon grains is marked by a hollow circle and corresponding serial number.
4.1.2. Fenghuangling Pluton

The Th content in zircon was 72–204 ppm, the U content was 94–317 ppm, and the Th/U ratio was 0.62–1.10, all of which are consistent with the Th/U ratios of zircon of magmatic origin [46]. The weighted mean $^{206}\text{Pb}/^{238}\text{U}$ age of 12 ablation points in the Fenghuangling pluton was 160.1 ± 3.0 Ma (MSWD = 2.0) (Figure 4e), representing the emplacement age.

![U-Pb concordia diagram of zircon in the Guiping complex: (a) sample 11XS01-1, (b) sample 11XS03-1, (c) sample 11XS04-2-2, (d) sample 11XS04-5-1, and (e) sample 11XS05-1.](image)

Figure 4. U-Pb concordia diagram of zircon in the Guiping complex: (a) sample 11XS01-1, (b) sample 11XS03-1, (c) sample 11XS04-2-2, (d) sample 11XS04-5-1, and (e) sample 11XS05-1.
| Spot No. | Contents (ppm) | Isotope Ratios | Age (Ma) |
|---------|----------------|----------------|----------|
|         | Pb  | Th  | U  | 207Pb/206Pb | 1σ | 207Pb/235U | 1σ | 206Pb/238U | 1σ | rho | 207Pb/206Pb | 1σ | 206Pb/238U | 1σ |  |
| 11XS01-1 | 17  | 356 | 579 | 0.61 | 0.04869 | 0.0024 | 0.17251 | 0.0087 | 0.0254 | 0.00031 | 0.2453 | 131.6 | 121.3 | 161.6 | 7.5 | 161.5 | 2.0 |
| 11XS01-2 | 26  | 436 | 832 | 0.52 | 0.05107 | 0.0022 | 0.17871 | 0.0080 | 0.0251 | 0.00024 | 0.2153 | 242.7 | 98.1 | 166.9 | 6.9 | 160.1 | 1.5 |
| 11XS01-1-3 | 22 | 444 | 734 | 0.60 | 0.04961 | 0.0025 | 0.16969 | 0.0085 | 0.0247 | 0.00027 | 0.2180 | 176.0 | 123.1 | 159.2 | 7.4 | 157.4 | 1.7 |
| 11XS01-1-4 | 19 | 352 | 625 | 0.56 | 0.04718 | 0.0022 | 0.16210 | 0.0072 | 0.0249 | 0.00026 | 0.2354 | 57.5 | 107.4 | 152.5 | 6.3 | 158.8 | 1.6 |
| 11XS01-1-5 | 17 | 311 | 607 | 0.51 | 0.04723 | 0.0020 | 0.16448 | 0.0068 | 0.0252 | 0.00026 | 0.2442 | 61.2 | 105.5 | 154.6 | 5.9 | 160.4 | 1.6 |
| 11XS01-1-6 | 19 | 255 | 689 | 0.37 | 0.05019 | 0.0037 | 0.17372 | 0.0117 | 0.0252 | 0.00028 | 0.1636 | 211.2 | 165.7 | 162.6 | 10.1 | 160.5 | 1.7 |
| 11XS01-1-7 | 17 | 320 | 569 | 0.56 | 0.04807 | 0.0050 | 0.17311 | 0.0212 | 0.0251 | 0.00031 | 0.0999 | 101.9 | 229.6 | 162.1 | 18.4 | 159.6 | 1.9 |
| 11XS01-1-8 | 14 | 273 | 513 | 0.53 | 0.04606 | 0.0019 | 0.15909 | 0.0063 | 0.0249 | 0.00027 | 0.2704 | 400.1 | 305.5 | 149.9 | 5.5 | 158.9 | 1.7 |
| 11XS01-1-9 | 26 | 380 | 938 | 0.41 | 0.04800 | 0.0022 | 0.16483 | 0.0069 | 0.0250 | 0.00030 | 0.2844 | 98.2 | 112.9 | 154.9 | 6.0 | 159.4 | 1.9 |
| 11XS01-1-10 | 22 | 584 | 734 | 0.80 | 0.04931 | 0.0025 | 0.16821 | 0.0082 | 0.0248 | 0.00028 | 0.2345 | 161.2 | 118.5 | 157.9 | 7.1 | 158.2 | 1.8 |
| 11XS01-1-11 | 7 | 109 | 230 | 0.48 | 0.04818 | 0.0019 | 0.17037 | 0.0070 | 0.0254 | 0.00029 | 0.2763 | 109.4 | 92.6 | 159.7 | 6.1 | 161.9 | 1.8 |
| 11XS01-1-12 | 21 | 469 | 724 | 0.65 | 0.04948 | 0.0018 | 0.17499 | 0.0064 | 0.0256 | 0.00028 | 0.2978 | 172.3 | 85.2 | 163.7 | 5.5 | 162.9 | 1.7 |
| 11XS01-1-13 | 27 | 474 | 941 | 0.50 | 0.04802 | 0.0023 | 0.16496 | 0.0078 | 0.0250 | 0.00029 | 0.2479 | 101.9 | 107.4 | 155.0 | 6.8 | 159.0 | 1.8 |
| 11XS01-1-14 | 32 | 603 | 1083 | 0.56 | 0.05099 | 0.0022 | 0.17507 | 0.0072 | 0.0250 | 0.00027 | 0.2645 | 239.0 | 102.8 | 163.8 | 6.2 | 159.3 | 1.7 |
| 11XS01-1-15 | 17 | 309 | 599 | 0.52 | 0.05550 | 0.0045 | 0.18756 | 0.0146 | 0.0247 | 0.00029 | 0.1477 | 431.5 | 184.2 | 174.5 | 12.5 | 157.5 | 1.8 |

Table 1. LA-ICPMS zircon U–Pb analytical results of the Guiping complex.
## Minerals

### 11XS04-2-2, Xishan Pluton

| Sample | Width | Length | Thickness | Density | Porosity | Water | Temperature | Pressure | Oxygen Activity | Oxygen Potential | Iron Activity | Iron Potential | Oxygen Gas | Oxygen Composition | Oxygen Isotopes | Temperature Range | Pressure Range | Oxygen Isotopes |
|--------|-------|--------|-----------|---------|----------|-------|-------------|-----------|----------------|----------------|---------------|----------------|-------------|----------------|------------|-------------------|----------------|-----------------|---------------|----------------|
| 11XS04-5-1-12 | 10 | 147 | 380 | 0.39 | 0.04989 | 0.0026 | 0.16892 | 0.0093 | 0.0245 | 0.00032 | 0.2336 | 190.8 | 124.1 | 158.5 | 8.1 | 156.2 | 2.0 |
|---------------|----|-----|-----|------|---------|--------|---------|--------|--------|---------|--------|-------|-------|-----|-----|-----|
| 11XS05-1-1    | 4  | 96  | 120 | 0.80 | 0.21051 | 0.0160 | 0.02574 | 0.0006 | 0.0630 | 0.00496 | 0.2831 | 707.0 | 126.0 | 194.0 | 13.0 | 164.0 | 3.0 |
| 11XS05-1-2    | 3  | 72  | 94  | 0.76 | 0.21123 | 0.0278 | 0.02525 | 0.0006 | 0.0902 | 0.00603 | 0.3810 | 628.0 | 302.0 | 195.0 | 23.0 | 161.0 | 4.0 |
| 11XS05-1-3    | 4  | 109 | 107 | 1.02 | 0.25231 | 0.0169 | 0.02608 | 0.0006 | 0.0742 | 0.00568 | 0.3255 | 1047.0 | 99.0 | 228.0 | 14.0 | 166.0 | 4.0 |
| 11XS05-1-4    | 7  | 187 | 185 | 1.02 | 0.19126 | 0.0106 | 0.02508 | 0.0005 | 0.0569 | 0.00341 | 0.3323 | 488.0 | 90.0 | 178.0 | 9.0  | 160.0 | 3.0 |
| 11XS05-1-5    | 5  | 158 | 146 | 1.08 | 0.22969 | 0.0149 | 0.02462 | 0.0004 | 0.0698 | 0.00477 | 0.2722 | 923.0 | 105.0 | 210.0 | 12.0 | 157.0 | 3.0 |
| 11XS05-1-6    | 11 | 198 | 317 | 0.62 | 0.20058 | 0.0210 | 0.02640 | 0.0004 | 0.0712 | 0.00321 | 0.3103 | 416.0 | 242.0 | 186.0 | 18.0 | 168.0 | 3.0 |
| 11XS05-1-7    | 7  | 184 | 170 | 1.08 | 0.19381 | 0.0254 | 0.02495 | 0.0005 | 0.0815 | 0.00459 | 0.3318 | 466.0 | 302.0 | 180.0 | 22.0 | 159.0 | 3.0 |
| 11XS05-1-8    | 4  | 98  | 117 | 0.83 | 0.16335 | 0.0208 | 0.02564 | 0.0006 | 0.0662 | 0.00549 | 0.3028 | 8.0   | 244.0 | 154.0 | 18.0 | 163.0 | 4.0 |
| 11XS05-1-9    | 7  | 204 | 185 | 1.10 | 0.16128 | 0.0151 | 0.02518 | 0.0004 | 0.0586 | 0.00312 | 0.3211 | 21.0  | 206.0 | 152.0 | 13.0 | 160.0 | 3.0 |
| 11XS05-1-10   | 3  | 82  | 94  | 0.87 | 0.22498 | 0.0299 | 0.02419 | 0.0005 | 0.0922 | 0.00684 | 0.2777 | 852.0 | 297.0 | 206.0 | 25.0 | 154.0 | 3.0 |
| 11XS05-1-11   | 4  | 96  | 103 | 0.94 | 0.16811 | 0.0691 | 0.02385 | 0.0007 | 0.1021 | 0.00707 | 0.2746 | 246.0 | 728.0 | 158.0 | 60.0 | 152.0 | 4.0 |
| 11XS05-1-12   | 7  | 167 | 159 | 1.05 | 0.19134 | 0.0416 | 0.02447 | 0.0006 | 0.1046 | 0.00705 | 0.2652 | 481.0 | 437.0 | 178.0 | 35.0 | 156.0 | 4.0 |
4.2. Whole-Rock Element Geochemistry

Twelve samples of the Guiping complex were collected to perform major and trace elemental analyses. The results are shown in Table 2.

Table 2. Major (wt.%) and trace element (ppm) components of the Guiping complex.

| Sample | Xishan Pluton | Xishan MME | Fenghuangling Pluton |
|--------|---------------|------------|----------------------|
|        | X11XS01-1    | X11XS02-1  | X11XS03-1            |
|        | X11XS03-3    | X11XS04-2-1| X11XS04-5-2          |
|        | X11XS04-6-2  | X11XS04-5-1| X11XS04-6-1          |
|        | X11XS04-5-1  | X11XS05-1  | X11XS05-3            |
| SiO₂   | 71.7          | 71.1       | 65.2                 |
|        | 66.8          | 66.0       | 68.8                 |
|        | 70.2          | 70.2       | 68.3                 |
| TiO₂   | 0.5           | 0.5        | 0.8                  |
|        | 0.9           | 0.9        | 0.9                  |
| Al₂O₃  | 13.1          | 13.1       | 15.0                 |
|        | 14.8          | 14.8       | 14.3                |
| Fe₂O₃  | 1.1           | 1.2        | 1.7                  |
|        | 1.5           | 1.6        | 0.9                  |
| MnO    | 0.1           | 0.1        | 0.1                  |
| MgO    | 0.8           | 0.9        | 1.4                  |
|        | 1.3           | 1.4        | 1.4                  |
| CaO    | 1.5           | 1.6        | 3.0                  |
|        | 2.8           | 3.0        | 1.9                  |
| Na₂O   | 3.8           | 3.7        | 4.2                  |
|        | 4.0           | 4.2        | 4.2                  |
| K₂O    | 4.7           | 4.6        | 4.3                  |
|        | 4.3           | 4.3        | 4.1                  |
| P₂O₅   | 0.2           | 0.1        | 0.3                  |
|        | 0.3           | 0.3        | 0.3                  |
| CO₂    | 0.1           | 0.1        | 0.1                  |
|        | 0.0           | 0.0        | 0.0                  |
| H₂O⁺   | 0.6           | 0.6        | 0.7                  |
|        | 0.6           | 0.6        | 0.6                  |
| LOI    | 0.5           | 0.6        | 0.2                  |
|        | 0.6           | 0.4        | 0.3                  |
|        | 0.5           | 0.6        | 0.4                  |
|        | 0.5           | 1.0        | 0.7                  |
|        | 100.1         | 100.1      | 100.0                |
|        | 99.8          | 100.1      | 99.8                |
|        | 100.3         | 101.2      | 100.4                |
| Na₂O + K₂O | 8.4   | 8.3   | 8.4   |
|        | 8.3           | 8.3        | 8.3                  |
|        | 8.8           | 8.2        | 8.7                  |
|        | 7.6           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |
|        | 7.8           | 7.8        | 7.8                  |

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For the Fenghuangling pluton, the SiO$_2$ contents were in the range of 54.26–60.31%, the total alkali contents were 6.68–7.76%, and the CaO contents were 4.58–6.06%. Those values belong to the monzonite diorite and diorite domain on the SiO$_2$-(Na$_2$O + K$_2$O) diagram and the calc-alkalic series according to the SiO$_2$-MALI diagram (Figure 5a,b). The Fenghuangling pluton's K$_2$O content was in the range of 2.41–3.72%, falling into the high-K calc-alkaline series on the SiO$_2$-K$_2$O diagram (Figure 5c). The A/CKN (molar Al$_2$O$_3$/[(CaO + Na$_2$O + K$_2$O)] and A/NK (molar Al$_2$O$_3$/[Na$_2$O + K$_2$O]) values were in the ranges of 0.84–0.87 and 1.50–1.86, respectively, falling into the metaluminous series on the A/CKN–A/NK diagram (Figure 5d). For the host rock of the Xishan pluton, the SiO$_2$ content was in the range of 65.19–71.18%, the total alkali content was in the range of 8.17–8.82%, and the CaO content was 1.45–3.00%, placing it in the domain of granite and quartz monzonite on the SiO$_2$-(Na$_2$O + K$_2$O) diagram, and the calc-alkalic series according to the SiO$_2$-MALI diagram (Figure 5a,b). Its K$_2$O content ranged from 4.08 to 4.69%, and it falls into the high-K calc-alkaline series on the SiO$_2$-K$_2$O diagram (Figure 5c). The A/CKN and A/NK values ranged from 0.88 to 0.96 and 1.16 to 1.32, respectively, and it falls into the metaluminous series on the A/CKN-A/NK diagram (Figure 5d). For the mafic microgranular enclaves of the Xishan pluton, the SiO$_2$ content was in the range of 65.19–71.18%, the total alkali was in the range of 7.58–7.81%, and the CaO content was 1.45–3.00%. They fall into the domain of monzonite on the SiO$_2$-(Na$_2$O + K$_2$O) diagram and belong to the calc-alkalic and alkali series on the SiO$_2$-MALI diagram (Figure 5a,b). Their K$_2$O content ranged from 2.13 to 2.43%, which corresponds to the high-K calc-alkaline series on the SiO$_2$-K$_2$O diagram (Figure 5c). Its A/CKN and A/NK values ranged from 0.76 to 0.84 and 1.39 to 1.40, respectively, which corresponds to the metaluminous series on the A/CKN-A/NK diagram (Figure 5d).

For the Fenghuangling pluton, the SiO$_2$ contents were in the range of 54.26–60.31%, the total alkali contents were 6.68–7.76%, and the CaO contents were 4.58–6.06%. Those values belong to the monzonite diorite and diorite domain on the SiO$_2$-(Na$_2$O + K$_2$O) diagram and the calc-alkalic series according to the SiO$_2$-MALI diagram (Figure 5a,b). The Fenghuangling pluton’s K$_2$O content was in the range of 2.41–3.72%, falling into the high-K calc-alkaline series on the SiO$_2$-K$_2$O diagram (Figure 5c). The A/CKN (molar Al$_2$O$_3$/[(CaO + Na$_2$O + K$_2$O)] and A/NK (molar Al$_2$O$_3$/[Na$_2$O + K$_2$O]) values were in the ranges of 0.84–0.87 and 1.50–1.86, respectively, falling into the metaluminous series on the A/CKN–A/NK diagram (Figure 5d). For the host rock of the Xishan pluton, the SiO$_2$ content was in the range of 65.19–71.18%, the total alkali content was in the range of 8.17–8.82%, and the CaO content was 1.45–3.00%, placing it in the domain of granite and quartz monzonite on the SiO$_2$-(Na$_2$O + K$_2$O) diagram, and the calc-alkalic series according to the SiO$_2$-MALI diagram (Figure 5a,b). Its K$_2$O content ranged from 4.08 to 4.69%, and it falls into the high-K calc-alkaline series on the SiO$_2$-K$_2$O diagram (Figure 5c). The A/CKN and A/NK values ranged from 0.88 to 0.96 and 1.16 to 1.32, respectively, and it falls into the metaluminous series on the A/CKN-A/NK diagram (Figure 5d). For the mafic microgranular enclaves of the Xishan pluton, the SiO$_2$ content was in the range of 65.19–71.18%, the total alkali was in the range of 7.58–7.81%, and the CaO content was 1.45–3.00%. They fall into the domain of monzonite on the SiO$_2$-(Na$_2$O + K$_2$O) diagram and belong to the calc-alkalic and alkali series on the SiO$_2$-MALI diagram (Figure 5a,b). Their K$_2$O content ranged from 2.13 to 2.43%, which corresponds to the high-K calc-alkaline series on the SiO$_2$-K$_2$O diagram (Figure 5c). Its A/CKN and A/NK values ranged from 0.76 to 0.84 and 1.39 to 1.40, respectively, which corresponds to the metaluminous series on the A/CKN-A/NK diagram (Figure 5d).

**Figure 5.** Chemical characteristics of the Guiping complex. (a) SiO$_2$ versus total alkalis diagram (after Middlemost, 1994) [47]; (b) SiO$_2$ versus MALI diagram (after [48]); (c) SiO$_2$ versus K$_2$O diagram (after [49]); (d) an A/CKN versus A/NK diagram (after [50]).
As shown in chondrite-normalized REE patterns (Figure 6a,b), the differentiation between LREEs and HREEs was marked for the Fenghuangling pluton and the host rock of the Xishan pluton. (La/Yb)\text{N} ranges were 17.2–19.4 and 13.1–28.9, respectively. For mafic microgranular enclaves of the Xishan pluton, such differentiation was indistinct: (La/Yb)\text{N} ranged from 4.11 to 5.52. The Fenghuangling pluton exhibited almost no Eu anomalies, as δEu ranged from 0.91 to 0.96. Weak negative Eu anomalies were observed for the host rock of the Xishan pluton: δEu values ranged from 0.52 to 0.77. Negative Eu anomalies were observed for the mafic microgranular enclaves of the Xishan pluton: δEu values ranged from 0.32 to 0.36. In the primitive mantle-normalized spider diagrams (Figure 6c,d), the Fenghuangling pluton was enriched in Th, U, and Pb and depleted in Ba, P, and Ti. There was no Sr anomaly or weak Sr anomaly. The host rock of the Xishan pluton was also enriched in large ion lithophile elements (LILEs) and more depleted in Ba, Sr, and P than the Fenghuangling pluton. The mafic microgranular enclaves of the Xishan pluton were enriched in LILEs such as Th, U, and Pb and depleted in Ba, Sr, and Ti. They consequently displayed Nb and Ta-positive anomalies. In contrast, no important Nb or Ta anomaly was observed for the Fenghuangling pluton and the host rock of the Xishan pluton.

4.3. Whole-Rock Sr-Nd Isotopes

The analytical results of the Sr-Nd isotopes of the Guiping complex are shown in Table 3.
Table 3. Whole-rock Sr–Nd isotopic compositions of the Guiping complex.

| Sample         | SrRb/86Sr | Sr87Sr/86Sr ±2σ | I87Sr | 142Sm/144Nd | 143Nd/144Nd ±2σ | Age (Ma) | εNd(t) | TDM(Ga) | TDM2(Ga) |
|----------------|-----------|-----------------|-------|-------------|-----------------|----------|--------|---------|----------|
| Xishan Pluton  | 3.691     | 0.7129          | 3.0746| 0.0957      | 0.512629        | 159.7    | 1.88   | 0.67    | 0.80     |
| 11XS01-2       | 3.467     | 0.7128          | 4.0749| 0.0915      | 0.512611        | 159.7    | 1.62   | 0.67    | 0.82     |
| 11XS03-1       | 0.9955    | 0.7081          | 6.0758| 0.1056      | 0.512547        | 160.8    | 0.09   | 0.85    | 0.94     |
| 11XS03-3       | 1.290     | 0.7086          | 6.0757| 0.1104      | 0.512556        | 160.8    | 0.17   | 0.88    | 0.94     |
| 11XS04-2-2     | 43.49     | 0.7934          | 8.6947| 0.1686      | 0.512578        | 159.6    | −0.60  | 1.93    | 1.00     |
| 11XS04-5-2     | 1.827     | 0.7086          | 6.0758| 0.1149      | 0.512620        | 159.1    | 0.58   | 0.97    | 1.00     |
| Xishan MME     | 1.369     | 0.7099          | 4.0754| 0.1372      | 0.512523        | 159.6    | 0.86   | 1.06    | 0.88     |
| Fenghuangling  | 0.7610    | 0.7074          | 5.0757| 0.1075      | 0.512644        | 160.1    | 1.94   | 0.73    | 0.79     |
| Pluton         | 0.2413    | 0.7063          | 1.0738| 0.1160      | 0.512608        | 160.1    | 1.06   | 0.85    | 0.86     |

In general, the Guiping complex had low initial $\varepsilon$Sr ratios ($I_{Sr}$) and high $\varepsilon$Nd(t) values (Figure 7). The $I_{Sr}$ values of the Fenghuangling pluton were in the range of 0.7057–0.7058, and the $\varepsilon$Nd(t) values ranged from 1.06 to 1.94. Except for sample 11XS04-2-2 with an $I_{Sr}$ value of 0.6947, the host rock of the Xishan pluton exhibited $I_{Sr}$ values ranging from 0.7046 to 0.7058; $\varepsilon$Nd(t) values ranged from -0.60 to 1.88. One sample of the microgranular enclave of the Xishan pluton showed $I_{Sr}$ values of 0.7054 and an $\varepsilon$Nd(t) value of 0.86.

Figure 7. $\varepsilon$Nd(t) versus $I_{Sr}$ diagram of the Guiping complex. Data sources: [20,31,40,41,52,54].

5. Discussion

5.1. Genetic Types of Granitites in the Xishan Pluton

Chappell and White (1974) classified granites into I and S types based on the nature of the source rocks [55]. I-type granites derive from unweathered igneous rocks and S-type granites originate from sedimentary rocks. A-type granites were defined by Loiselle and Wones (1979) [56]. It is worth noting that, unlike I and S granites, A-type granites are defined according to their geochemical characteristics and the tectonic setting. It originally referred to anorogenic, moderately alkaline, and water-deficient granites that evolved from alkaline basaltic magma. As research continues in more depth, the definition of A-type granites is expanding [57]; for example, A-type granite can be formed in an anorogenic environment or post-orogenic environment. The extension of the domain of A-type granites has caused considerable controversies [58–62]. Moreover, many discriminant diagrams or classification diagrams of A-type granites were proposed [63–65], but some discriminant diagrams (e.g., K2O-Na2O diagram) resulted in the expansion of A-type
granites, causing some non-A-type granites to be included in the domain of A-type granites [66]. Although some of the diagrams for A-type granites are controversial, a few of them are still broadly accepted. These include the Zr + Nb + Ce + Y vs. Ga/Al diagram proposed by Whalen et al. (1987) [63]; the discriminant diagram of A1-type and A2-type granites based on the Y, Nb, Ce, and Ga contents and Y/Nb and Sc/Nb ratios proposed by Eby (1992) [64]; the classification diagram for the reduced and oxidized A-type granites based on FeO/(FeO + MgO) and Al2O3/(K2O/Na2O) ratios proposed by Dall’Agnol and Oliveira (2007) [65]. The Xishan granites mainly fall outside the A-type granite domain (Figure 8a) according to the classification diagram for the reduced and oxidized A-type granites proposed by Dall’Agnol and Oliveira (2007) [65]. However, they are classified as A-type granites according to the diagrams of Whalen et al. (1987) [63] and Frost et al. (2001) [67] due to their high Nb, Ce, and Zr contents and high ratios of Ga/Al and Fe index (Figure 8b–f). Therefore, the Fenghuangling and Xishan plutons are considered to be A-type granites.

Figure 8. Discrimination diagrams of A-type granite for the Guiping complex. (a) Al2O3/(K2O/Na2O) versus FeO/(FeO + MgO) diagram (after [63]); (b) SiO2 versus Fe-index diagram (after Frost et al., 2001) [67]; (c) (Zr + Nb + Ce + Y) versus FeO*/MgO diagram (after [67]); (d) 10,000Ga versus Nb diagram (after [63]); (e) (Zr + Nb + Ce + Y) versus (Na2O + K2O)/CaO diagram (after [63]); (f) 10,000 Ga versus Zr diagram (after [67]).
5.2. Petrogenesis

5.2.1. Genesis of the Xishan Granites

A-type granites genesis may be explained by at least six variants of melt sources: (1) fractionation from mantle-derived basic magmas and interactions with the continental crust in some cases [57,68]; (2) high-temperature partial melting of a granulitic residue in the lower crust formed after extraction of an orogenic granite [63,69]; (3) shallow dehydration melting of calc-alkaline (hornblende-bearing and biotite-bearing) granitoids [70]; (4) partial melting of an underplated lower crustal source at high temperatures in an extensional environment [71,72]; (5) high-temperature melting of granulitic metasedimentary rocks [73]; (6) recycling of subducted oceanic crust—a novel exotic source for the origin of alkaline A-type granites in intraplate extensional settings [74].

The Xishan pluton has $^{87}\text{Sr}/^{86}\text{Sr}$ values of 0.7046 to 0.7058 and $\varepsilon_{\text{Nd}}(t)$ values of −0.60 to 1.88. Those $\varepsilon_{\text{Nd}}(t)$ values are apparently different from those of the Precambrian basement in South China, indicating that the Xishan pluton unlikely originated from partial melting of the Precambrian basement in South China (Figure 7). Furthermore, the A-type granites at the northeast margin of the southwest section of the Shihang belt, such as Qitianling and Jiuyishan plutons, which are contemporary with the Xishan rock but have significantly lower $\varepsilon_{\text{Nd}}(t)$ values (Figure 7), are often considered to be the products of crust–mantle mixing. The Qitianling and Jiuyishan plutons have lower Nb contents (16.4–38.2 ppm) and more marked negative Nb anomalies, consistent with the assumption that they mainly stemmed from the crust [20,52–54]. In contrast, the Xishan pluton has high Nb content (52–66 ppm) and indistinct Nb anomalies (Figure 6c,d), making it obviously different from the Qitianling and Jiuyishan plutons, further proving that the Xishan pluton did not originate from the melting of ancient crustal materials.

Mafic microgranular enclaves are well developed in the Xishan pluton. Although major elements of the Xishan granites display marked mixing trends with mafic microgranular enclaves, trace elements, such as Sr, Ba, and U, do not show mixing trends between the acidic end members and mafic microgranular enclaves (Figure 9). Thus, the Xishan granites were unlikely mainly formed by mixing of the acidic end members and mafic microgranular enclaves.

On the Harker diagram, the samples of the Xishan and Fenghuangling plutons display linear variations. For example, the contents of TiO$_2$, Al$_2$O$_3$, FeO, MgO, CaO, P$_2$O$_5$, Sr, and V were negatively correlated with SiO$_2$ (Figure 9), and the K$_2$O content was positively correlated with SiO$_2$ (Figure 5). The above linear relationships imply that the Xishan and Fenghuangling plutons probably originated from similar parental magmas, and they were supposed to have experienced the crystallization differentiation of plagioclase, hornblende, apatite, and Fe–Ti oxides, which was supported by similar REE patterns for the Xishan and Fenghuangling plutons, and marked negative anomalies of Eu, Sr, and P and more depleted middle REE of the Xishan pluton. Besides, the $^{87}\text{Sr}/^{86}\text{Sr}$ and $\varepsilon_{\text{Nd}}(t)$ values of the Fenghuangling and Xishan plutons remained constant with increasing SiO$_2$, suggesting that assimilation and contamination were absent or extremely limited during their evolution (Figure 10).

5.2.2. Genesis of the Microgranular Enclave in the Xishan Pluton

Mafic microgranular enclaves in the Xishan pluton often show signs of magma mixing, including their flame-like and irregular morphology; composite enclaves; the granitic back veins and acicular apatite developed in some mafic microgranular enclaves; the obscure or gradational contact between enclaves and host rock; large crystals of potassium feldspar cutting through the boundary between the enclaves and the host rocks. However, the trace element characteristics of the mafic microgranular enclaves are clearly different from those of the Xishan pluton, especially in terms of high Nb contents (116–183 ppm). The enclaves have positive Nb anomalies, which is consistent with the Jurassic Ningyuan OIB-type basalt in the southwestern section of the Shihang belt. Thus, we believe that the mafic microgranular enclaves in the Xishan pluton were derived from asthenospheric
mantle, similarly to the Ningyuan OIB-type basalts [31,41]. After their evolutionary products intruded into the Xishan granitic melt, magma mixing processes resulted in the Sr-Nd isotopic equilibrium between mafic microgranular enclaves and the Xishan granitic magma, and mafic microgranular enclaves consequently have similar Sr-Nd isotopic compositions to the Xishan granites but different chemical characteristics, because isotopic exchange proceeds much more quickly than chemical homogenization. Therefore, mafic microgranular enclaves inherited the trace element characteristics of OIB-type basalt.

Figure 9. Harker diagrams for the Guiping complex.
5.2.3. Genesis of the Fenghuangling Pluton

The Fenghuangling pluton has low SiO$_2$ content (54.26–60.31%) and I$_{Sr}$ values (0.7057–0.7058) and high $\varepsilon$Nd(t) values (1.06–1.94). It has inconspicuous negative anomalies of Nb, Sr, and Eu, ruling out the possibility of its formation via partial melting of ancient crustal materials in South China. Besides, assuming it originated from the Ningyuan OIB-type basalts, which have positive Nb anomalies with high Nb values of 67.3–78.9 ppm and relatively depleted Sr-Nd isotope compositions with I$_{Sr} = 0.7035–0.7046$ and $\varepsilon$Nd(t) = 5.40–6.10 [31,53,54], the assimilation and contamination of ancient crustal materials would have reduced the Nb content and $\varepsilon$Nd(t) values and raised the I$_{Sr}$ values. However, the relationships among $\varepsilon$Nd(t), I$_{Sr}$, and the SiO$_2$ contents indicate that assimilation of continental crust had a very limited effect on the formation of the Fenghuangling pluton (Figure 10). Therefore, it is impossible that the Fenghuangling pluton derived from parental magma similarly to the Ningyuan OIB-type basalt through crustal assimilation. It is worth noting that in the southwest part of the Shihang belt, not only were Ningyuan OIB-type basalts derived from asthenosphere mantle, but arc basalts were derived from the lithospheric mantle [31,40,41]. For instance, Daoxian, Guiyang, and Changchengling basalts were developed in the Jurassic. These arc basalts have relatively enriched Sr-Nd isotopic compositions with I$_{Sr} = 0.7052–0.7076$ and $\varepsilon$Nd(t) = −3.75–1.05 and important negative Nb anomalies with low Nb values of 8.30–15.0 ppm. Therefore, we proposed that the basaltic parental magma of the Fenghuangling pluton originated from the partial melting of the enriched lithospheric mantle with contributions from the asthenosphere-related OIB-type basaltic magma (Figure 7).

5.3. Geotectonic Setting

Many tectonic models have been proposed to describe the magmatism, tectonism, and mineralization during the Yanshanian period in South China, including the rift model [18], the mantle plume model [9], and the Paleo-Pacific Plate subduction model [75]. Besides, disagreement exists among researchers about the geodynamic setting of the formation of Late Jurassic A-type granites in the southwest section of the Shihang belt [19,20,22–26,29,54,66–80]. According to the discriminant diagram of A-type granites proposed by Eby (1992) [64], the Xishan granites fall into the A1-type granite domain (Figure 11), which seems to fit the rift model or mantle plume model. However, from Figure 11, it can be observed that for the Late Jurassic, northeast-trending, A-type granite belt in the southwest section of the Shihang belt, A1-type and A2-type granites developed simultaneously, and some plutons, such as the Huashan–Guposhan pluton, have both A1-type and A2-type granites. Thus, it is inappropriate to conclude only based on the discriminant diagram that the A1-type granites (Fenghuangling and Xishan plutons) were formed in the rift or mantle plume setting, and the A2-type granites (Qitianling and Jiuyishan plutons) were generated in post-collisional or post-orogenic settings. The granite distribution matches the idea that the A1-type and A2-type granites coexisted in the early Cretaceous.
A-type granite belt in the middle and lower reaches of the Yangtze River and the late Cretaceous A-type granite belt in the coastal area [81,82]. Moreover, Eby (1992) pointed out that the trace element geochemical characteristics of A1 and A2-type granites are not only attributable to their tectonic settings, but also to the nature of their source areas [64]. As indicated by Zhou et al. (2006) [10], the rift only represents a tectonic pattern rather than representing the most fundamental dynamic mechanism.

The Late Jurassic (about 165–150 Ma) A-type granites in the southwest of the Shihang belt extend from the Qianlishan and Qitianling plutons in the northeast, through the Juyishan–Xishan pluton and Huashan–Guposhan pluton in the central part, to the Fenghuangling–Xishan pluton in the Guiping area of Guangxi in the southwest (Figure 1). The whole belt extends in a NE direction, which is in line with the subduction of the Paleo-Pacific Plate. In the last 15 years, many studies were performed regarding the magmatism, tectonism, and mineralization of the Yanshanian period in South China. Most scholars preferred the Paleo-Pacific Plate subduction model, but considerable controversy still exists in the understanding of how the Paleo-Pacific Plate subduction formed the large-scale magmatism–tectonism–mineralization in South China in the Yanshanian period [10,12,13,16,33,39,83]. For example, Zhou et al. (2007) suggested that the continuous subduction of the Paleo-Pacific Plate since the Middle Jurassic period has caused extrusion in the deep area and extension in the shallow area of the lithosphere [75], resulting in the extensional magmatism in the Yanshanian period in South China. Jiang et al. (2009, 2015) emphasized that back-arc extension as a result of the rollback of the Paleo-Pacific Plate led to the extensional magmatism in the Yanshanian period in South China [31,83]. As for the model of the Paleo-Pacific Plate’s subduction-plate delamination–lithospheric extension, it emphasizes that the delamination of the Paleo-Pacific Plate during its horizontal subduction induced the upwelling of the asthenosphere and the continental lithosphere extension, which were the dominant factors in the formation of the A-type granites in the early Yanshanian period [32,39,84,85]. In addition to the Late Jurassic (ca. 165–150 Ma) NE-trending A-type granite belt in the southwest section of the Shihang belt, there are also early Cretaceous (ca. 140–125 Ma) NE-trending A-type granite belts extending from the northeast of Jiangxi to the southwest of Zhejiang and a late Cretaceous (ca. 100–90 Ma) NE-trending A-type granite belt in the southeast coast of China (Figure 1). Spatially, granite belts migrate from inland areas to coastal areas. The granites are younger the closer they are to the coast, suggesting continuous rollback of the Paleo-Pacific Plate (Figure 12). Therefore, we concluded that the Late Jurassic (ca. 165–150 Ma) NE-trending A-type granite belt in the southwest section of the Shihang belt was formed in a post-arc extensional environment as a result of the rollback of the Paleo-Pacific Plate.
Figure 12. A geodynamic modal accounting for the genesis of the Yanshanian NE-trending A-type granite belts in South China.

6. Conclusions

1. The Guiping complex consists of the Xishan and Fenghuangling plutons. Zircon U-Pb dating indicates that the Guiping complex was formed at ca. 160.8 ± 0.9 Ma–159.1 ± 1.1 Ma.

2. The whole-rock geochemical and Sr-Nd isotope data indicate that the Guiping complex belongs to A-type granites. We proposed that the basaltic parental magma of the Guiping complex originated from the partial melting of the enriched lithospheric mantle, which was metasomatized by the asthenosphere-related basaltic magma. Its mafic microgranular enclaves were formed by the magma mixing between the asthenosphere-derived magma and the evolutionary magma of the host Xishan pluton.

3. The Guiping complex is located on the southwest margin of the Late Jurassic NE-trending A-type granite belt in the southwest section of the Shihang belt. We believe that this granite belt (ca. 165–150 Ma) was probably formed in a back-arc extensional environment because of the rollback of the Paleo-Pacific Plate.

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