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Temporal–spatial distribution and tectonic implications of the batholiths in the Gaoligong–Tengliang–Yingjiang area, western Yunnan: Constraints from zircon U–Pb ages and Hf isotopes

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A B S T R A C T

Considerable progress has recently been made regarding temporal and spatial distribution of magmatism in the Lhasa Terrane. However the eastward and southeastward correlation of these Tibetan magmatic suites in western Yunnan and Burma remains poorly constrained. This paper reports zircon U–Pb dating and Hf isotopic compositions of granites in the Gaoligong–Tengliang–Yingjiang area, west Yunnan. It reveals three episodes of plutonism, and more importantly a southwestward magmatic migration. The Gaoligong batholiths in the northeast were mainly emplaced during early Cretaceous (126–121 Ma) and comprised predominantly S-type granites with negative zircon εHf values ($\varepsilon_{Hf} = -2\sim-12$). The Tengliang granites, situated southwest of the Gaoligong belt, were emplaced in late Cretaceous (68–76 Ma) and also displayed a strong peraluminous affinity and negative ε_{Hf} ($-5\sim-14$), indicating a provenance from a Proterozoic sedimentary source with little mantle contribution. The youngest phase of magmatism (52–66 Ma) occurred in Yingjiang, southwestmost of the study area. It is composed of S-type granites (εHf = $-2\sim-12$) in east Yingjiang and I-type granites ($\varepsilon_{Hf} = -4\sim+6$) in west Yingjiang, near the China–Burma border. The late Cretaceous–early Cenozoic plutons in the Tengliang and Yingjiang area are thus considered as the northern continuation of the late Cretaceous magmatic arc (west), which comprises I-type granites and andesitic rocks, and of the belt of predominant S-type granites (east) in Burma, Thailand and Malaysia. Such a chemical polarity of the dual I-type and S-type granites is strongly reminiscent of the northern American Cordillera, indicating a Cordilleran-style continental margin during the late Cretaceous–early Cenozoic. While the magmatic arc was related to eastward subduction of the Neo-Tethys beneath the Asian continent, the S-type granites represented the melting products of thickened crust in the hinterland, in response to subduction-induced decrease in lithospheric strength and compressive plate-convergence forces and to a less degree to the collision between Burma and Sundaland blocks. The Gaoligong early Cretaceous granites, which bear strong similarities in lithology, geochemistry and emplacement age to those in the northern magmatic belt in the Lhasa Terrane, are also the magmatic expression of crustal thickening. This crustal thickening may have stemmed from the collision between the Lhasa Block and the Qiangtang Block in late Jurassic and Early Cretaceous. The magmatism in western Yunnan thus recorded a long-term subduction of the Neo-Tethyan plate, enhanced by continental collisions at different time.

1. Introduction

The large scale northward penetration of the Indian Plate into Asia since the early Cenozoic resulted in the formation of the most spectacular collisional orogen in world. This has stimulated considerable investigation into how this largest orogenic belt was formed and when the Tibetan plateau was uplifted (Tapponnier et al., 2001; Harrison et al., 1992; Turner et al., 1993; Chung et al., 1998; Yin and Harrison, 2000). Accompanied by the deformation and uplift, plutonism and volcanism occurred in the interior of the plateau, providing opportunities to characterize the magmatic response during the evolution of the Tibetan Plateau (e.g., Chung et al., 2005). Dating

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Table 1
Zircon U–Pb isotopic data of the Gaoligong–Tengliang–Yingjiang batholiths.

Spot No.	$f^{206}Pb^*$	U (ppm)	Th (ppm)	$^{232}Th/^{238}U$	$^{207}Pb/^{206}Pb$	±% (1σ)	$^{207}Pb/^{235}U$	±% (1σ)	$^{206}Pb/^{238}U$ (1σ)	±% (Ma)	$^{206}Pb/^{238}U$ (Ma)	Age
SHRIMP												
GLS-36 (98°35′07″E, 27°45′32″N)												
1.1	3.64	269	235	0.90	0.04100	34	0.1040	35	0.01827	4.4	116.7	±5.1
2.1	2.15	272	185	0.70	0.04420	12	0.1240	14	0.02030	6.5	129.7	±8.4
3.1	1.94	614	527	0.89	0.04340	11	0.1110	12	0.01852	3.8	118.3	±4.5
4.1	0.34	678	412	0.63	0.05140	4.9	0.1309	6.2	0.01846	3.8	117.9	±4.4
5.1	0.53	846	711	0.87	0.04930	4.1	0.1321	5.6	0.01942	3.8	124.0	±4.6
6.1	0.79	1123	1456	1.34	0.04670	4.8	0.1287	6.1	0.01998	3.8	127.5	±4.7
7.1	1.02	477	361	0.78	0.04860	4.6	0.1329	6.1	0.01985	3.9	126.7	±4.9
8.1	2.48	245	213	0.90	0.04820	17	0.1260	17	0.01891	4.8	120.8	±5.7
9.1	1.41	458	524	1.18	0.05470	9	0.1510	9.7	0.02002	3.8	127.8	±4.9
10.1	0.59	1003	334	0.34	0.04730	4.6	0.1279	5.9	0.01962	3.7	125.2	±4.6
11.1	0.31	1695	1082	0.66	0.04860	2	0.1358	4.2	0.02026	3.7	129.3	±4.8
12.1	0.56	491	462	0.97	0.04940	4	0.1334	5.6	0.01958	3.8	125.0	±4.7
13.1	2.59	208	179	0.89	0.05560	8.8	0.1520	9.7	0.01984	4	126.7	±5.1
14.1	0.37	714	768	1.11	0.05180	3.6	0.1450	7.8	0.02020	7	129.1	±8.9
GLS-58 (98°47′19″E, 27°09′52″N)												
1.1	0.52	1216	637	0.54	0.04720	4.5	0.1601	4.7	0.02460	1.6	156.7	±2.5
2.1	0.69	902	412	0.47	0.04830	3.3	0.1278	3.7	0.01919	1.7	122.5	±2.1
3.1	0.47	1160	581	0.52	0.05010	4	0.1325	4.5	0.01919	2	122.5	±2.5
4.1	0.46	1303	743	0.59	0.04850	3.5	0.1305	3.8	0.01951	1.5	124.6	±1.9
5.1	0.11	1070	745	0.72	0.05200	2.8	0.1398	3.3	0.01951	1.6	124.6	±2.0
6.1	0.62	1202	725	0.62	0.04870	7.4	0.1280	7.6	0.01906	1.7	121.7	±2.0
7.1	1.02	816	533	0.67	0.04490	7	0.1172	7.2	0.01892	1.7	120.8	±2.0
8.1	0.60	703	438	0.64	0.05240	5.1	0.1417	5.3	0.01961	1.6	125.2	±2.0
9.1	0.88	784	465	0.61	0.04840	6.3	0.1228	6.5	0.01840	1.8	117.5	±2.1
10.1	1.26	862	405	0.49	0.04550	5.8	0.1175	6	0.01873	1.6	119.6	±1.9
11.1	0.26	1117	587	0.54	0.04970	4	0.1321	4.3	0.01929	1.5	123.2	±1.9
12.1	0.62	1169	504	0.45	0.04470	8	0.1202	8.1	0.01951	1.5	124.6	±1.9
13.1	0.41	974	598	0.63	0.05120	3.4	0.1359	3.7	0.01924	1.5	122.8	±1.9
14.1	0.98	1391	902	0.67	0.04600	6.3	0.1219	6.5	0.01924	1.5	122.9	±1.9
15.1	1.30	803	458	0.59	0.04750	5.9	0.1201	6.1	0.01832	1.7	117.0	±2.0
GLS-62 (98°49′37″E, 27°08′01″N)												
1.1	0.67	1524	901	0.61	0.04670	4.3	0.1181	4.6	0.01832	1.6	117.1	±1.8
2.1	0.10	4538	945	0.22	0.04757	1.3	0.1241	3	0.01892	2.7	120.9	±3.3
3.1	0.23	2167	754	0.36	0.04800	2.5	0.1307	2.9	0.01976	1.5	126.2	±1.8
4.1	0.47	657	404	0.64	0.04880	3.7	0.1224	4	0.01818	1.6	116.1	±1.9
5.1	0.58	1523	1051	0.71	0.04980	4.8	0.1250	5	0.01819	1.6	116.2	±1.8
6.1	0.61	2236	851	0.39	0.04750	3.9	0.1405	4.2	0.02144	1.5	136.8	±2.0
7.1	0.39	1314	658	0.52	0.04700	3	0.1264	3.4	0.01953	1.6	124.7	±1.9
8.1	0.92	989	639	0.67	0.04970	9.4	0.1170	9.8	0.01705	2.5	109.0	±2.7
9.1	0.30	2581	778	0.31	0.04720	3.6	0.1363	3.9	0.02095	1.5	133.6	±2.0
10.1	0.16	3381	2326	0.71	0.04847	1.8	0.1157	2.5	0.01731	1.7	110.7	±1.9
11.1	0.42	1326	758	0.59	0.04760	3.8	0.1217	4.2	0.01853	1.9	118.4	±2.2
12.1	0.17	1355	571	0.44	0.04970	3.3	0.1459	3.7	0.02130	1.6	135.9	±2.2
13.1	0.41	1435	843	0.61	0.04910	3.5	0.1259	3.8	0.01859	1.5	118.7	±1.8
14.1	0.14	3406	2144	0.65	0.04980	2.2	0.1362	4.5	0.01985	3.9	126.7	±4.9
15.1	0.45	1419	622	0.45	0.04450	6	0.1079	6.2	0.01757	1.6	112.3	±1.8
16.1	0.20	3150	1710	0.56	0.04879	1.9	0.1288	2.3	0.01915	1.4	122.3	±1.7
17.1	0.32	2804	1492	0.55	0.04870	2.4	0.1295	2.8	0.01926	1.4	123.0	±1.7
18.1	0.62	1684	796	0.49	0.04980	3.6	0.1265	3.9	0.01843	1.5	117.8	±1.7
GSL-38 (98°35′07″E, 27°45′32″N)												
1.1	0.52	1262	559	0.46	0.05140	4.7	0.1438	5.5	0.02029	2.9	129.5	±3.7
2.1	0.81	1262	423	0.35	0.04700	5.4	0.0694	6	0.01071	2.5	68.7	±1.7
3.1	1.84	521	631	1.25	0.04230	11	0.1100	12	0.01883	2.5	120.2	±3.0
4.1	0.84	384	509	1.37	0.04590	6	0.1215	6.6	0.01920	2.6	122.6	±3.2
5.1	0.94	672	630	0.97	0.04480	9.8	0.1190	11	0.01926	3.8	123.0	±4.7
6.1	2.58	505	544	1.11	0.03850	15	0.1060	16	0.01990	6	127.3	±7.6
7.1	0.97	703	1089	1.60	0.04880	7.3	0.1360	7.7	0.02016	2.5	128.7	±3.2
8.1	0.66	1060	1138	1.11	0.04640	4.6	0.1297	5.2	0.02026	2.4	129.3	±3.1
9.1	2.15	484	527	1.13	0.04040	13	0.1100	13	0.01974	2.6	126.0	±3.2
10.1	0.54	632	535	0.87	0.04380	5.3	0.1192	5.9	0.01974	2.5	126.0	±3.1
11.1	1.72	360	395	1.13	0.04020	14	0.1110	15	0.02001	2.7	127.7	±3.5
12.1	1.09	339	343	1.04	0.06440	5.3	0.1625	6	0.01831	2.7	117.0	±3.1
13.1	2.20	188	197	1.08	0.06440	12	0.1730	12	0.01944	2.9	124.1	±3.5
14.1	5.81	343	364	1.10	0.02100	49	0.0540	49	0.01814	3.1	115.9	±3.5
15.1	0.00	177	167	0.98	0.06080	6.1	0.1630	6.7	0.01940	2.8	123.9	±3.5
16.1	0.46	934	780	0.86	0.04870	4.3	0.1459	4.9	0.02172	2.4	138.5	±3.3
GLS-53 (98°42′48″E, 27°12′11″N)												
1.1	1.12	2185	1200	0.57	0.04490	5.6	0.0782	6.8	0.01263	3.7	80.9	±3.0
2.1	1.29	821	413	0.52	0.05230	3.8	0.0856	7.8	0.01187	6.8	76.1	±5.1
3.1	3.00	555	378	0.70	0.04560	18	0.0680	19	0.01077	5.8	69.1	±4.0