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Dating of the volcanic rocks from the Shuzhugang Hill, Guangzhou: age constraints on the Late Cretaceous strata in the Sanshui and Zhujiangkou basins

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Abstract

Well-developed Cretaceous-Paleogene strata are exposed in the Guangzhou-Foshan area. Owing to limited volcanic activity, isotopically datable material is scarce, and the chronology of these strata relies primarily on biostratigraphic correlations. The Baihedong Formation has been generally regarded as a sedimentary sequence deposited during the late Early Cretaceous, although robust chronological constraints are lacking. In the Shuzhugang Hill area, located south of Guangzhou, a suite of volcanic rocks is exposed and is generally assigned to the upper part of the Baihedong Formation, though some scholars attribute it to the Paleogene. Zircon U-Pb dating conducted in this study yielded an absolute age of 83.5 ± 0.7 Ma for these volcanic rocks, thereby constraining the deposition of the Baihedong Formation to the Late Cretaceous. This study provides a crucial chronological reference for defining the Cretaceous-Paleogene stratigraphic chronology framework across the Sanshui and Zhujiangkou basins.

Keywords: Baihedong Formation, Late Cretaceous, volcanism, isotopic dating

Introduction

The Sanshui Basin is an important hydrocarbon-bearing basin in South China, characterized by a thick and continuous succession of Mesozoic-Cenozoic strata. The Cretaceous-Paleogene succession, in ascending order, consists of the Baizushan, Baihedong, Sanshui, Dalangshan, Xinzhuangcun, Buxin, Baoyue and Huayong formations (Zhang *et al*., 2008). Similar Mesozoic-Cenozoic strata are developed in the Guangzhou area of the Zhujiangkou Basin to the east. Although these strata contain abundant terrestrial fossil assemblages (GGS, 2017), their precise geological ages remain highly debated. This uncertainty arises primarily from the scarcity of volcanic rocks suitable for isotopic dating. Except for the Huayong Formation, volcanic rocks are rare within these strata and are mostly encountered in boreholes. Consequently, isotopic geochronological studies in this region are limited. In particular, constraining the age of the Late Cretaceous strata remains challenging.

Additionally, the evolutionary history of the South China Sea remains debated, with several genetic models proposed (Taylor & Hayes, 1983; Tapponnier *et al*., 1990; Niu, 2005). Several rift basins are developed north of the South China Sea. Volcanic rocks within these basins provide key insights not only into basin evolution but also into the transformation from the continental lithosphere breakup to oceanic accretion. The Sanshui Basin is one of the rifting basins and preserves multiple volcanic eruptions during this transformation (Zhu *et al*., 1991; Dong *et al*., 2006; Wei *et al*., 2018). However, the volcanic records have been rarely reported, yet they are crucial for investigating the evolution during this period.

In the Shuzhugang and Fenggang hills, a suite of rhyolite porphyry, dacite, and pyroclastic rocks occurs. They are generally attributed to the upper part of the Baihedong Formation (Tang, 1994; Xiao *et al*., 2006). Previous K-Ar dating studies yielded ages of 59.38 ± 0.95 Ma for the Fenggang rhyolite porphyry (Zhang *et al*., 1993; Dong *et al*., 2006) and 52.6 Ma for the Shuzhugang granite porphyry (Zhang *et al*., 1993), respectively. Consequently, Zhang *et al*. (1993) interpreted these igneous rocks as Paleocene in age. However, this view conflicts markedly with the Cretaceous age assigned

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to the surrounding sedimentary strata, implying these volcanic rocks may represent later volcanic eruptions. Given the questionable reliability of these K-Ar ages, we reinvestigated the volcanic rocks using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) zircon U-Pb dating.

Material and methods

Sample N20241103Z36 was collected near the Chunyang taoist temple in the Shuzhugang hill, south Guangzhou (Fig. 1). This rock exhibits a tuffaceous texture and comprises roughly equal proportions of crystal fragments (50%) and cement (50%) (Fig. 2). The crystal fragments are mainly composed of quartz (20%), alkali feldspar (15%), plagioclase (10%) and biotite (5%), while the cement consists primarily of volcanic ash. Minor amounts of plastic detritus are also observed (Fig. 2). Based on these characteristics, the rock is classified as rhyolitic crystal tuff.

Zircon U-Pb dating was conducted using LA-ICP-MS at Nanjing Hongchuang Geological Exploration Technology Service Co., Ltd. The Resolution SE model laser ablation system (Applied Spectra) was equipped with ATL (ATLEX 300) excimer laser and a Two Vol

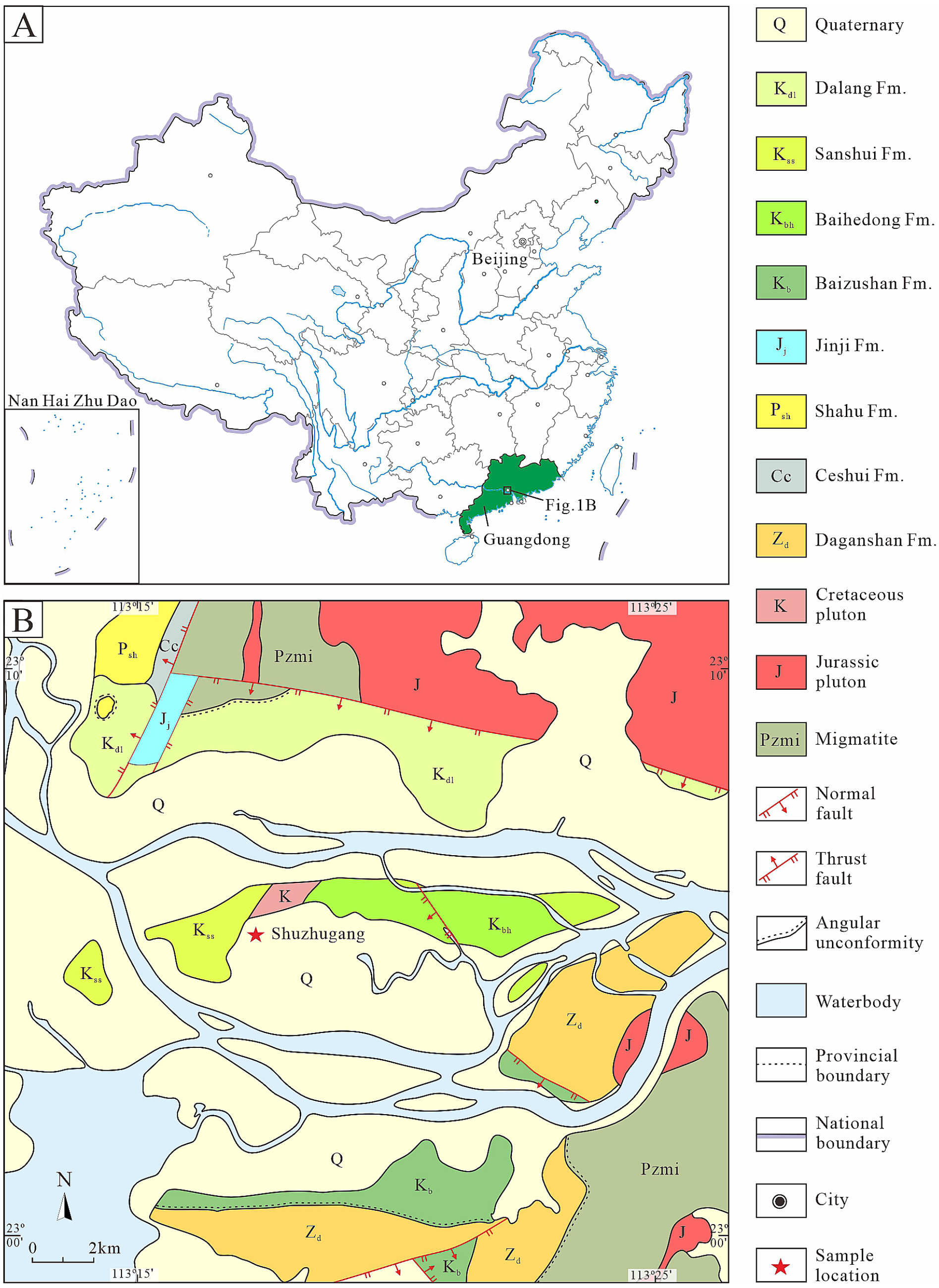

FIGURE 1. The location and geological maps of the study area. **A**, The location of the study area. **B**, Simplified geological map of the study area.

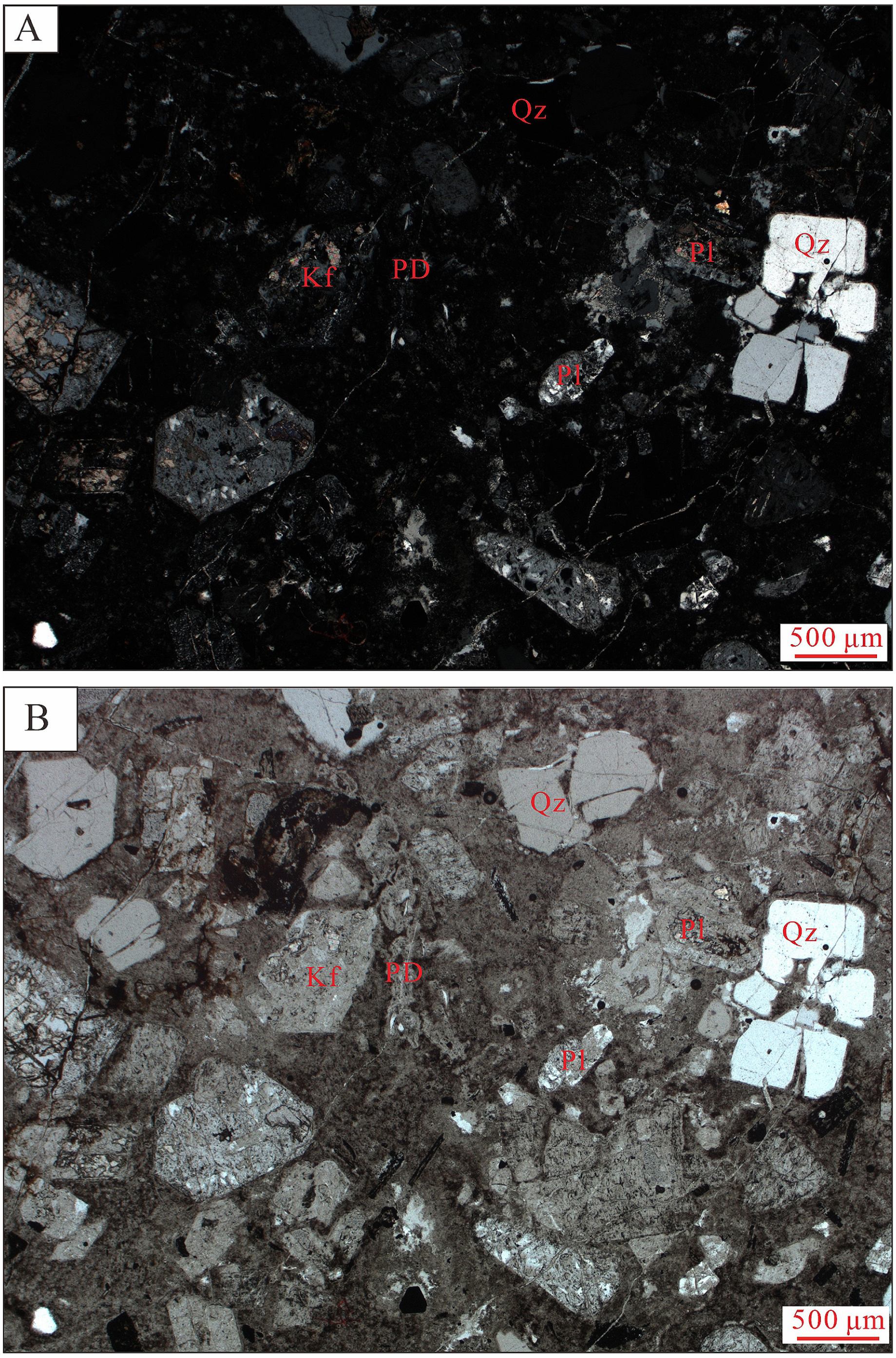

FIGURE 2. Photomicrographs for the sample N20241103Z36 from the Shuzhugang Hill, Guangzhou, Guangdong, China. **A**, Crossed nicols. **B**, Under the plan-polarized light. Abbreviations: Pl, plagioclase; Kf, potassium feldspar; Qz, quartz; PD, Plastic detritus. The scale bar is 500 µm.

S155 ablation cell. The laser ablation system was coupled to an Agilent 7900 ICP-MS. Zircon grains were mounted in epoxy discs, polished to expose the grains, cleaned ultrasonically in ultrapure water, then cleaned again before the analysis using AR-grade methanol. Pre-ablation was conducted for each spot analysis using 5 laser shots (~ 0.3 µm in depth) to remove potential surface contamination. The analysis was performed using a 30 µm diameter spot at 5 Hz and a fluence of 2 J/cm^2. Iolite software package was used for data reduction (Paton *et al*., 2010). Zircon 91500 and GJ-1 were used for instrumental calibration and quality control. Zircon U-Pb concordia and weighted mean age plots were produced using Isoplot/Ex_ver 4.15. Analytical results are presented in Table 1.

TABLE 1. Results of LA-ICP-MS zircon U-Pb analyses for the rhyolitic crystal tuff from the Baihedong Formation in the Shuzhugang, Guangzhou, Guangdong Province, China.

Analyses					$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		$^{207}Pb/^{206}Pb$		$^{207}Pb/^{235}U$		$^{206}Pb/^{238}U$		Concordance (%)
	Pb	Th	U	Th/U	Ratio	2σ	Ratio	2σ	Ratio	2σ	Age	2σ	Age	2σ	Age	2σ	
N20241103Z36																	
01	2	170	137	1.2	0.046943	0.007259	0.085438	0.013161	0.013092	0.000421	-148.5	365.7	82.4	12.2	83.8	2.7	98
02	3	245	195	1.3	0.050262	0.005898	0.091048	0.010824	0.013201	0.000348	64.5	272.0	87.7	10.0	84.5	2.2	96
04	3	142	215	0.7	0.050721	0.006274	0.091882	0.011057	0.013310	0.000421	63.7	279.4	88.7	10.2	85.2	2.7	96
05	2	125	89	1.4	0.052720	0.008264	0.089880	0.012881	0.012986	0.000519	-139.7	437.5	86.2	11.9	83.2	3.3	96
06	3	154	174	0.9	0.049386	0.005075	0.087335	0.008966	0.012944	0.000314	-143.6	316.2	84.4	8.3	82.9	2.0	98
07	5	70	223	0.3	0.049998	0.003307	0.138443	0.009528	0.020086	0.000576	20.7	176.4	130.8	8.5	128.2	3.6	98
08	27	621	944	0.7	0.049341	0.001560	0.152195	0.005034	0.022320	0.000275	139.2	77.4	143.6	4.4	142.3	1.7	99
09	65	205	411	0.5	0.064129	0.001784	1.082072	0.032136	0.121581	0.001461	729.1	60.3	742.9	15.8	739.6	8.4	100
10	127	77	186	0.4	0.214060	0.002567	14.453192	0.180560	0.487871	0.005701	2933.5	19.6	2778.7	11.9	2560.7	24.7	92
12	24	63	114	0.6	0.071062	0.002228	1.663673	0.059558	0.169016	0.002816	964.3	66.0	990.9	22.8	1006.4	15.6	98
13	109	421	226	1.9	0.097254	0.002034	3.699907	0.078540	0.275348	0.002761	1563.7	39.8	1569.3	17.0	1567.7	14.0	100
14	14	70	284	0.3	0.052419	0.002292	0.314870	0.016448	0.043276	0.001115	267.3	106.4	276.3	12.7	273.0	6.9	99
15	4	205	239	0.9	0.046764	0.005935	0.084598	0.010907	0.013011	0.000315	-97.5	276.5	81.6	10.2	83.3	2.0	98
16	4	64	307	0.2	0.044569	0.006324	0.090865	0.013751	0.014071	0.000412	-401.3	444.9	87.6	12.7	90.1	2.6	97
17	1	161	47	3.4	0.053352	0.014337	0.091313	0.023218	0.013416	0.000716	411.5	431.1	90.2	22.7	85.9	4.6	95
19	2	157	108	1.5	0.045946	0.007175	0.082358	0.012423	0.013024	0.000451	47.8	384.9	79.4	11.6	83.4	2.9	95
20	11	103	414	0.3	0.049187	0.002701	0.171179	0.009073	0.024668	0.000517	94.4	128.4	160.1	7.8	157.1	3.3	98
23	31	279	389	0.7	0.054493	0.002326	0.445978	0.018593	0.058014	0.000704	358.2	95.2	373.5	13.0	363.5	4.3	97
24	2	200	106	1.9	0.046207	0.010533	0.083307	0.018756	0.012827	0.000539	-469.2	619.7	79.9	17.4	82.2	3.4	97
25	50	374	271	1.4	0.063247	0.001702	1.066568	0.031930	0.119761	0.001825	697.5	57.9	735.0	15.7	729.0	10.5	99
27	4	91	162	0.6	0.050218	0.004060	0.149917	0.011274	0.021423	0.000556	32.1	203.7	141.0	9.9	136.6	3.5	97
29	2	86	98	0.9	0.051402	0.009330	0.093019	0.016158	0.013012	0.000651	-111.3	488.6	89.2	15.0	83.3	4.1	93
30	16	51	372	0.1	0.053199	0.002768	0.278959	0.013708	0.037839	0.000665	293.5	118.1	249.3	10.8	239.4	4.1	96
31	11	817	516	1.6	0.050527	0.004171	0.088759	0.007384	0.012980	0.000343	183.3	171.8	86.0	6.9	83.1	2.2	97
32	2	123	89	1.4	0.048455	0.008382	0.085706	0.015706	0.013094	0.000482	-263.8	490.3	82.1	14.5	83.9	3.1	98
33	3	168	114	1.5	0.048486	0.006626	0.088933	0.011550	0.013635	0.000369	-212.8	394.1	85.3	10.7	87.7	2.5	97
34	6	163	289	0.6	0.049524	0.003097	0.121281	0.008013	0.018038	0.000437	76.3	148.4	115.7	7.2	115.2	2.8	100
36	27	139	202	0.7	0.062486	0.002338	0.863735	0.033581	0.101021	0.001295	647.8	83.9	628.9	18.2	620.3	7.6	99
37	2	168	129	1.3	0.047792	0.006512	0.087290	0.012640	0.012823	0.000337	64.4	306.5	84.0	11.6	82.1	2.1	98
38	79	131	453	0.3	0.071509	0.000978	1.465437	0.021606	0.148627	0.001225	962.8	28.3	916.2	9.1	893.1	6.9	97
40	7	133	345	0.4	0.049260	0.002650	0.123685	0.006666	0.018123	0.000258	24.5	134.7	117.9	6.0	115.8	1.6	98
41	66	265	175	1.5	0.087787	0.001807	2.846168	0.061949	0.233400	0.002520	1367.2	39.4	1365.3	16.3	1352.0	13.2	99
42	29	159	370	0.4	0.054989	0.001346	0.498389	0.013705	0.065210	0.001050	380.3	55.3	409.2	9.3	407.1	6.4	99

Analysers are Agilent 7900, laser is 30 μm and error is 2σ. Calculated by Iolite software.

FIGURE 3. CL images of representative zircons for the sample N20241103Z36 from the Baihedong Formation in the Shuzhugang Hill, Guangzhou. Red circles show the locations of analysis spots, and U-Pb ages (Ma) are provided nearby.

Results

Zircon U-Pb dating

Zircons separated from the rhyolitic crystal tuff are colourless, euhedral and range in size from 50 to 250 μm, with length-to-width ratios of 1:1 to 5:1. Cathodoluminescence (CL) images reveal that most grains show well-developed oscillatory zoning, whereas a subset exhibits core-mantle textures (Fig. 3). Analytical results show significant compositional variation: Th (51–817 ppm) and U (47–8392 ppm) concentrations yield Th-U ratios ranging from 0.1 to 3.4, indicating an igneous origin. Discordant analyses (concordance < 90%) and statistically scattered data points were excluded from concordia and weighted mean age calculations.

A total of 42 zircon grains were analysed. Among them, five analyses were rejected due to Pb loss, and four were excluded for discordance (concordance < 90%). Twenty analyses yielded ages ranging from 89 Ma to 2561 Ma, interpreted as inherited zircon ages. The remaining 13 concordant analyses yielded a concordia age of 83.5 ± 0.7 Ma and a weighted mean age of 83.3 ± 0.7 Ma (Fig. 4).

Discussion

The Baihedong Formation was formally established in 1975 by the No. 735 Geological Team, with its

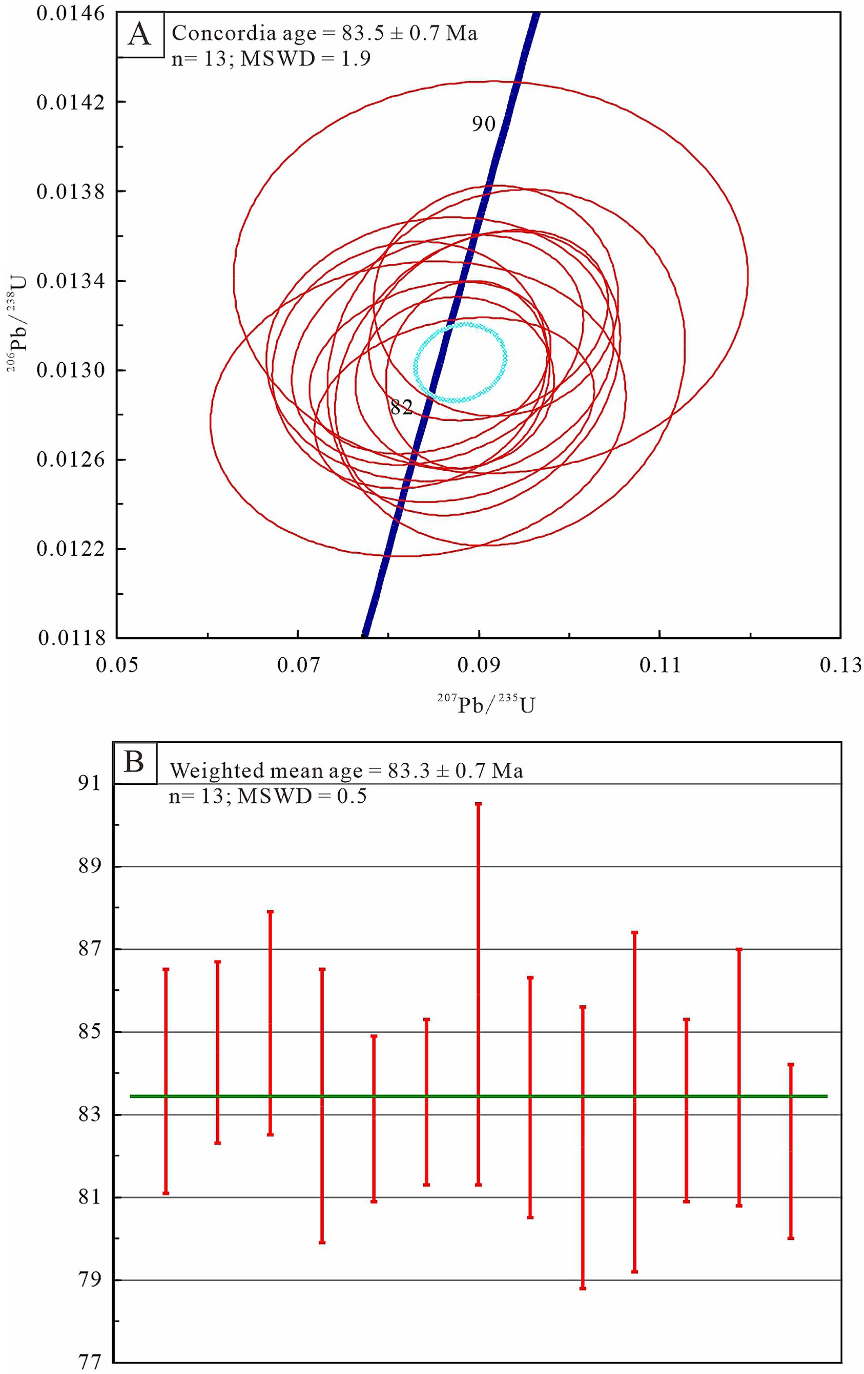

FIGURE 4. Age plots for the sample of N20241103Z36 from the Shuzhugang Hill, Guangzhou, Guangdong, China. **A**, Zircon U-Pb concordia age plot. **B**, Weighted mean age plot.

stratotype section defined from borehole ZK III-1 in the Donglang Village, south of Baihedong, Guangzhou City. Lithologically, it is characterized by interbedded grey and dark red calcareous mudstone, marl, and calcareous siltstone, with intercalated sandstones and gypsum. The formation yields fossils including conchostracans, ostracods, gastropods, charophytes, palynomorphs, and plants (Zhang *et al*., 1993).

The age of the Baihedong Formation has generally been regarded as Early Cretaceous or late Early Cretaceous (Zhang *et al*., 1993; Tang, 1994; Xiao *et al*., 2006; Hou *et al*., 2007; GGS, 2017). Based on paleomagnetic analysis, Yuan *et al*. (1992) proposed an age range of 93–129 Ma, corresponding to the mid-late Early Cretaceous to the earliest Late Cretaceous (GPBGMR, 1996). The Yetang Formation in the Xingning Basin of eastern Guangdong has been considered correlative with the Baihedong Formation, and has yielded abundant plant and animal fossils, including amber (Song *et al*., 2024). Stratigraphic correlation is supported by the presence of *Tenuestheria* conchostracans within the Baihedong Formation in both the Sanshui and Xingning basins (Chen, 1989).

Our new zircon U-Pb age of 83.5 ± 0.7 Ma, obtained from volcanic rocks near the top of the formation, provides a robust constraint on its upper age limit. This age, integrated with existing biostratigraphic and paleomagnetic data, suggests that the Baihedong Formation was deposited during the early Late Cretaceous, corresponding to the Santonian, Coniacian, and Turonian stages, and possibly extending into the upper Cenomanian.

Conclusion

Geochronological analysis of the volcanic rocks near the top of the Baihedong Formation provides a robust upper age constraint (83.5 ± 0.7 Ma), indicating that the formation as a whole was deposited during the early Late Cretaceous. This finding holds significant implications for refining the Mesozoic-Cenozoic stratigraphic framework across the Sanshui and the Zhujiangkou basins. These strata are rich in diverse and well-preserved fossil assemblages from multiple disciplines. Therefore, calibrating and further revising the temporal ranges of these assemblages based on the newly established absolute ages is now feasible.

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