文章编号: 1007-3701(2012)04-290-08

两广云开地区基底深变质岩的形成时代

龙文国,徐德明,王 磊,周 岱,金鑫镖,张 鲲

(武汉地质矿产研究所, 武汉 430205)

摘要: 两广云开地区出露的前寒武纪基底岩石主要是以天堂山岩群为代表的深变质岩系和以云开群为代表的浅变质岩系。对天堂山岩群的副片麻岩中的锆石U-Pb年代学研究显示,其主要由新元古代(651 ~ 760 Ma)、Grenvill期(939 ~ 1206 Ma)的碎屑物质组成,其中还包括一定数量早中元古代 - 早元古代(1439 ~ 2369 Ma)、新太古代(2540 Ma)碎屑物质,天堂山岩群中部分深变质岩的原岩是新元古代形成的沉积岩,与粤北、粤东北及闽西地区基底变质岩原岩的形成时代是基本一致的。云开群的形成时代晚于天堂山岩群的形成时代。

关 键 词: 前寒武纪基底;副片麻岩;新元古代;锆石U-Pb年龄;云开地区

中图分类号: P618.4 **文献标识码:** A

华南由扬子地块和华夏地块沿早新元古代江南造山带拼合而成[1-5],两个地块具有明显不同的前寒武纪演化历史。扬子地块的结晶基底主要由太古代的崆岭群和早元古代物质组成[6-8],褶皱基底主要由冷家溪群及与其相当的四堡群、梵净山群、双桥山群等组成[3-4,9]。华夏地块是一个颇有争议的地质块体,它经历了多次肯定与否定的认识过程。其基底以往被认为主要由早元古代的八都群、麻源群、云开群和周潭群等组成,岩性包括片岩、片麻岩、角闪岩、混合岩和变火山岩等[10-13]。近年来,于华夏地块内原划归前寒武纪的基底岩石中获得了不少新元古代甚至更年轻的锆石年龄(包括变质年龄和岩石形成年龄)[14-22],而获得的古元古代甚至更老的年龄数据较少[12,15,23-26],从而重新唤起了人们对华夏古陆是否存在的争议。

两广交界的云开地区是华夏地块前寒武纪基底出露的主要地区之一。学者们对该地区前寒武纪基底的划分及时代归属、花岗岩和混合岩的成因、时代及形成背景等展开过一定程度的研究[27-36],以往的研究结果多显示云开地区的基底主要形成于古元古代至中新元古代。然而,近期于该区原划归基底的岩石中陆续有一些加里东期的年龄报道[10,14,16,18-19,22],除一部分为变质年龄外,主要为酸性侵入岩的形成时代。这些新的高精度年龄的获得,使得云开地区乃至整个华夏地块的基底组成与时代归属重新成为了研究的焦点。本文采用锆石LA-ICP-MS U-Pb法对云开地区原划归前寒武纪结晶基底的副片麻岩进行了定年,获得了一组介于651 ~ 760 Ma间的年龄,从而对云开地区前寒武纪结晶基底岩石的形成时代进行探讨。

1 地质背景

云开地块位于广东西部和广西东部交界地区,呈NE-SW向展布,东西两侧界限分别为吴川 - 四会断裂带和岑溪 - 博白断裂带,大地构造上被认为是华夏地块中武夷 - 云开加里东褶皱带或武云造山带的西南部分[15](图1-a)。云开地块长期被认为是高级改造的古元古代到中元古代深层次基底岩石、中等变质的晚新元古代到早古生代浅层次变质基底的出露区,盖层岩石由弱变质到未变质的寒武纪 - 泥盆纪地层组成[32]。另外,还出露一些古生代到早中生代沉积物及大量的花岗质岩石[14,33,37-38](图1-b)。深层变质基底岩石主要出露在两广交界的广东高

收稿日期: 2012-9-28; **修回日期:** 2012-10-31.
基金项目: 中国地质调查局基础地质综合研究项目《钦杭成矿带(西段)基础地质调查综合研究》(编号: 1212011085416).
作者简介: 龙文国(1967—),男,研究员,主要从事岩石学、地球化学和大地构造学研究,E-mail: longwg21cn@126.com.

表1 云开信宜地区前寒武纪基底中片麻岩LA-ICP-MS锆石U-Th-Pb同位素分析结果

Table 1 U-Th-Pb isotope analyses results for zircons from the paragneiss of Precambian basement in the Yunkai area

Analytical spot	Pb	Th	U	Th/U ratio	Isotopic Ratios						Apparent Ages (Ma)					
		$\times 10^{-6}$			$^{207}Pb/^{206}Pb$	±1σ	$^{207}Pb/^{235}U$	±1σ	$^{206}Pb/^{238}U$	±1σ	$^{207}Pb/^{206}Pb$	±1σ	$^{207}Pb/^{235}U$	±1σ	$^{206}Pb/^{238}U$	±1σ
1017-1-01	52.3	108	253	0.43	0.0724	0.0016	1.6929	0.0367	0.1694	0.0013	996	46	1006	14	1009	7
1017-1-02	6.65	15.0	53.7	0.28	0.0612	0.0028	0.8801	0.0366	0.1062	0.0014	656	98	641	20	651	8
1017-1-03	99.1	123	189	0.65	0.1397	0.0024	7.5428	0.1328	0.3904	0.0035	2233	30	2178	16	2125	16
1017-1-04	60.1	113	282	0.40	0.0754	0.0017	1.8320	0.0441	0.1753	0.0020	1080	44	1057	16	1041	11
1017-1-05	92.1	184	344	0.53	0.0906	0.0023	2.5364	0.0696	0.2015	0.0020	1439	48	1283	20	1183	10
1017-1-06	155.9	248	402	0.62	0.1019	0.0018	4.1068	0.0753	0.2915	0.0026	1661	33	1656	15	1649	13
1017-1-07	156.90	88.8	806	0.11	0.0736	0.0012	1.7290	0.0300	0.1697	0.0014	1031	33	1019	11	1011	8
1017-1-08	64.4	143	279	0.51	0.0766	0.0014	1.9419	0.0415	0.1831	0.0021	1109	37	1096	14	1084	12
1017-1-09	21.92	67.3	93.3	0.72	0.0921	0.0219	2.2323	0.5600	0.1752	0.0046	1470	433	1191	178	1040	26
1017-1-10	191.2	100	961	0.10	0.0756	0.0014	1.7985	0.0339	0.1718	0.0016	1085	35	1045	12	1022	9
1017-1-11	69.54	81.0	299	0.27	0.0803	0.0016	2.1351	0.0443	0.1919	0.0017	1206	45	1160	14	1132	9
1017-1-12	71.1	176	336	0.52	0.0762	0.0017	1.7104	0.0359	0.1642	0.0032	1100	44	1012	13	980	18
1017-1-13	94.2	255	710	0.36	0.0620	0.0012	0.9291	0.0171	0.1084	0.0009	672	45	667	9	664	6
1017-1-14	128.2	199	396	0.50	0.0930	0.0016	3.2828	0.0598	0.2548	0.0027	1487	33	1477	14	1463	14
1017-1-15	50.7	156	214	0.73	0.0763	0.0018	1.8766	0.0449	0.1774	0.0018	1103	46	1073	16	1053	10
1017-1-16	62.4	240	385	0.62	0.0652	0.0014	1.1160	0.0244	0.1237	0.0012	789	44	761	12	752	7
1017-1-17	22.52	35.7	90.5	0.39	0.1520	0.0725	3.7937	1.7277	0.1885	0.0021	2369	913	1591	383	1113	11
1017-1-18	59.0	137	245	0.56	0.0780	0.0016	1.9921	0.0389	0.1847	0.0015	1148	40	1113	13	1093	8
1017-1-19	38.70	30.0	203	0.15	0.0720	0.0018	1.6240	0.0409	0.1631	0.0016	985	18	980	16	974	9
1017-1-20	24.51	81.8	107	0.76	0.0742	0.0021	1.7369	0.0487	0.1699	0.0020	1048	56	1022	18	1012	11
1017-1-21	198.5	53.6	357	0.15	0.1683	0.0028	10.3276	0.1770	0.4437	0.0037	2540	27	2465	16	2367	16
1017-1-22	103.5	235	321	0.73	0.0906	0.0016	3.0210	0.0595	0.2412	0.0025	1439	33	1413	15	1393	13
1017-1-23	0.2970	0.10	6.80	0.02	0.4891	0.0859	2.1774	0.2699	0.0416	0.0019	4209	262	1174	86	262	11
1017-1-24	43.29	89.5	220	0.41	0.0711	0.0015	1.5783	0.0364	0.1608	0.0016	961	44	962	14	961	9
1017-1-25	10.27	19.1	73.8	0.26	0.0649	0.0029	1.0689	0.0483	0.1201	0.0017	770	94	738	24	731	10
1017-1-26	36.10	63.0	160	0.39	0.0762	0.0019	1.9799	0.0511	0.1889	0.0020	1100	50	1109	17	1115	11
1017-1-27	27.6	101	116	0.87	0.0710	0.0021	1.7114	0.0501	0.1761	0.0019	967	62	1013	19	1046	10
1017-1-28	52.7	241	239	1.01	0.0700	0.0016	1.5102	0.0346	0.1568	0.0016	928	45	935	14	939	9
1017-1-29	33.7	166	139	1.19	0.0717	0.0019	1.6351	0.0429	0.1663	0.0019	976	53	984	17	992	10
1017-1-30	180.6	277	410	0.68	0.1141	0.0022	5.2622	0.1123	0.3339	0.0033	1866	35	1863	18	1857	16
1017-1-31	70.9	112	347	0.32	0.0734	0.0015	1.7454	0.0359	0.1725	0.0017	1033	41	1025	13	1026	9
1017-1-32	5.23	14.0	34.6	0.40	0.0657	0.0037	1.1013	0.0577	0.1251	0.0020	794	119	754	28	760	12
1017-1-33	17.66	37.1	78.7	0.47	0.0766	0.0024	1.9283	0.0610	0.1834	0.0023	1109	58	1091	21	1085	13
1017-1-34	50.09	104	387	0.27	0.0628	0.0015	0.9650	0.0237	0.1114	0.0011	702	49	686	12	681	6

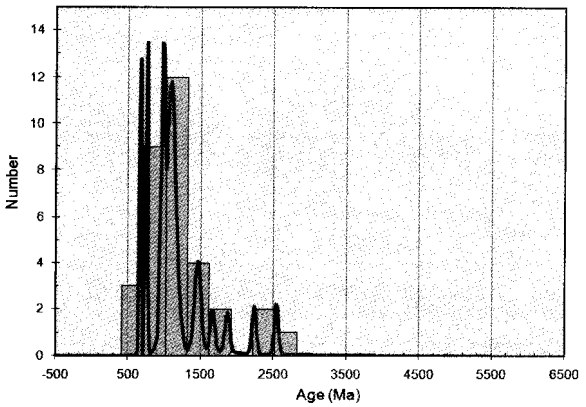

图4片麻岩中锆石年龄频率直方图

Fig 4 Age probability and histogram of zircons from paragneisses in the Yunkai area

片麻岩中锆石主要形成于中元古代 (1.2 ~ 1.7 Ga)和新太古代(2.7 ~ 2.5 Ga)，只有少量形成于 Grenville 期至晚新元古代[46]。可见龙川片麻岩和潭溪片麻岩具有相似的年龄谱，二者与澜河片麻岩却具有明显不同的年龄谱。信宜片麻岩与上述地区片麻岩所具的年龄谱均有差异，澜河片麻岩最年轻碎屑锆石 $^{207}Pb/^{206}Pb$ 谐和年龄为 856 Ma[46]，暗示其沉积时代可能早于龙川(548 Ma)和潭溪片麻岩(545 Ma)，信宜片麻岩(856 Ma)沉积时代可能早于龙川(548 Ma)和潭溪片麻岩(545 Ma)，而晚于澜河片麻岩。上述研究说明华夏地块不同地区不同时代沉积岩的源区是变化的，从新元古代中期到晚期华夏中部沉积盆地的物源区发生了改变。这些新元古代锆石很可能是 Rodinia 裂解峰期岩浆活动的产物[47]，有可能来源于扬子地块，因为那里非常发育新元古代的岩浆活动[47-48]。

5 结论

云开地区原“前寒武纪结晶基底岩石”实际由三套岩石组合组成，即片麻岩类(普遍混合岩化)、片麻状花岗岩、变质沉积岩类(片岩、石英岩类)。信宜地区片麻岩中的锆石年代学研究显示其主要由新元古代(651 ~ 760 Ma)、Grenvill 期(939 ~ 1206 Ma)的碎屑物质组成，变质岩的原岩是新元古代形成的沉积岩，云开群形成时代晚于此片麻岩类的形成时代，也应属新元古代。从整个云开地块来看，中元古代结晶基底的出露可能并不像以往认为的那么广泛。天堂山片麻岩是中—新元古代形成的一套杂岩，信宜地区部分天堂山片麻岩的形成时代晚于650Ma。信宜片麻岩与华夏地块其它地区片麻岩所具的年龄谱均有一定差异，说明华夏地块不同地区不同时代沉积岩的源区是变化的。

锆石阴极发光照相和锆石U-Pb同位素测试的过程中，分别得到了中国地质大学地质过程与矿产资源国家重点实验室郑曙高级工程师和胡兆初研究员的帮助；成文过程中与李武显研究员、杨东生博士进行了有益的探讨，在此一并致谢！

参考文献：

[1] Li Z X, Zhang L H, Powell C M. South China in Rodinia: part of the missing link between Australia-East Antarctica and Laurentia? [J]. Geology, 1995, 23: 407-410.

[2] Zhao G C, Cawood P A. Tectonothermal evolution of the Mayuan assemblage in the Cathaysia Block: new evidence for Neoproterozoic collision-related assembly of the South China craton [J]. American Journal of Science, 1999, 299: 309-339.

[3] Wang X L, Zhou J C, Qiu J S, et al. LA-ICP-MS U-Pb zircon geochronology of the Neoproterozoic igneous rocks from northern Guangxi, south China: Implications for tectonic evolution [J]. Precambrian Research, 2006, 145: 111-130.

[4] Wang X L, Zhou J C, Griffin W L, et al. Detrital zircon geochronology of Precambrian basement sequences in the Jiangnan orogen: Dating the assembly of the Yangtze and Cathaysia blocks [J]. Precambrian Research, 2007, 59: 117-131.

[5] Zhao J H, Zhou M F, Yan D P, et al. Reappraisal of the ages of Neoproterozoic strata in South China: No connection with the Grenvillian orogeny [J]. Geology, 2011, 39: 299-302.

[6] Gao S, Lin W L, Qiu Y M. Contrasting geochemical and Sm-Nd isotopic compositions of Archean metasediments from the Kongling high-grade terrain of the Yangtze craton: evidence for cratonic evolution and redistribution of REE during crustal anatexis [J]. Geochimica et Cosmochimica Acta, 1999, 13(14): 2071-2088.

[7] Qiu Y M, Gao S, McNaughton N J, et al. First evidence of > 3.2 Ga continental crust in the Yangtze craton of South China and its implications for Archean crustal evolution and Phanerozoic tectonics [J]. Geology, 2000, 28 (1): 11-14.

[8] Zheng J P, Griffin W L, O'Reilly S Y, et al. Widespread Archean basement beneath the Yangtze Craton [J]. Geology, 2006, 34: 417-420.

[9] 刘锐，张利，周汉文，等. 闽西北加里东期混合岩及花岗岩的成因：同变形地壳深熔作用[J].岩石学报, 2008, 24

(6): 1205-1222.

[10] Wang Y J, Zhang A M, Fan W M, et al. Kwangsian crustal anatexis within the eastern South China Block: Geochemical, zircon U-Pb geochronological and Hf isotopic fingerprints from the gneissoid granites of Wugong and Wuyi-Yunkai Domains [J]. Lithos, 2011, 127: 239-260.

[11] Zhou J C, Wang X L, Qiu J S. Geochronology of Neoproterozoic mafic rocks and sandstones from northeastern Guizhou, South China: Coeval arc magmatism and sedimentation[J]. Precambrian Research, 2009, 170: 27-42.

[12] Yu J H, Wang L J, Griffin W L, et al. A Paleoproterozoic orogeny recorded in a long-lived cratonic remnant (Wuyishan terrane), eastern Cathaysia Block, China [J]. Precambrian Research, 2009, 174: 347-363.

[13] Yu J H, O'Reilly S Y, Wang L J, et al. Components and Episodic growth of Precambrian crust in the Cathaysia Block, South China: evidence from U-Pb ages and Hf isotopes of zircons in Neoproterozoic sediments[J]. Precambrian Research, 2010, 181: 97-114.

[14] Wang Y J, Zhang A M, Fan W M, et al. Kwangsian crustal anatexis within the eastern South China Block: Geochemical, zircon U-Pb geochronological and Hf isotopic fingerprints from the gneissoid granites of Wugong and Wuyi-Yunkai Domains [J]. Lithos, 2011, 127: 239-260.

[15] Li Z X, Li X H, Wartho J A, et al. Magmatic and metamorphic events during the early Paleozoic Wuyi-Yunkai orogeny, southeastern South China: New age constraints and pressure-temperature conditions [J]. GSA Bulletin, 2010, 122: 772-793.

[16] 覃小锋, 潘元明, 李 江, 等. 桂东南云开地区变质杂岩锆石SHRIMP U-Pb年代学 [J]. 地质通报, 2006, 25 (5): 553-559.

[17] Wan Y S, Liu D Y, Xu M H, et al. SHRIMP U-Pb zircon geochronology and geochemistry of metavolcanic and metasedimentary rocks in Northwestern Fujian, Cathaysia Block, China: Tectonic implications and the need to redefine lithostratigraphic units [J]. Gondwana Research, 2007, 12: 166-183.

[18] Wan Y S, Liu D Y, Wilde S A, et al. Evolution of the Yunkai Terrane, South China: Evidence from SHRIMP zircon U-Pb dating, geochemistry and Nd isotope [J]. Journal of Asian Earth Sciences, 2010, 37: 140-153.

[19] Wang Y J, Fan W M, Zhao G C, et al. Zircon U-Pb geochronology of gneissic rocks in the Yunkai massif and its implications on the Caledonian event in the South China Block [J]. Gondwana Research, 2007, 12: 404-416.

[20] Yang D S, Li X H, Li W X, et al. U-Pb and ^{40}Ar-^{39}Ar geochronology of the Baiyunshan gneiss (central Guangdong, south China): constraints on the timing of early Palaeozoic and Mesozoic tectonothermal events in the Wuyun (Wuyi-Yunkai) Orogen [J]. Geological Magazine. 2010, 147: 481-496.

[21] Liu R, Zhou H W, Zhang L, et al. Zircon U-Pb ages and Hf isotope compositions of the Mayuan migmatite complex, NW Fujian Province, Southeast China: Constraints on the timing and nature of a regional tectonothermal event associated with the Caledonian orogeny[J]. Lithos, 2011, 119:163-180.

[22] Chen C H, Liu Y H, Lee C Y, et al. Geochronology of granulite, charnockite and gneiss in the polymetamorphosed Gaozhou Complex (Yunkai Massif), South China: Emphasis on the in-situ EMP monazite dating [J]. Lithos, 2012, 144/145: 109-129.

[23] Li Z X, Li X H. Formation of the 1300-km-wide intracontinental orogen and postorogenic magmatic province in Mesozoic South China: a flat-slab subduction model [J]. Geology, 2007, 35: 179-182.

[24] Li L M, Sun M, Wang Y J, et al. Geochronological and Geochemical study of Paleoproterozoic gneissic granites and clinopyroxenite xenoliths from NW Fujian, SE China: Implications for the crustal evolution of the Cathaysia Block [J]. Journal of Asian Earth Sciences, 2011, 41: 204-212.

[25] Li X H. Timing of the Cathaysia Block formation: Constraints from SHRIMP U-Pb zircon geochronology [J]. Episodes, 1997, 20(3): 188-192.

[26] 汪 相,陈 洁,罗 丹.浙西南淡竹花岗闪长岩中锆石的成因研究及其地质意义[J]. 地质论评, 2008, 54 (3): 387-398.

[27] 简 平. 云开隆起西南端混合岩、花岗岩同位素地质年代学研究[J]. 广东地质, 1991 , 6(2): 58-67.

[28] 于津生,桂训唐,黄 琳.广东罗定泗纶混合岩田同位素组成特征[J]. 广东地质, 1991, 6(3) : 73-82.

[29] 张伯友, 俞鸿年. 糜棱岩、混合岩、花岗岩三者成因联系——粤西深层次推覆构造研究的特殊意义[J].地质论评,1992, 38(5): 407-413.

[30] 周汉文,游振东,钟增球,等.云开隆起区钾长球斑片麻状黑云母花岗岩锆石特征研究——形貌、成分以及U-Pb同位素年龄[J]. 地球科学——中国地质大学学报, 1994, 19(4): 427-433.

[31] 周汉文、游振东、钟增球,等. 云开隆起区热中心式区域混合岩的成因研究 [J]. 地球科学——中国地质大学学报, 1997, 22(3): 332-340.

[32] 钟增球, 游振东, 周汉文,等. 云开隆起区基底的组成、演化及其基本结构格局 [J]. 中国区域地质, 1996, 56: 36-43.

[33] 彭少梅, 符力奋, 周国强, 等. 云开地块构造演化及片麻状花岗质岩石的剪切深熔成因[M]. 武汉:中国地质大学出版社, 1996: 1-167.

[34] 王江海,涂湘林,孙大中. 粤西云开地块内高州地区深熔混合岩的锆石U-Pb年龄 [J]. 地球化学,1999, 28(3): 231-238.

[35] 叶真华, 劳秋元, 胡世玲.云开大山云开群地层时代和层序的研究现状与新认识 [J]. 地质论评, 2000, 46(5): 449-454.

[36] 彭松柏, 金振民, 刘云华, 等. 云开造山带强过铝深熔花岗岩地球化学、年代学及构造背景[J]. 地球科学——中国地质大学学报, 2006, 31(1): 110-120.

[37] 广东地矿局. 广东省区域地质志[M]. 北京:地质出版社, 1988: 1-941.

[38] 广西地矿局. 广西壮族自治区区域地质志[M].北京:地质出版社,1985: 1-853.

[39] Liu Y S, Gao S, Hu Z C, et al. Continental and oceanic crust recycling-induced melt-peridotite interactions in the Trans-North China Orogen: U-Pb dating, Hf isotopes and trace elements in zircons of mantle xenoliths [J]. Journal of Petrology, 2010, 51: 537-571.

[40] Liu Y S, Hu Z C, Gao S. In situ analysis of major and trace elements of anhydrous minerals by LA-ICP-MS without applying an internal standard [J]. Chemical Geology, 2008, 257: 34-43.

[41] Liu Y S, Hu Z C, Zong K Q, et al. Reappraisement and refinement of zircon U-Pb isotope and trace element analyses by LA-ICP-MS [J]. Chinese Science Bulletin, 2010, 55: 1535-1546.

[42] Andersen T. Correction of common lead in U-Pb analyses that do not report ^{204}Pb [J]. Chemical Geology, 2002, 192: 59-79.

[43] Ludwig K R. ISOPLOT 3: a geochronological toolkit for Microsoft excel [M]. Berkeley Geochronology Centre Special Publication 4, 2003: 1-74.

[44] 于津海,王丽娟,周新民, 等. 粤东北基底变质岩的组成和形成时代[J].地球科学——中国地质大学学报, 2006, 31(1): 38-48.

[45] 于津海, O'Reilly Y S, 王丽娟, 等. 华夏地块古老物质的发现和前寒武纪地壳的形成 [J]. 科学通报, 2007, 52(1): 11-18.

[46] Xu X S, O'Reilly S Y, Griffin W L, et al. Relict Proterozoic basement in the Nanling Mountains (SE China) and its tectonothermal overprinting [J]. Tectonics, 2005, 24(2), doi: 10.1029/2004TC001652.

[47] Zheng Y F, Zhao Z F, Wu Y B, et al. Zircon U-Pb age, Hf and O isotope constraints on protolith origin of ultrahigh-pressure eclogite and gneiss in the Dabie orogen [J]. Chemical Geology, 2006, 231: 135-158.

[48] 郑永飞. 新元古代岩浆活动与全球变化 [J]. 科学通报, 2003, 48(16):1705-1720.

Formation Age of Hypometamorphic Rocks in Basement of Yunkai Area, South China

LONG Wen-Guo, XU De-Ming, WANG Lei, ZHOU Dai, JIN Xin-Biao, ZHANG Kun

(Wuhan Institute of Geology and Mineral Resources, Wuhan 430205, China)

Abstract: Precambrian basement rocks outcropping Yunkai area are composed of high metamorphic rocks represented by Tantangshan Group and lower metamorphic rocks represented by Yukai Group. U-Pb dating for detrital zircon from a paragneiss of Tantangshan Group, indicates that the Neoproterozoic sediments in Yunkai area hinterland are mainly composed of Neoproterozoic (651 ~ 760 Ma) and Grenvill period (939 ~ 1206 Ma) clastic materials, which also including a certain number of early Mesoproterozoic - early Proterozoic (1439 ~ 2369 Ma), the Neoarchean (2540 Ma) clastic materials, The formation age of basement rocks in Yunkai area is basically same with those in the northern part of Guangdong, northeastern Guangdong and western Fujian. The formation age of Yunkai Group is younger than the formation age of Tiantangshan Group.

Key Words: Precambrian basement; paragneiss; Neoproterozoic; Zircon U-Pb dating, Yunkai area, South China