Jian Xu, Xiao-Ping Xia, Qiang Wang, Christopher J. Spencer, Chun-Kit Lai, and Le Zhang, 2021, Two magma fractionation paths for continental crust growth: Insights from the adakite-like and normal-arc granites in the Ailaoshan fold belt (SW Yunnan, China): GSA Bulletin, <https://doi.org/10.1130/B36230.1>.

Supplemental Material

1. Supplemental Figures

Figure S1. Primitive mantle-normalized multi-element diagrams for hornblende diorites and cumulative diorites

Figure S2. SiO₂ versus Sr/Y (a) and La/Yb (b) plots for adakite-like rocks formed by partial melting of lower continental crust, showing no binary correlations

Figure S3. FeOT versus TiO₂ plot for the mantle-derived hornblende diorites and associated fractionates, which shows intensive Fe-Ti oxides fractionation

2. Supplemental Tables

Table S1. Major (wt%) and trace element (ppm) and Sr-Nd isotope data for the Group 1 adakite-like and Group 2 normal arc granites

Table S2. SIMS U-Pb data for the Group 1 adakite-like and Group 2 normal arc granites

Table S3. In situ zircon Hf-O isotope data for the Group 1 adakite-like and Group 2 normal arc granites

Table S4. Partition coefficients used in fractionation crystallization modeling as shown in Figures 4, 5 and 11

Figure S1. Primitive mantle-normalized multi-element diagrams for hornblende diorites (Xu et al., 2020) and cumulative diorites (Guo et al., 2016). Upper and lower continental crust are from Rudnick and Gao (2003). This plot show that the hornblende diorites have higher concentrations of LILEs and other strongly incompatible elements (e.g., Rb, Ba, Th and U) than the average lower continental crust (LCC), distinct from the cumulative diorites. Moreover, from this plot, we found 5% crustal assimilation has limited influence on the trace element compositions of the parental magma (i.e., hornblende diorite) of Group 1 adakitic granites.

Figure S2. SiO_2 versus Sr/Y (a) and La/Yb (b) plots for adakite-like rocks formed by partial melting of lower continental crust, showing no binary correlations. Data are compiled from Wang et al. (2005), Wang et al. (2007), Wen et al. (2008), He et al. (2011), Lu et al. (2013), and Ou et al. (2017). Similar color symbols represent samples from individual intrusions.

Figure S3. FeO^T versus TiO_2 plot for the mantle-derived hornblende diorites and associated fractionates, which shows intensive Fe-Ti oxides fractionation. Hornblende diorites and granodiorites are from Xu et al. (2020).

2. SUPPLEMENTAL TABLES

Table S1. Major (wt%) and trace element (ppm) and Sr-Nd isotope data for the Group 1 adakite-like and Group 2 normal arc granites.

Sample	XD39-2	17DL-25C	17DL-25D	17DL-25F	17DL-25H	17DL-25J	17DL-25A	17DL-25B	17DL-25G	17DL-25I	17DL-25K	17DL-25L	17DL-25M	BHVO-2	17DL-25K
	Group 1	Group 1	Group 1	Group 1	Group 1	Group 1	Group 2	Group 2	Group 2	Group 2	Group 2	Group 2	Group 2	Standard	Duplicate
Latitude	24°52.8' N						24°52.85'N								
Longitude	100°47.3' E						100°47. 86'E								
SiO ₂	69.02	66.87	72.44	70.99	72.50	73.75	73.75	72.75	74.01	76.53	76.73	75.95	72.57	49.72	
TiO ₂	0.44	0.53	0.26	0.27	0.19	0.15	0.21	0.22	0.25	0.12	0.12	0.12	0.35	2.76	
Al ₂ O ₃	16.63	16.70	15.28	15.91	15.93	15.26	13.93	14.25	14.30	12.56	12.42	12.53	14.27	13.44	
Fe ₂ O ₃ ^T	2.40	3.24	1.42	1.98	1.30	1.15	3.01	2.98	2.28	2.03	2.11	2.68	2.99	12.40	
MnO	0.06	0.07	0.04	0.08	0.04	0.04	0.08	0.09	0.07	0.07	0.05	0.07	0.07	0.17	
MgO	0.98	1.09	0.48	0.48	0.28	0.19	0.35	0.32	0.49	0.06	0.05	0.07	0.83	7.23	
CaO	2.26	1.68	1.08	1.18	0.68	0.44	0.88	0.83	1.81	0.28	0.34	0.25	1.66	11.24	
Na ₂ O	4.64	4.16	4.15	4.24	4.72	5.44	5.82	5.03	4.29	4.51	4.49	4.57	4.33	2.22	
K ₂ O	3.40	5.42	4.76	4.79	4.31	3.52	1.93	3.51	2.44	3.82	3.67	3.72	2.84	0.52	
P ₂ O ₅	0.17	0.24	0.09	0.09	0.06	0.06	0.05	0.03	0.06	0.02	0.01	0.01	0.10	0.27	
LOI	0.49	0.76	0.28	0.72	0.40	0.28	0.28	0.40	0.50	0.18	0.06	0.20	0.38	0.00	
A/CNK	1.08	1.06	1.10	1.11	1.17	1.13	1.05	1.05	1.10	1.04	1.04	1.04	1.08		
Ti	2589	2956	1511	1418	1051	734	1084	1114	1228	538	733	379	2002		
V	39	40	14	15	17	8	6	4	19	2	3	2	24	319	2
Cr	59	42	20	56	30	45	45	18	18	22	13	37	15	285	12
Co	4.9	6.0	2.2	2.7	1.8	1.5	1.7	1.5	3.4	0.7	0.6	0.8	3.7	45.2	0.6
Ni	4	16	7	8	7	7	7	1	3	3	1	6	2	123	1
Rb	87.3	185.5	172.9	167.0	137.7	111.9	60.4	90.7	75.3	92.6	91.0	65.1	85.9	69.1	92.3
Sr	639.5	974.7	672.2	700.8	571.1	492.4	64.4	61.5	218.9	21.8	32.9	16.0	194.2	658.5	32.8
Y	7.2	15.9	4.0	4.2	3.1	3.7	28.3	41.3	22.9	25.2	39.5	30.9	22.4	19.9	40.6
Zr	162	260	131	123	114	100	198	255	114	207	289	216	80	232	240
Nb	3.2	8.1	3.8	3.7	2.4	1.9	10.7	11.9	5.5	14.3	14.2	9.1	5.6	14.5	14.1
Cs	1.63	5.13	2.07	2.16	1.32	1.29	3.15	2.68	1.79	0.67	0.78	0.61	6.34	1.17	0.92
Ba	998	1335	851	860	820	651	337	604	267	387	402	247	372	1134	411
La	36.22	52.89	29.89	26.64	19.77	24.79	34.46	37.81	22.59	18.20	44.61	27.82	24.53	38.67	46.3
Ce	67.14	99.04	52.41	47.26	38.34	45.27	72.88	79.37	42.37	37.87	70.20	60.86	46.81	69.69	69.0
Pr	7.64	11.43	5.75	5.05	4.21	5.06	9.18	9.92	4.84	4.82	11.37	7.94	5.70	8.14	11.9
Nd	26.53	40.66	18.56	16.59	14.13	16.23	35.99	37.83	17.21	18.26	46.08	31.04	21.15	30.98	46.1
Sm	3.66	6.35	2.45	2.17	2.18	2.03	7.05	8.00	3.42	3.69	9.28	6.53	4.13	5.67	9.27

Eu	0.86	1.54	0.52	0.50	0.47	0.38	1.02	1.10	0.60	0.26	0.63	0.49	0.79	1.57	0.64
Gd	2.76	4.74	1.65	1.51	1.36	1.24	6.06	7.36	3.31	3.29	7.86	5.56	3.78	4.43	7.97
Tb	0.27	0.58	0.17	0.17	0.15	0.13	0.93	1.24	0.57	0.58	1.17	0.92	0.59	0.63	1.28
Dy	1.30	2.88	0.77	0.77	0.67	0.67	5.26	7.19	3.54	4.08	6.98	5.57	3.57	3.58	7.16
Ho	0.24	0.52	0.14	0.14	0.11	0.13	1.06	1.48	0.76	1.00	1.46	1.17	0.75	0.70	1.41
Er	0.63	1.40	0.36	0.37	0.28	0.33	3.00	4.24	2.25	3.35	4.34	3.56	2.23	1.84	4.50
Tm	0.10	0.18	0.05	0.05	0.04	0.05	0.46	0.66	0.37	0.62	0.74	0.60	0.35	0.26	0.73
Yb	0.63	1.13	0.33	0.34	0.26	0.33	3.15	4.43	2.57	4.40	5.76	4.41	2.42	1.71	5.78
Lu	0.10	0.17	0.05	0.06	0.04	0.05	0.53	0.71	0.41	0.72	0.90	0.73	0.39	0.25	0.89
Hf	4.09	6.56	3.46	3.34	3.28	3.28	5.66	6.87	3.66	6.82	8.78	7.03	2.50	5.26	7.49
Ta	0.16	0.32	0.20	0.19	0.17	0.09	0.58	0.72	0.73	0.84	0.98	0.62	0.47	0.87	0.93
Pb	8.90	17.78	15.04	16.58	15.09	15.00	5.11	4.88	6.08	7.37	9.06	8.24	9.32	13.49	9.16
Th	13.10	19.89	16.29	15.33	12.41	26.72	9.00	9.22	15.71	10.74	12.77	8.85	11.54	6.36	12.8
U	1.99	2.92	1.89	1.85	1.64	2.51	2.21	2.83	4.54	2.24	3.70	2.44	3.69	1.95	3.39
Eu/Eu*	0.83	0.86	0.78	0.85	0.83	0.74	0.48	0.44	0.55	0.22	0.22	0.25	0.61		
Sr/Y	88	61	167	165	183	133	2	1	10	1	1	1	9		
La/Yb	58	47	90	78	77	75	11	9	9	4	8	6	10		
⁸⁷ Sr/ ⁸⁶ Sr	0.706044	0.706172	0.706000	0.706003	0.706358	0.706412	0.711130						0.709134		
2σ	0.000009	0.000008	0.000007	0.000008	0.000007	0.000008	0.000007						0.000007		
(⁸⁷ Sr/ ⁸⁶ Sr) _i	0.704713	0.704316	0.703492	0.703679	0.704006	0.704196	0.701972						0.704819		
¹⁴³ Nd/ ¹⁴⁴ Nd	0.512516	0.512594	0.512593	0.512601	0.512512	0.512548	0.512712	0.512722		0.512720		0.512729	0.512731		
2σ	0.000005	0.000006	0.000005	0.000005	0.000006	0.000004	0.000005	0.000006		0.000004		0.000005	0.000005		
(¹⁴³ Nd/ ¹⁴⁴ Nd) _i	0.512385	0.512446	0.512469	0.512478	0.512366	0.512430	0.512527	0.512522		0.512529		0.512530	0.512547		
εNd(t)	1.03	2.21	2.65	2.83	0.65	1.89	3.78	3.69		3.83		3.85	4.18		

Table S2. SIMS U-Pb data for the Group 1 adakite-like and Group 2 normal arc granites.

Analysis	Th/U	Isotopic ratios						Isotopic ages (Ma)					
		$^{207}\text{Pb}/^{206}\text{Pb}$	$\pm 1\sigma(\%)$	$^{207}\text{Pb}/^{235}\text{U}$	$\pm 1\sigma(\%)$	$^{206}\text{Pb}/^{238}\text{U}$	$\pm 1\sigma(\%)$	$^{207}\text{Pb}/^{206}\text{Pb}$	$\pm 1\sigma$	$^{207}\text{Pb}/^{235}\text{U}$	$\pm 1\sigma$	$^{206}\text{Pb}/^{238}\text{U}$	$\pm 1\sigma$
XD39-2 (Group 1 adakite-like granite)													
XD39-2@01	0.55	0.05133	1.03	0.27244	1.84	0.0385	1.53	256	24	245	4	243	4
XD39-2@02	0.64	0.05119	0.62	0.26703	1.63	0.0378	1.51	249	14	240	3	239	4
XD39-2@04	0.74	0.05062	1.31	0.26910	2.03	0.0386	1.54	223	30	242	4	244	4
XD39-2@05	0.67	0.05024	0.95	0.26318	1.78	0.0380	1.50	206	22	237	4	240	4
XD39-2@07	0.73	0.05099	1.48	0.24800	2.14	0.0353	1.55	240	34	225	4	223	3
XD39-2@08	0.81	0.05075	1.60	0.26717	2.22	0.0382	1.53	230	37	240	5	242	4
XD39-2@10	0.61	0.05101	0.66	0.25628	1.71	0.0364	1.58	241	15	232	4	231	4
XD39-2@11	0.58	0.05107	1.16	0.25598	1.90	0.0364	1.50	244	27	231	4	230	3
XD39-2@12	0.94	0.05137	0.94	0.26880	1.77	0.0379	1.50	258	21	242	4	240	4
XD39-2@13	0.73	0.05139	0.90	0.26995	1.76	0.0381	1.51	259	20	243	4	241	4
XD39-2@14	0.58	0.05072	1.06	0.26124	1.87	0.0374	1.55	228	24	236	4	236	4
XD39-2@15	0.73	0.04995	1.68	0.25524	2.26	0.0371	1.51	193	39	231	5	235	3
XD39-2@17	0.59	0.05112	1.25	0.25933	1.97	0.0368	1.53	246	29	234	4	233	3
XD39-2@20	0.62	0.05033	1.90	0.25989	2.48	0.0375	1.59	210	43	235	5	237	4
17DL-25B (Group 2 normal arc granite)													
17DL-25B@1	0.52	0.05246	1.04	0.26366	1.83	0.03645	1.51	305	24	238	4	231	3
17DL-25B@02	0.59	0.05153	1.34	0.27522	2.08	0.03874	1.59	265	31	247	5	245	4
17DL-25B@03	0.64	0.05080	1.13	0.25458	2.00	0.03634	1.65	232	26	230	4	230	4
17DL-25B@04	0.58	0.05113	1.03	0.26835	1.82	0.03807	1.50	246	23	241	4	241	4
17DL-25B@05	0.56	0.05088	1.01	0.26112	1.97	0.03722	1.70	235	23	236	4	236	4
17DL-25B@06	0.61	0.05128	1.35	0.26201	2.15	0.03706	1.67	254	31	236	5	235	4
17DL-25B@09	0.63	0.05072	1.32	0.25709	2.00	0.03676	1.51	228	30	232	4	233	3
17DL-25B@10	0.57	0.05114	1.77	0.26398	2.33	0.03744	1.52	247	40	238	5	237	4
17DL-25B@11	0.60	0.05124	1.10	0.26314	2.05	0.03725	1.73	252	25	237	4	236	4
17DL-25B@12	0.58	0.05118	0.98	0.26258	1.86	0.03721	1.59	249	22	237	4	236	4
17DL-25B@13	0.63	0.05169	1.62	0.26537	2.24	0.03724	1.55	272	37	239	5	236	4
17DL-25B@14	0.49	0.05149	1.09	0.25890	1.87	0.03646	1.53	263	25	234	4	231	3
17DL-25B@15	0.83	0.05136	0.87	0.26726	1.75	0.03774	1.52	257	20	240	4	239	4
17DL-25B@16	0.93	0.04982	0.77	0.26054	1.86	0.03793	1.70	187	18	235	4	240	4
17DL-25B@17	0.42	0.05189	1.84	0.26512	2.65	0.03706	1.90	280	42	239	6	235	4
17DL-25B@18	0.63	0.05105	1.02	0.26531	2.11	0.03770	1.85	243	23	239	5	239	4

17DL-25B@19	0.56	0.05129	1.23	0.26998	2.02	0.03818	1.61	254	28	243	4	242	4
17DL-25B@21	0.66	0.05000	1.17	0.26354	1.93	0.03823	1.53	195	27	238	4	242	4
17DL-25B@22	0.84	0.05015	1.69	0.25877	2.37	0.03742	1.67	202	39	234	5	237	4
17DL-25B@23	0.56	0.05197	1.22	0.26389	1.94	0.03683	1.51	284	28	238	4	233	3

Table S3. In situ zircon Hf-O isotope data for the Group 1 adakite-like and Group 2 normal arc granites.

Sample	t (Ma)	$^{176}\text{Yb}/^{177}\text{Hf}$	$^{176}\text{Lu}/^{177}\text{Hf}$	$^{176}\text{Hf}/^{177}\text{Hf}$	$2\sigma_m$	$\varepsilon_{\text{Hf}}(t)$	T_{DM1}	T_{DM2}	$f_{\text{Lu/Hf}}$	$\delta^{18}\text{O} (\text{‰})$	$2\sigma_m$
XD39-2											
XD39-2-01	243	0.110633	0.002390	0.283011	0.000008	13.4	354	380	-0.93	6.3	0.23
XD39-2-02	239	0.108857	0.002319	0.283100	0.000010	16.5	222	218	-0.93	6.1	0.21
XD39-2-04	244	0.110197	0.002289	0.282979	0.000009	12.3	401	438	-0.93	6.4	0.17
XD39-2-05	240	0.105541	0.002203	0.283010	0.000009	13.3	355	382	-0.93	6.5	0.19
XD39-2-07	223	0.078634	0.001674	0.282925	0.000008	10.1	472	537	-0.95	6.0	0.21
XD39-2-08	242	0.033842	0.000605	0.282994	0.000009	13.1	362	397	-0.98	6.3	0.22
XD39-2-10	231	0.120214	0.002534	0.283039	0.000009	14.1	314	333	-0.92	6.0	0.13
XD39-2-11	230	0.100085	0.002046	0.282986	0.000009	12.3	388	427	-0.94	6.5	0.20
XD39-2-12	240	0.142852	0.002956	0.283061	0.000008	15.0	285	294	-0.91	6.5	0.22
XD39-2-13	241	0.119589	0.002565	0.283046	0.000009	14.6	304	319	-0.92	6.7	0.24
XD39-2-14	236	0.115345	0.002340	0.283044	0.000009	14.5	305	322	-0.93	6.6	0.23
XD39-2-15	235	0.095229	0.001920	0.282929	0.000008	10.4	469	529	-0.94	6.6	0.27
XD39-2-17	233	0.068911	0.002265	0.282971	0.000013	11.8	412	455	-0.93	6.4	0.19
XD39-2-20	237	0.061305	0.001962	0.282931	0.000014	10.5	467	525	-0.94	6.0	0.21
17DL-25B											
17DL-25B-01		0.136356313	0.002726	0.283105	0.000010	16.6	217	213	-0.92	6.0	0.21
17DL-25B-02		0.254058664	0.005041	0.283082	0.000012	15.4	269	273	-0.85	6.0	0.20
17DL-25B-03		0.195627077	0.003896	0.283098	0.000010	16.1	236	236	-0.88	6.2	0.17
17DL-25B-04		0.16967025	0.003403	0.283090	0.000010	15.9	245	246	-0.90	5.9	0.17
17DL-25B-05		0.162253387	0.003290	0.283063	0.000011	15.0	285	295	-0.90	6.0	0.20
17DL-25B-06		0.179210805	0.003593	0.283115	0.000010	16.8	207	201	-0.89	5.8	0.20
17DL-25B-08		0.069258586	0.001437	0.283053	0.000008	14.9	285	298	-0.96	5.1	0.16
17DL-25B-10		0.223004218	0.004195	0.283124	0.000011	17.0	196	189	-0.87	6.1	0.22
17DL-25B-11		0.227233087	0.004334	0.283082	0.000012	15.5	263	268	-0.87	5.8	0.17
17DL-25B-12		0.126908808	0.002528	0.283021	0.000010	13.6	342	366	-0.92	6.2	0.18
17DL-25B-13		0.226468843	0.004298	0.283104	0.000010	16.3	229	228	-0.87	6.1	0.16
17DL-25B-14		0.17514755	0.003391	0.283135	0.000010	17.5	176	163	-0.90	6.0	0.23
17DL-25B-15		0.201432862	0.003880	0.283087	0.000011	15.7	252	255	-0.88	5.2	0.20
17DL-25B-16		0.14801209	0.002863	0.283073	0.000010	15.4	266	272	-0.91	5.6	0.21
17DL-25B-17		0.154893822	0.002932	0.283108	0.000010	16.6	214	209	-0.91	5.8	0.17
17DL-25B-18		0.12550399	0.002456	0.283088	0.000011	16.0	241	243	-0.93	5.3	0.21
17DL-25B-19		0.157577019	0.003002	0.283150	0.000011	18.1	152	133	-0.91	6.0	0.20
17DL-25B-20		0.13458055	0.002578	0.283080	0.000010	15.7	253	257	-0.92	5.8	0.14

17DL-25B-21	0.152880647	0.002853	0.283064	0.000011	15.1	280	289	-0.91	5.9	0.23
17DL-25B-22	0.253426736	0.004716	0.283091	0.000011	15.7	252	255	-0.86	5.8	0.17
17DL-25B-23	0.116878107	0.002274	0.283075	0.000008	15.6	259	264	-0.93	5.6	0.22
17DL-25B-24	0.130592259	0.002543	0.283084	0.000010	15.8	247	249	-0.92	5.3	0.22
17DL-25B-25	0.073930556	0.001501	0.283017	0.000008	13.6	338	365	-0.95	5.7	0.22

Table S4. Partition coefficients used in fractionation crystallization modelling as shown in Figures 5, 11 and 12.

End-member component (ppm)/partition coefficient ¹	Sr	Rb	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Y
Initial compositions	432	43	285	12.51	28.78	4.00	17.99	4.42	1.30	4.46	0.74	4.57	0.98	2.72	0.42	2.71	0.42	27.15
Partition coefficient (cpx/melt)	0.5	0.0324	0.1	0.07	0.098	0.15	0.21	0.26	0.31	0.3	0.315	0.33	0.33	0.3	1.09	0.28	0.27	0.3
Partition coefficient (opx/melt)	0.01	0.01	0.0036	0.002	0.003	0.003	0.0068	0.01	0.01	0.016	0.019	0.02	0.1	0.03	--	0.049	0.058	0.03
Partition coefficient (grt/melt)	0.003	0.0007	0.0007	0.04	0.08	0.054	0.2	1	0.98	3.8	7.5	11	--	16	--	21	21	16
Partition coefficient (amp/melt)	0.6	0.18	0.28	0.2	0.3	--	0.8	1.1	1.5	1.8	2	2	--	1.9	--	1.7	1.5	1.9
Partition coefficient (pl/melt)	2.87	0.24	1.05	0.3	0.2	0.17	0.028	0.14	2.15	0.129	0.013	0.06	0.048	0.02	0.036	0.077	0.062	0.2
Partition coefficient (kf/melt)	3.87	0.4	6.12	0.129	--	0.87	0.025	0.03	9.06	0.011	0.018	0.97	0.022	0.16	--	0.015	0.012	--
Partition coefficient (ap/melt)	2.1	--	--	8	16	--	32.8	46	44	43.9	30	34.8	13.3	22.7	--	15.4	13.8	--
Partition coefficient (alla/melt)	--	--	--	960	940	--	750	630	590	370	270	200		100	--	54	41	30
Partition coefficient (mag/melt)	--	--	--	0.015	0.016	--	0.026	0.024	0.025	0.018	0.019	0.3	0.017	--	--	0.018	0.023	--

1-Partition coefficients are from the GERM Partition Coefficient (Kd) Database (<https://earthref.org/KDD/>). The Kd values are chosen based on fractional mineral assemblages at different fractional steps. Kd values of clinopyroxene (cpx), orthopyroxene (opx), amphibole (amp), plagioclase (pl), garnet (grt) and magnetite (mag) are chosen for basalt, while K-feldspar (kf), apatite (ap), and allanite (alla) are chosen for dacite-granite. Since early stage (step 1-2) of mineral assemblages fractionation mainly happens in the basaltic melt. And as fractionation undergoes, the melts would evolve to be more felsic. Thus, late stage (step 3) fractionation of Kf, Ap and Alla is likely to occur in dacitic and granitic melts

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