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福建北部近岸东台山岛火山岩形成时代、地球化学与古太平洋板块俯冲的响应

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提要:福建北部沿岸岛屿岩石组合以晚中生代火成岩为主,研究认为是古太平洋俯冲消减的产物,对反演洋盆构造演化具有重要的指示意义。本次对其中的福建北部海域东台山岛上广泛发育的酸性火山岩进行了锆石U−Pb定年以及全岩主微量地球化学分析工作。2件年代学样品分别获得了92 Ma和86 Ma的锆石U−Pb年龄,确定东台山岛火山岩形成于晚白垩世。全岩地球化学特征指示火山岩样品以酸性钙碱性岩石为主,整体富集Rb、Ba等元素,亏损Nb、Ta、Sr、Eu等元素,显示弧型岩浆岩的地球化学组成。研究认为东台山岛火山岩起源于古老下地壳变沉积岩熔融,并在浅层岩浆房内经历了不同程度的结晶分异过程。结合区域上晚中生代岩浆作用由陆向海的时空迁移特征,福建北部沿岸岛屿火山岩形成的深部动力学机制应该与古太平洋俯冲过程中的板片回转过程相关。

关 键 词:晚白垩世;高硅流纹岩;锆石U−Pb定年;地球化学;海洋地质调查工程;东台山岛;福建

中图分类号:P588.1;P597;P595 **文献标志码**:A **文章编号**:1000−3657(2020)05−1426−12

The age and geochemistry of volcanic rocks of Dongtaishan Island in northern Fujian and their response to the subduction of the Paleo-Pacific Plate

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Abstract: Coastal islands of northern Fujian are mainly composed of volcanic rocks, which were produced by the paleo−Pacific oceanic subduction. These volcanic rocks provide critical information about the geodynamic evolution of paleo−Pacific Ocean. In this paper, the authors report new zircon U−Pb ages and whole−rock major and trace element geochemistry of the felsic rocks from the Dongtaishan Island of northern Fujian. Two geochronological samples yielded zircon ages of ~92 Ma and ~84 Ma, indicating that the volcanic rocks in Dongtaishan Island were formed in Late Cretaceous. Geochemically, all these felsic samples are calc−

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alkaline, enriched in Rb, Ba, and depleted in Nb, Ta, Sr and Eu, suggesting a geochemical affinity with arc volcanic rocks. It is thus concluded that these volcanic rocks were derived by partial melting of ancient crustal metasedimentary sources and followed by fractional crystallization in the shallow magma chamber. These new data, combined with the oceanward migration of late Mesozoic magmatic activity, have led the authors to propose that the coastal islands of northern Fujian were triggered by the slab rollback during oceanic subduction of paleo−Pacific Ocean.

Keywords: Late Cretaceous; high silica rhyolite; Zircon U− Pb dating; geochemistry; marine geological survey engineering；Dongtaishan Island; Fujian Province

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1　引　言

中国东南沿海地区在晚中生代爆发了规模巨大的岩浆活动，在中国东南沿海诸省形成了近北东向展布的火山−侵入岩，同时该期岩浆活动同时伴生着大规模的金属钨锡钼铋和铜铅锌等成矿作用，构成了世界罕见的岩浆−成矿区（陶奎元等, 1999；Wang et al., 2012；舒良树, 2012；阳杰华等, 2017）。前人已经对该期岩浆作用进行了大量的研究工作，相继报道了大量的年代学、地球化学以及同位素的研究资料，在岩石成因、成岩动力学机制等方面的研究均取得了重要进展（Li et al., 2007；Liu et al., 2012；Wang et al., 2012；赵希林等, 2012；王小雨等, 2016；Pan et al., 2018；Zhang et al., 2018；宋传中等, 2019）。早期的研究对于晚中生代岩浆作用的深部动力学机制存在不同的认识（Jahn et al., 1990；Gilder et al., 1996；谢窦克等, 1997；Hsü et al., 1988；Ling et al., 2009；孙卫东等, 2010；Li et al., 2012），近年来，依靠大量年代学、地球化学与同位素资料，沿海地区晚中生代岩浆岩时空变异格架已经逐渐清晰，越来越多的学者支持古太平洋俯冲消减、玄武质岩浆底侵和地壳重熔的成岩模式来解释东南沿海地区晚中生代岩浆岩的成因（Li et al., 2007, 2019；毛建仁等, 2014；Pan et al., 2018；Zhang et al., 2018；Suo et al., 2019）。

以往的研究主要集中在交通便利的沿海陆域地区，而在陆地之外的近岸海域，还出露着数量众多的近岸岛屿。这些岛屿整体沿海岸线展布，发育于大陆架之上。近年来开展的海洋区域地质调查表明这些岛屿岩石多由火山−侵入岩组成，指示岛屿早期的形成与演化应该与火山岩浆活动事件相关。然而受客观条件的影响，岛屿岩石样品往往较难获得，整体研究程度较低，其形成时代、岩石成因以及成岩地球动力学机制等问题尚不明确，制约了对中国东南地区构造−岩浆−成矿系统的认识。大陆架作为大陆板块在海域的延伸，其上发育的海岛岩浆岩是建立中国东南沿海地区晚中生代岩浆作用时空格架的重要组成部分，查明近岸岛屿岩浆岩的形成时代与岩石成因，对于重建古太平洋俯冲消减过程、探讨中国东南海陆转换带形成与演化具有重要的指示意义，亟待进一步研究。

本文对福建北部沿岸台山列岛中的东台山岛上出露的火山岩进行岩石学、年代学以及全岩主微量地球化学的研究，同时结合浙闵地区陆域岩浆岩的研究资料，查明东台山岛火山岩的形成时代与岩石成因，进一步探讨其形成的构造背景与深部地球动力学机制，以期为古太平洋晚中生代俯冲消减过程提供新的约束。

2　地质概况

台山列岛位于福建省霞浦县三沙镇以东约50 km的海域，大地构造位置处于华南板块的东缘，该列岛由西台、东台、南船屿、南屿等多个岛屿与海礁组成，本次研究区东台山岛是台山列岛中第二大岛屿。岛屿岩石地层主要为上白垩统寨下组火山岩，在与岛屿相邻的三沙镇地区，其岩石地层组合相对复杂，主要由上侏罗统—下白垩统南园组（J_3K_1n）、下白垩统小溪组（K_1x）、黄坑组（K_1h）等火山−沉积

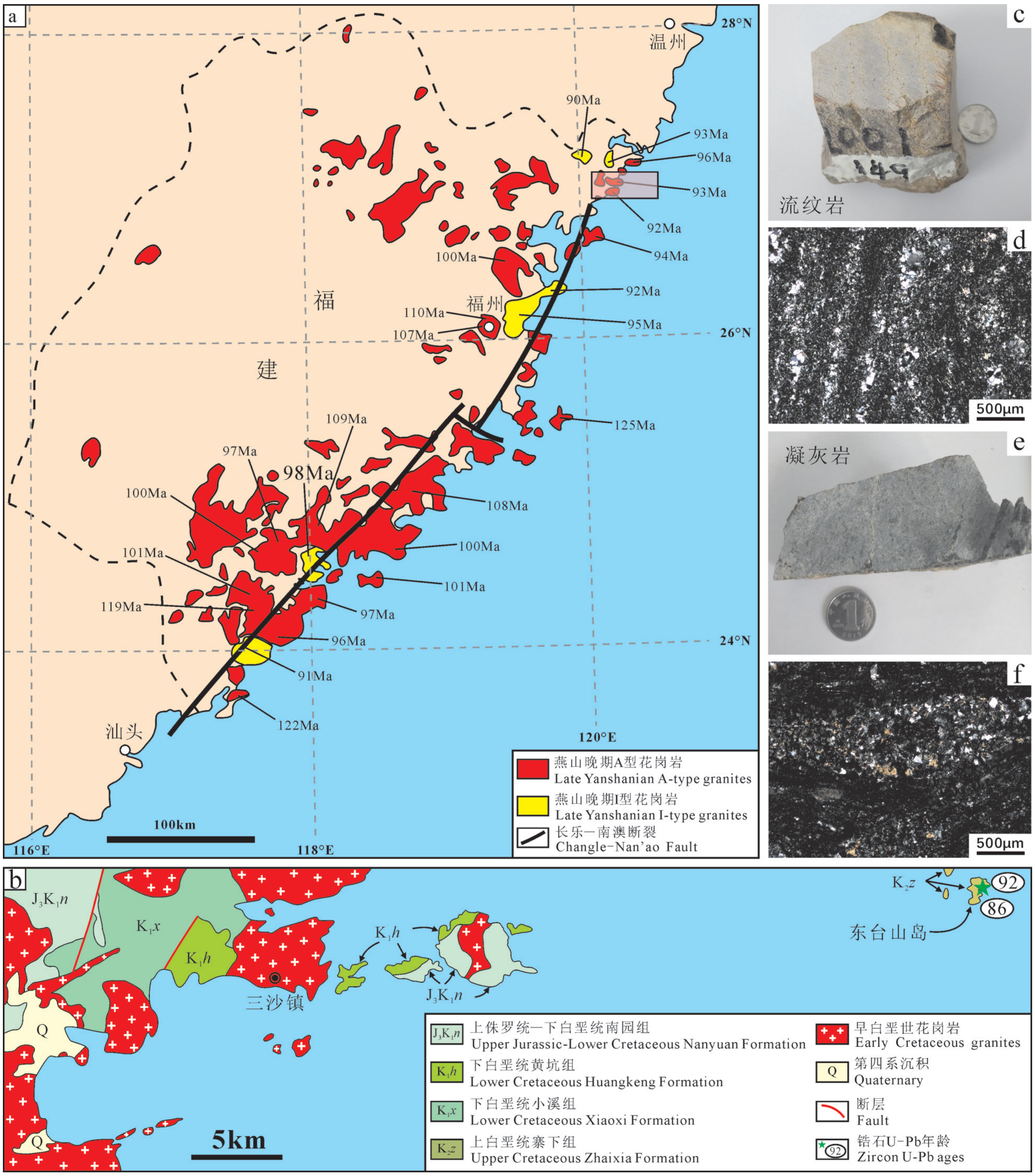

图1研究区地质简图与采样位置(a, b)、流纹岩手标本与镜下照片(c, d)和流纹质凝灰岩手标本与镜下照片(e, f)(图a据Li et al., 2014)

Fig. 1 Simplified geological map of the study area and sampling location(a, b),Field and petrographic photographs of rhyolites(c, d) and field and petrographic photographs of rhyolitic tuffs(e, f)(Fig. a after Li et al., 2014)

地层组成,此外,区域上还广泛发育早白垩世花岗岩体(图1a,b)。

东台山岛岩石岩性组合以流纹质碎屑岩为主,局部发育少量的英安岩和流纹岩。流纹岩手标本多数呈灰红色、灰紫色(图1c),具流动构造,显微镜下可见隐晶质和长石石英微晶各自组成条带相间排列构成流纹构造(图1d)。流纹质凝灰岩手标本呈灰紫色、灰色(图1e),显微镜下可见流动构造,部分样品中角砾

被拉长呈透镜状与流动方向一致(图1f)。

3 分析方法与结果

3.1 锆石U−Pb定年

锆石单矿物分离完成于河北廊坊市诚信地质服务有限公司，锆石制靶、透反射照、阴极发光(CL)图像分析及锆石U−Pb测年均在武汉上谱分析科技有限责任公司完成。激光剥蚀系统为GeolasPro，ICP−MS型号为Agilent 7700e。

本次在东台山岛采集2件锆石U−Pb定年样品(DTS−1、DTS−7)进行测年工作，测试结果见表1，代表性锆石阴极发光(CL)图像、测试点位及测试结

表1 东台山岛火山岩LA−ICP−MS锆石U−Pb定年结果

Table 1 LA−ICP−MS zircon U−Pb dating results of volcanic rocks from Dongtaishan Island

测点	元素含量/10^{-6}		Th/U	同位素比值						测年结果/Ma				谐和度
	Th	U		$^{207}Pb/^{206}Pb$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	$^{207}Pb/^{235}U$	1σ	$^{206}Pb/^{238}U$	1σ	
东台山岛寨下组流纹岩(DTS－1)														
3	15875	20198	0.79	0.0521	0.0034	0.1037	0.0058	0.0147	0.00049	100	5	94	3	93%
4	14197	18902	0.75	0.0469	0.0049	0.1073	0.0089	0.0147	0.00033	103	8	94	2	90%
6	11580	16095	0.72	0.0525	0.0040	0.1081	0.0076	0.0141	0.00025	104	7	90	2	85%
10	14867	20104	0.74	0.0499	0.0042	0.1077	0.0076	0.0149	0.00029	104	7	96	2	91%
11	21524	25299	0.85	0.0518	0.0056	0.1030	0.0111	0.0146	0.00034	100	10	94	2	93%
12	12377	18785	0.66	0.0508	0.0039	0.1094	0.0070	0.0150	0.00029	105	6	96	2	90%
14	11289	18222	0.62	0.0469	0.0044	0.1044	0.0076	0.0144	0.00034	101	7	92	2	91%
15	13946	21013	0.66	0.0478	0.0036	0.0922	0.0063	0.0139	0.00022	90	6	89	1	99%
17	12451	21028	0.59	0.0495	0.0048	0.1019	0.0082	0.0140	0.00030	99	8	89	2	90%
18*	16776	25110	0.67	0.0496	0.0020	0.1704	0.0067	0.0248	0.00027	160	6	158	2	98%
19	18020	22537	0.80	0.0525	0.0032	0.1055	0.0059	0.0144	0.00023	102	5	92	1	90%
20	10836	17627	0.61	0.0490	0.0041	0.1063	0.0070	0.0146	0.00027	103	6	93	2	90%
21*	6660	7946	0.84	0.0629	0.0027	0.5945	0.0236	0.0689	0.00091	474	15	430	5	90%
22	11966	19233	0.62	0.0466	0.0033	0.0957	0.0060	0.0145	0.00022	93	6	93	1	99%
23	13347	18378	0.73	0.0483	0.0037	0.0994	0.0070	0.0142	0.00021	96	6	91	1	94%
26*	12274	17683	0.69	0.0464	0.0054	0.0843	0.0100	0.0132	0.00019	82	9	84	1	97%
东台山岛寨下组流纹岩(DTS－7)														
1	10965	17679	0.62	0.0588	0.0043	0.1120	0.0075	0.0139	0.00027	108	7	89	2	80%
3	11462	17910	0.64	0.0418	0.0053	0.0902	0.0078	0.0138	0.00037	88	7	88	2	99%
4	12046	18705	0.64	0.0451	0.0044	0.0868	0.0080	0.0131	0.00021	85	7	84	1	99%
5*	12416	18843	0.66	0.0471	0.0055	0.0820	0.0088	0.0126	0.00023	80	8	80	1	99%
6*	37659	17602	2.14	0.0480	0.0057	0.1202	0.0136	0.0182	0.00020	115	12	116	1	99%
7	15198	19721	0.77	0.0481	0.0071	0.0915	0.0127	0.0137	0.00021	89	12	88	1	98%
9	14420	19215	0.75	0.0461	0.0057	0.0884	0.0104	0.0135	0.00020	86	10	86	1	99%
11	16171	19592	0.83	0.0476	0.0047	0.0857	0.0075	0.0132	0.00018	84	7	84	1	99%
12	12610	16821	0.75	0.0487	0.0053	0.0935	0.0086	0.0135	0.00025	91	8	87	2	95%
13	18722	23448	0.80	0.0498	0.0047	0.1024	0.0084	0.0149	0.00038	99	8	95	2	96%
14	16549	23825	0.69	0.0465	0.0035	0.0881	0.0066	0.0135	0.00017	86	6	86	1	99%
15	21529	24671	0.87	0.0544	0.0034	0.1007	0.0058	0.0138	0.00020	97	5	88	1	90%
16*	12100	9927	1.22	0.0448	0.0052	0.1124	0.0126	0.0185	0.00033	108	12	118	2	91%
17	16674	20839	0.80	0.0532	0.0033	0.0992	0.0061	0.0136	0.00021	96	6	87	1	90%
18	23244	26389	0.88	0.0509	0.0030	0.0907	0.0051	0.0133	0.00018	88	5	85	1	96%
19	20719	23323	0.89	0.0484	0.0026	0.0934	0.0045	0.0136	0.00018	91	4	87	1	96%
20	15042	21896	0.69	0.0541	0.0043	0.0999	0.0082	0.0132	0.00026	97	8	85	2	86%
21*	20055	23819	0.84	0.0488	0.0049	0.1030	0.0083	0.0144	0.00027	100	8	92	2	92%
22*	9256	16974	0.55	0.0425	0.0061	0.1011	0.0111	0.0151	0.00048	98	10	97	3	98%
26	17552	21891	0.80	0.0502	0.0036	0.0899	0.0057	0.0132	0.00022	87	5	84	1	96%
27	17571	21464	0.82	0.0540	0.0051	0.1023	0.0085	0.0140	0.00036	99	8	90	2	90%
28	21684	24181	0.90	0.0472	0.0040	0.0878	0.0068	0.0134	0.00027	85	6	86	2	99%

注：标注“＊”的测点为谐和度相对低或为捕获锆石，未参加加权平均年龄计算。

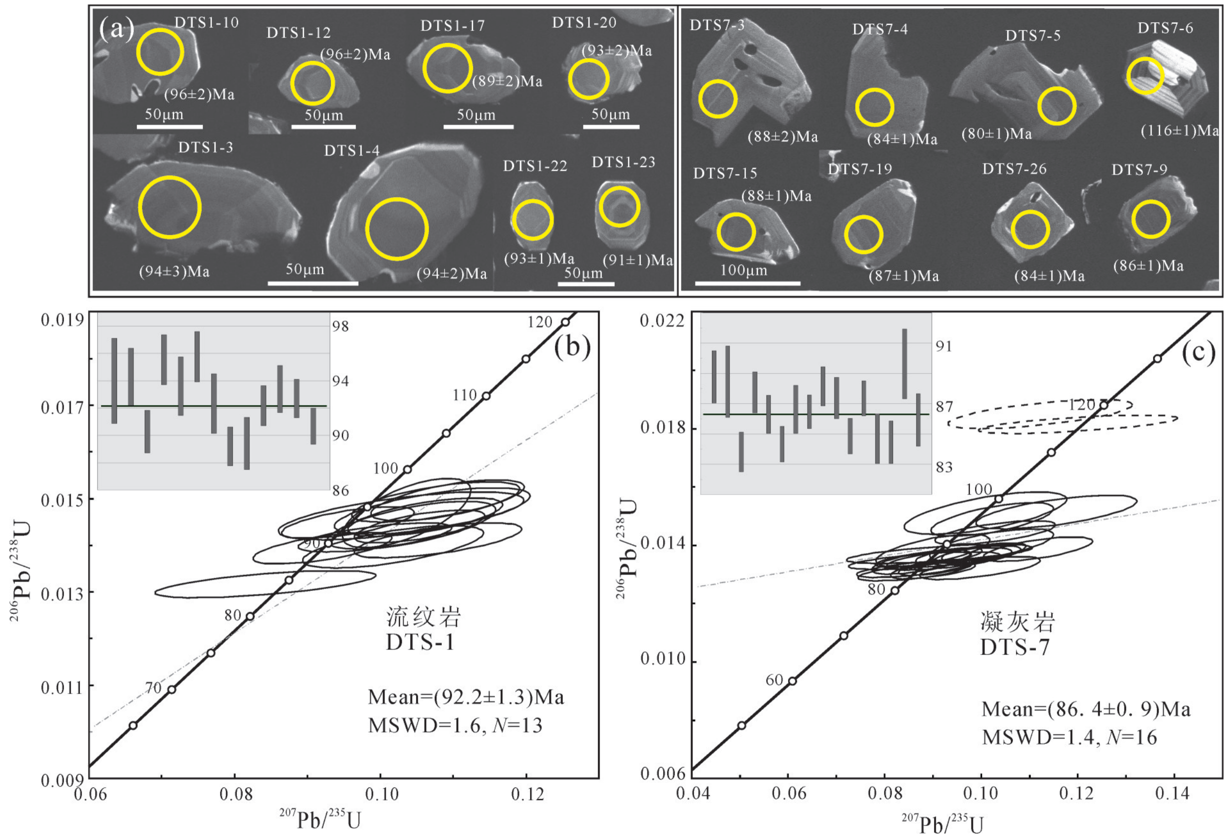

图2锆石U-Pb谐和年龄图

Fig. 2 Zircon U-Pb concordia diagrams

果见图2a。锆石多为短柱状，长宽比接近1∶1，CL图像显示岩浆成因振荡环带，锆石Th/U值分别为0.49~1.35、0.55~2.14，具有典型岩浆锆石的特征。样品DTS-1中存在年龄为(430±5)Ma及(158±2)Ma的捕获锆石，其中谐和度较好的13颗锆石获得加权平均年龄为(92.2±1.3)Ma(MSWD=1.6)(图2b)，样品DTS-7中15颗锆石测点获得加权平均年龄为(86.4±0.9)Ma(MSWD=1.4)(图2c)，2件样品测年结果均为晚白垩世早期，代表了东台山岛火山岩的形成时代。

3.2 地球化学组成

主量元素测试采用Axios荧光光谱仪在山东省第四地质矿产勘查院完成，微量及稀土元素测试采用ICP-AES及ICP-MS完成于青岛海洋地质研究所。

本次共采集5件地球化学样品进行全岩主微量元素含量分析，测试结果见表2。样品整体显示高的SiO_2(72.09%~76.03%)、全碱(Na_2O+K_2O=7.16%~9.17%)含量以及分异指数(*DI*=94~98)，低Al_2O_3(10.95%~14.06%)、MgO(0.05%~0.57%)、TiO_2(0.11%~0.36%)含量。在TAS岩石类型判别图解中(图3a)，样品落在流纹岩区域；在SiO_2-K_2O图解中(图3b)，样品落在高钾钙碱性-钾玄岩区域；在A/CNK-A/NK图解中(图3c)，样品落在过铝质区域。因此，东台山岛火山岩整体属于过铝质钙碱性系列岩石。

在球粒陨石标准化稀土配分曲线中(图4a)，样品呈轻稀土富集、重稀土亏损的右倾模式($(La/Yb)_N$=1.00~7.12)，显示不同程度的Eu负异常(Eu/Eu*=0.06~0.75)。在原始地幔标准化微量元素蛛网图中(图4b)，样品显示不同程度Rb、Th、U等元素的富集以及Ba、Sr等元素的亏损。

4 讨 论

4.1 形成时代与区域岩浆作用对比

中国东南沿海地区在晚中生代以来爆发了大规模的岩浆活动，具有分布范围广、持续时间长的特征，构成了濒太平洋地区构造-岩浆-成矿带的重要组成部分(Li and Li, 2007；毛建仁等, 2014)。近

表2 东台山岛火山岩主量元素（%）和微量元素（10^{-6}）分析结果

Table 2 Analytical results of major（%）and trace elements（10^{-6}）of volcanic rocks from Dongtaishan Island

样品	DTS－1	DTS－7	DTS－13	DTS－25	DTS－26	样品	DTS－1	DTS－7	DTS－13	DTS－25	DTS－26
SiO_2	76.03	73.99	72.61	74.01	72.09	Ga	20.62	23.71	18.18	12.17	20.74
Fe_2O_3T	3.28	7.34	3.97	2.73	3.03	Rb	280	246	207	302	253
Al_2O_3	11.61	11.06	12.88	12.89	14.06	Y	55.09	50.77	39.04	23.76	25.59
TiO_2	0.12	0.11	0.36	0.28	0.36	Mo	0.83	1.80	0.51	0.70	3.46
CaO	0.04	0.10	0.52	0.09	0.34	Cd	0.04	0.04	0.06	0.04	0.06
MgO	0.05	0.10	0.42	0.10	0.57	Cs	2.15	1.97	2.78	24.68	9.04
K_2O	6.07	4.88	4.96	6.83	5.77	La	9.00	15.79	65.51	33.43	29.66
Na_2O	1.42	2.80	3.04	2.34	1.39	Ce	24.51	46.59	114.97	32.76	52.40
MnO	0.04	0.13	0.08	0.04	0.09	Pr	2.54	4.76	14.86	7.03	6.71
P_2O_5	0.01	0.02	0.09	0.02	0.06	Nd	9.50	16.99	50.02	23.19	22.66
LOI	1.33	0.52	1.08	0.67	2.22	Sm	3.26	4.67	9.23	4.04	3.94
						Eu	0.10	0.10	0.74	0.66	0.94
Li	5.13	6.38	17.51	7.40	27.88	Gd	4.54	5.43	7.93	3.43	3.70
Be	2.69	3.68	3.76	2.22	2.43	Tb	1.11	1.23	1.22	0.58	0.61
Sc	3.18	3.49	6.74	4.94	9.02	Dy	8.35	8.56	7.07	3.79	4.00
V	1.48	4.18	32.47	7.36	19.99	Ho	1.91	1.86	1.41	0.86	0.91
Cr	8.36	19.29	15.72	5.50	4.58	Er	5.86	5.65	4.19	2.86	2.85
Co	0.87	3.36	4.47	1.42	1.59	Tm	0.96	0.89	0.64	0.48	0.46
Sr	16.4	18.9	46.6	117	117	Yb	6.43	6.02	4.22	3.37	3.17
Zr	695	669	272	295	297	Lu	0.94	0.89	0.63	0.50	0.49
Ba	61.60	11.30	319.00	1257	1191	Ta	2.82	2.62	1.69	1.11	1.05
Nb	124	112	76.0	47.	34.6	Tl	1.35	1.10	1.11	3.33	2.38
Ni	3.05	10.12	6.13	4.17	3.12	Pb	17.16	20.57	36.34	17.89	18.98
Cu	5.18	19.45	10.85	6.43	4.66	Th	26.81	23.24	18.17	16.41	13.69
Zn	77.72	96.50	72.49	26.29	83.89	U	7.02	5.23	3.87	3.20	3.00

年来，不同学者先后对晚中生代岩浆岩开展了高精度同位素年代学研究，获得了大量的年代学数据（Li and Li, 2007；邢光福等, 2009；高万里等, 2014；Liu et al., 2018；Zhang et al., 2018）。现有岩浆岩年龄数据指示中国东南沿海地区晚中生代岩浆活动具有持续时间长、多期次活动的特征，尽管不同学者对晚中生代岩浆作用的期次划分存在不同观点（Lapierre et al., 1997；Li et al., 2007；邢光福等, 2009；Wang et al., 2013；毛建仁等, 2014），但是不可否认，中国东南沿海地区晚中生代以来（J_3–K_2）岩浆岩在空间上具有明显的由内陆向沿海地区逐渐变年轻的趋势，显示岩浆作用由陆向海迁移的时空变异特征（Zhou et al., 2000；舒良树等, 2004；Li et al., 2007, 2019）。

本次2件锆石U–Pb测年样品分别获得了92 Ma和86 Ma的年龄信息，二者年龄近一致，表明东台山岛火山岩形成于晚白垩世早期，与区域上火山–岩浆活动爆发时代基本一致，是晚中生代岩浆活动末期的产物。东台山岛离岸约50 km，与内陆沿海地区岩浆岩相比，东台山岛岩浆岩形成时代更为年轻，显示出陆域岩浆岩的迁移规律在近岸岛屿岩浆岩中得到进一步延伸。近岸岛屿东台山岛火山岩形成时代的确定，表明中国东南沿海地区近岸岛屿早期的形成与区域晚中生代岩浆活动相关，同时进一步为中国东南沿海地区晚中生代岩浆岩由内陆向沿海迁移的时空变异特征提供了支撑。

4.2 岩浆源区与成岩过程

实验岩石学研究表明，不同组分的陆壳发生部分熔融可以形成不同类型的花岗质熔体（Winther, 1996；Skjerlie et al., 2002），其中中基性火成岩地壳部分熔融会形成化学成分偏基性的准铝质–弱过铝质的I型花岗岩（Wolf et al., 1994；Sisson et al., 2005），而地壳中沉积岩系部分熔融则会形成偏酸性的过铝质花岗岩类（Johannes et al., 1996）。东台

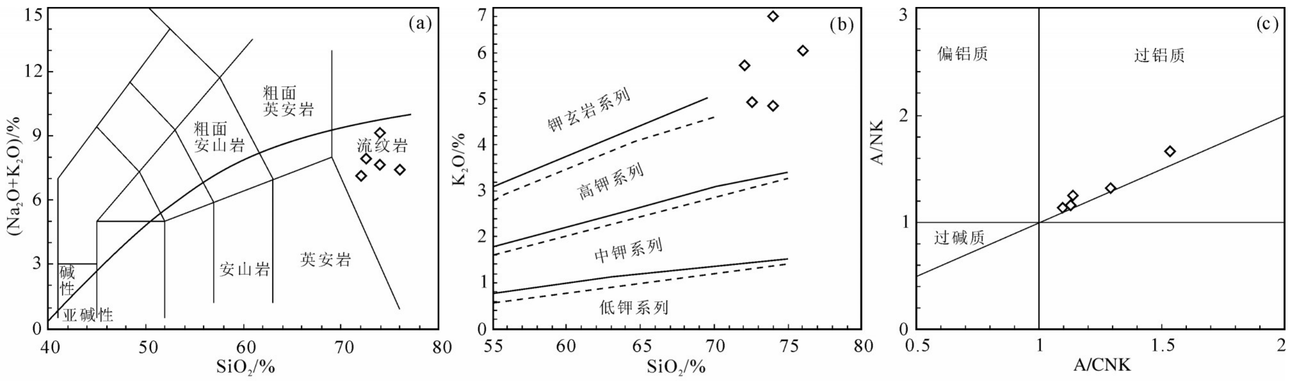

图3 SiO_2−(Na_2O+K_2O)−图解(a, 据Rickwood, 1989), SiO_2 − K_2O图解(b, 据Maitre, 1989)和A/CNK− A/NK图解(c, 据Shand, 1943)

Fig.3 SiO_2−(Na_2O+K_2O) diagram(a, after Rickwood, 1989), SiO_2 − K_2O diagram(b, after Maitre, 1989)and A/CNK− A/NK diagram(c, after Shand, 1943)

山岛火山岩以酸性流纹岩与流纹质火山碎屑岩为主,地球化学组成具有过铝质高钾钙碱性岩石的特征,反映其应该起源于下地壳变沉积岩部分熔融。在岩浆源区判别图解中(图5),火山岩样品特征地球化学元素比值同样指示其源区物质组成以沉积岩为主。

样品高的SiO_2含量(＞70%)、FeOt/MgO比值、分异指数(*DI*＞90)以及明显的Sr、Ba、Eu负异常,具有高分异岩石的地球化学特征,这与区域上早白垩世末期—晚白垩世初期的火山岩系地球化学特征相似(Chen et al., 2008, 2016; Guo et al., 2012; Zhang et al., 2018),指示火山岩在成岩过程中在浅层岩浆房内(＜10 km)经历了强烈的结晶分异作用(Bachmann et al., 2004; Hildreth, 2004; Gualda and Ghiorso, 2014)。在Sr−Rb/Sr和Sr−Ba图解中(图6),火山岩样品显示出强烈的钾长石结晶分异的趋势,这也合理解释了岩石样品中不同程度的Eu负异常。因此,东台山岛流纹质岩石应该起源于下地壳变沉积岩部分熔融,并在浅层岩浆房内经历广泛结晶分异作用的产物。

4.3 构造背景与深部地球动力学机制

晚中生代岩浆岩在中国东南沿海地区大规模发育,但是对于该期岩浆爆发的构造背景以及深部动力学机制一直存在较大的争议,先后提出了陆陆碰撞、大陆拉张裂解、地幔柱、古太平洋俯冲、走滑模型等动力学模型(Gilder et al., 1996;谢窦克等,

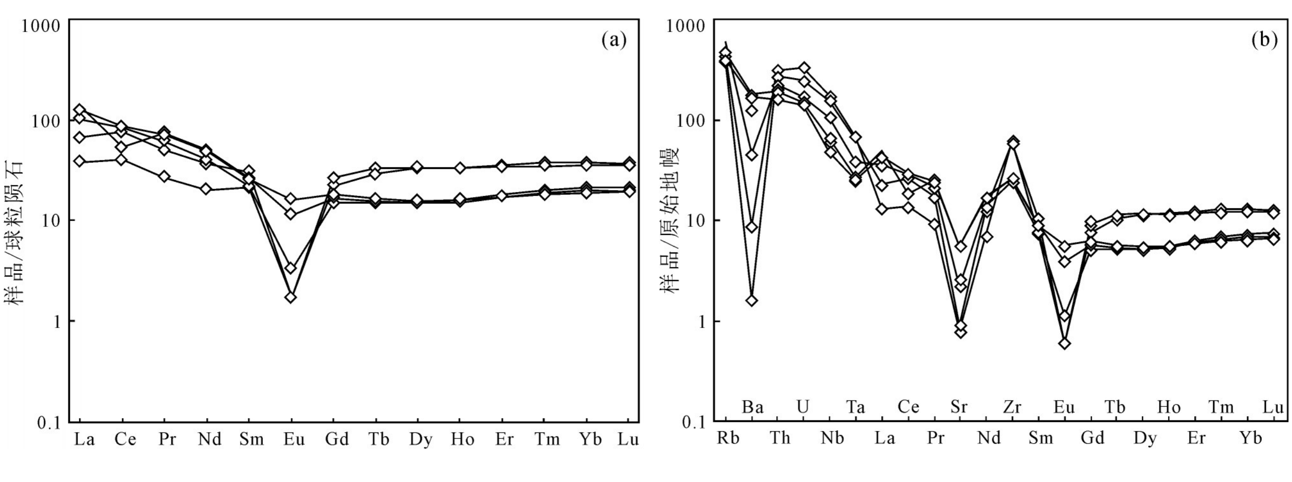

图4 球粒陨石标准化稀土元素模式图(a)和原始地幔标准化微量元素蛛网图(b)
(标准化值引自Sun and McDonough, 1989)

Fig.4 Chondrite−normalized REE(a)and primitive−mantle−normalized multi−element patterns(b)(after Sun and McDonough, 1989)

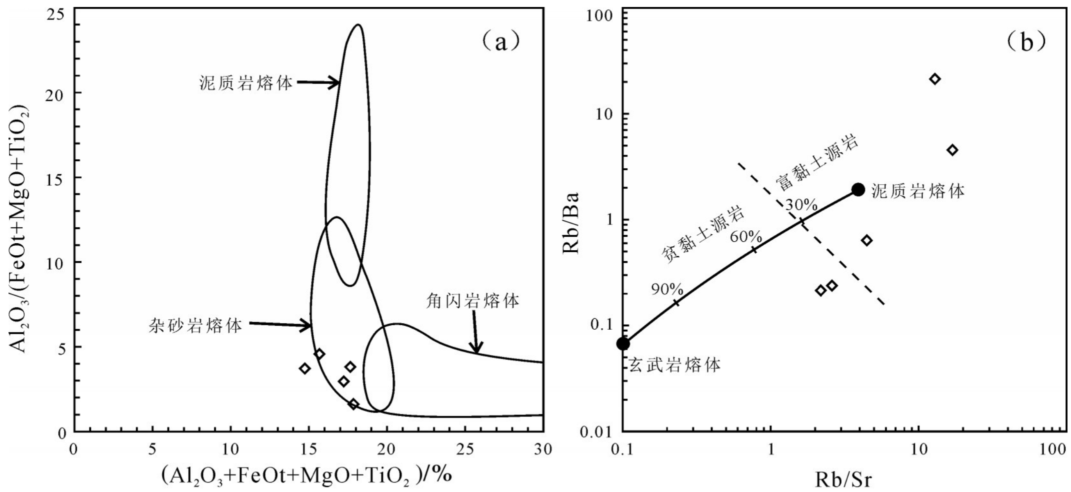

图5 $(Al_2O_3+FeOt+MgO+TiO_2)-Al_2O_3/(FeOt+MgO+TiO_2)$图解(a，据Douce, 1999)和Rb/Sr−Rb/Ba图解(b, Sylvester, 1998)
Fig.5 $(Al_2O_3+FeOt+MgO+TiO_2)-Al_2O_3/(FeOt+MgO+TiO_2)$diagram(a，after Douce, 1999) and Rb/Sr−Rb/Ba diagram(b, after Sylvester, 1998)

1997；Hsü et al., 1988；Li et al., 2007, 2012；Ling et al., 2009；孙卫东等, 2010；邵济安等, 2015)。岩浆岩地球化学以及同位素资料指示中国东南沿海地区晚中生代岩浆岩(J_3−K_2)整体以钙碱性酸性岩石为主，具有壳源成因弧型岩浆岩的特征(Li et al., 2007；高万里等, 2014；Zhang et al., 2018)。近年来，早白垩世A2型酸性岩以及双峰式岩石组合的识别，指示区域构造背景发生了从侏罗纪挤压到白垩纪伸展的转变(张招崇等, 2007；Wu et al., 2012；Yang et al., 2012；刘树文等, 2013；Li et al., 2013；Deng et al., 2014；Li et al., 2014)。

越来越多的研究指示中国东南沿海地区晚中生代构造−岩浆事件的深部动力学机制主要与古太平洋俯冲作用相关(Zhou et al., 2000；Li et al., 2007, 2019；徐先兵等, 2009；索艳慧等, 2017；李三忠等, 2018；Zhang et al., 2018；Suo et al., 2019)，而研究发现中生代以来古太平洋洋壳的俯冲方向以及俯冲几何形态可能发生过多次改变(Koppers et al., 2001；Sun et al., 2007；张旗等, 2009；Li et al., 2019；Suo et al., 2019)，Li et al.(2007)提出平板俯冲模型

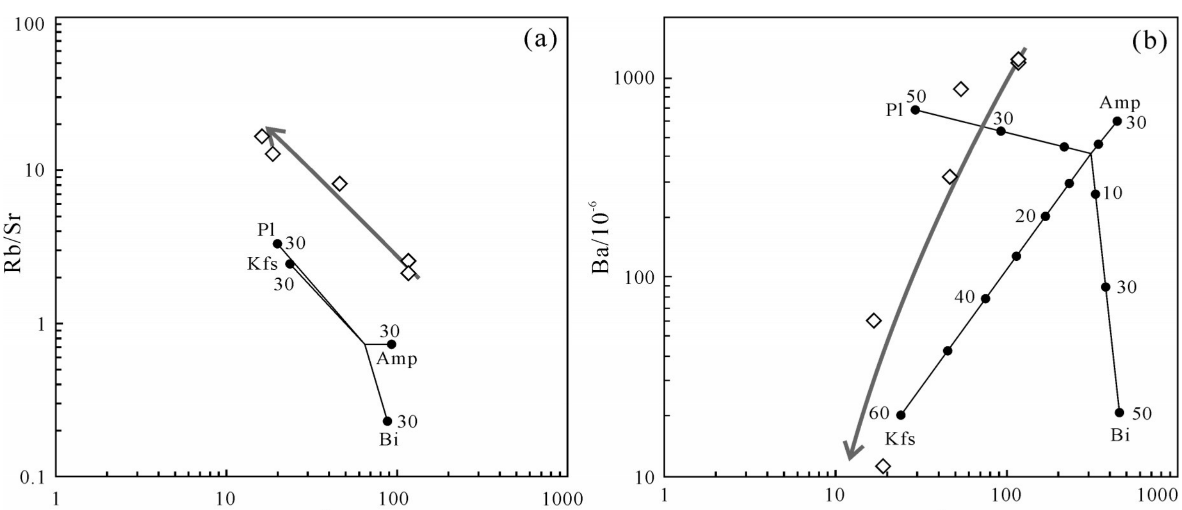

图6 Sr−Rb/Sr图解(a)和Sr−Ba图解(b)(据Rollinson, 1993)
Amp—角闪石；Bi—黑云母；Kfs—钾长石；Pl—斜长石
Fig.6 Sr−Rb/Sr diagram(a)and Sr−Ba diagram(b)(after Rollinson, 1993)
Amp−Hornblende；Bi−Biotite；Kfs−Potash feldspar；Pl−Plagioclase

来解释华南地区宽达1300 km的岩浆岩带，而早白垩世以来构造环境的转变与岩浆作用的迁移被认为是平板俯冲洋壳板片断离下沉后板片回转的产物。板片回转引发的深部软流圈地幔上涌会导致上覆岩石圈发生伸展，并发生部分熔融形成弧型岩浆作用，而随着俯冲角度增大，地幔楔的前进会导致弧型岩浆作用向海沟方向迁移（Tatsumi, 1990; Nakakuki and Mura, 2013）。板片回转模型无疑为中国东南沿海地区晚中生代构造-岩浆事件的深部动力学机制提供了一个合理的解释，东台山岛晚白垩世岩浆作用应该就是古太平洋洋壳俯冲过程中板片回转的产物。

5 结 论

(1) LA-ICP-MS锆石U-Pb测年在东台山岛火山岩中获得了92 Ma和86 Ma的谐和年龄信息，指示东台山岛火山岩浆活动形成于晚白垩世，其时代与东南沿海地区大规模出露的晚中生代火山-侵入岩相一致。

(2) 东台山岛火山岩以过铝质高钾钙碱性流纹质火山岩为主，高的分异指数（>90）与强烈的Sr、Ba、Eu元素亏损显示高演化岩石的特征，研究认为该套火山岩起源于变沉积岩地壳重熔，并在浅层岩浆房内经历了强烈的结晶分异作用。

(3) 东台山岛火山岩浆活动形成于洋壳俯冲背景，其深部地球动力学机制应该与古太平洋晚中生代板片回转相关。

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