doi:10.11764/j.issn.1672-1926.2017.09.006

天然气地质学

琼东南盆地上中新统—上新统中央峡谷沉积物来源

尹 娜[1,2],杨海长[3],马 明[1],张功成[3],吕成福[1],赵 钊[3],李 超[1]
(1.甘肃省油气资源研究重点实验室/中国科学院油气资源研究重点实验室,甘肃 兰州 730000;
2.中国科学院大学,北京 100049;3.中海油研究总院,北京 100027)

摘要:应用元素地球化学、重矿物组成及碎屑锆石测年方法,分析了琼东南盆地上中新统—上新统中央峡谷沉积物来源及源区母岩类型。研究表明:中央峡谷稀土元素总量介于 168.10×10^{-6} 至 218.79×10^{-6} 之间,平均值为 191.01×10^{-6},接近于 PAAS 而略高于 UCC 值。轻稀土(LREE)相对富集,La/Yb 值较高,介于 12.99~15.44 之间,平均值为 14.41。$(La/Yb)_N$ 值变化范围为 8.76~10.41,平均值为 9.72,LREE/HREE 值介于 3.62~4.24 之间,平均值为 3.91。铕具有明显的负异常,呈"V"字型,δEu 值变化范围为 0.53~0.71,平均值为 0.6。铈异常不明显,δCe 值变化范围为 1.03~1.10,平均值为 1.06。重稀土(HREE)相对平坦,$(Gd/Yb)_N$ 值变化范围为 1.74~2.01,平均值为 1.87,表明母岩为来自上地壳的酸性岩,这一结论与微量元素相关比值(Eu/Eu^*、La/Sc、La/Co、Th/Sc 以及 Cr/Th)以及源区岩性图解 Hf—La/Th、La/Sc—Co/Th 以及 V—Ni—Th×10 相一致。对比三大潜在物源区(红河、海南岛及越南中部)沉积物的稀土元素配分模式,发现中央峡谷沉积物稀土元素球粒陨石标准化配分模式与越南中部最为接近;重矿物中锆石、赤褐铁矿以及白钛矿含量高这一特征与越南中部沉积物重矿物特征相吻合;结合前人有关中央峡谷碎屑锆石测年的相关研究,确定中央峡谷沉积物主要来自越南中部的昆嵩隆起带。

关键词:琼东南盆地;上中新统;上新统;中央峡谷;物源
中图分类号:TE121.3 **文献标志码**:A **文章编号**:1672-1926(2017)10-1582-11
引用格式:Yin Na,Yang Haizhang,Ma Ming,*et al*.Provenance of Central Canyon in the Upper Miocene to the Pliocene in the Qiongdongnan Basin[J].Natural Gas Geoscience,2017,28(10):1582-1592.[尹娜,杨海长,马明,等.琼东南盆地上中新统—上新统中央峡谷沉积物来源[J].天然气地球科学,2017,28(10):1582-1592.]

0 引言

近年来,以西非、墨西哥湾和巴西坎坡斯等盆地为代表的世界深水油气勘探开发相继取得了重大突破,我国亦于 2006 年在珠江口盆地深水区荔湾凹陷,2010—2014 年在琼东南盆地深水区陵水凹陷中央峡谷获得重大油气发现[1]。但是,目前有关琼东南盆地中央峡谷沉积物来源的研究争议很大,普遍认为南海北部存在三大潜在的物源区,分别为红河、海南岛及越南中部[2-15],而且中央峡谷明显受这三大物源的影响,尤其是红河物源与越南中部物源,不同学者持有不同观点。元素地球化学方法是分析沉积物来源、源区风化条件以及构造背景等方面的有效手段,目前已被国内外学者所接受并广泛应用[16-23]。元素地球化学分析方法主要包括:主量元素和微量元素含量及其相关比值;微量元素是很好的地球化学参数,这些元素包括:稀土元素、Y、Th、Zr、Hf 以及 Sc 等,沉积物由物源区搬运至沉积盆地过程中,遭受风化、剥蚀、搬运以及沉积成岩改造等,在这一过程中这些元素含量并不会发生改变[24,25]。

收稿日期:2017-07-08;**修回日期**:2017-09-06.
基金项目:国家科技重大专项(编号:2016ZX05026-007-05)资助.
作者简介:尹娜(1992-),女,山东日照人,硕士研究生,主要从事储层沉积学研究.**E-mail**:18306422290@163.com.
通信作者:马明(1989-),男,宁夏固原人,博士研究生,主要从事储层沉积学研究.**E-mail**:13893681262@163.com.

沉积岩中各种重矿物类型、含量以及各种特殊重矿物组合与物源区的相似性，也可以被用来确定碎屑沉积物的来源[8-10,26,27]。目前最常用的沉积岩物源研究方法是碎屑锆石U—Pb测年，通过锆石测年可以获得最大限度的沉积物年龄，而且不同来源或者不同时期的沉积物在年龄谱图上有较大差异，对比潜在物源区的锆石年龄，既可以确定单一来源的沉积物，也可以确定混合来源的沉积物，这一方法目前已经得到国内外学者的广泛应用[2-10,27]。

1　区域地质背景

琼东南盆地位于南海北部的海南岛与西沙群岛之间的海域，平面呈北东向，面积为 8.29×10^4 km^2[28]。盆地北部为海南隆起，南端为西沙隆起，西部与莺歌海盆地相接并被红河断裂带分割，东北部则为珠江口盆地(图1)。盆地内部发育一系列北东向和北东东向的凹陷和凸起，形成了总体两隆三坳的构造格局[29]。盆地分为北部坳陷、中部隆起和中央凹陷3个一级单元。盆地的二级单元，凹陷、凸起相间排列，划分出10个凹陷、9个凸起/低凸起，即崖北凹陷、崖南凹陷、松西凹陷、松东凹陷、北礁凹陷、长昌凹陷、松南—宝岛凹陷、乐东—陵水凹陷、永乐凹陷、华光凹陷，以及崖城凸起、陵水低凸起、松涛凸起、宝岛凸起、长昌凸起、崖南低凸起、陵南低凸起、松南低凸起和北礁凸起[30]。

莺歌海—琼东南盆地的构造演化可分为早期断陷阶段和后期坳陷阶段，早期断陷裂陷可划分为：第一幕发生于晚白垩纪—始新世初，此时在盆地内形成了小型裂陷群；第二幕发生于始新世—早渐新世，进一步分为中始新世—晚始新世的快速沉降阶段和始新世末—早渐新世相对稳定沉降阶段；第三幕发生于晚渐新世；新近纪以后盆地进入了热沉降阶段[29]。

琼东南盆地为发育在岩石圈减薄机制下的新生代沉积盆地，中—晚元古代变质岩、早古生代海相碎屑岩与碳酸盐岩、晚古生代—中生代沉积岩组成了盆地基底。盆地新生代地层包括：始新统，渐新统崖城组和陵水组，中新统三亚组、梅山组以及黄流组，上新统莺歌海组，更新统乐东组，年龄依次由老到新[29]。

2　样品采集与分析测试

本文研究选取2口钻遇中央峡谷钻井的砂岩样品，其中一口钻井位于峡谷源头并采集岩心样品8块，另一口位于峡谷中游并采集砂岩岩屑样品3份，对上述样品进行元素地球化学分析(表1，表2)，测试中所采用的仪器是美国Thermo公司X Series电感耦合等离子体质谱仪(ICP-MAS)，所有的样品前处理及分析测试工作均在中国科学院青藏高原研究所完成。详细的样品前处理过程及分析测试步骤见文献[31]。

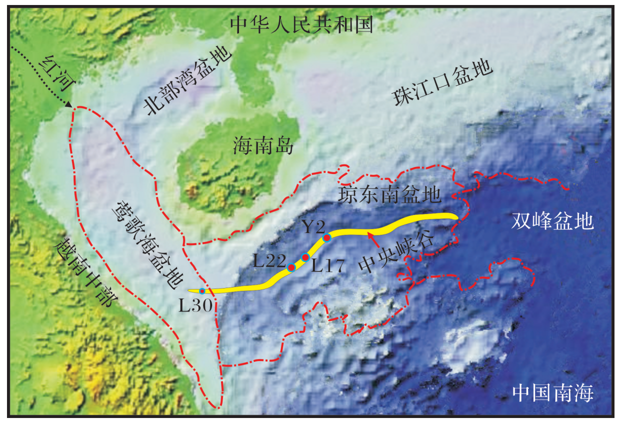

图1　研究区构造位置

Fig.1　The tectonic sketch map of the study area

3　母岩岩性特征

微量元素含量及其相关比值常常被用来确定沉积物母源区的岩性。镁铁质岩石中富集微量元素Sc、Cr以及Co，长英质岩石富集元素La、Th和REE，稀土元素REE配分模式以及Eu的异常特征均可以作为分析沉积物源区岩性的有利方法[16,24,32,33]。一些活动性相对较低的元素如La、Co、Th、Zr、Hf、Ti、Nd、Sc、Y以及REE等，在海(湖)水中停留的时间相对较短，地表岩石遭受风化、剥蚀、搬运与沉积等地质过程中容易保存到沉积物中，因此这些元素含量及其相关比值对物源很敏感，可以用来确定沉积物物源区的岩石类型。这些元素比值主要包括Eu/Eu*、La/Sc、La/Co、Th/Sc以及Cr/Th等[24,34]。中央峡谷砂岩的上述元素比值见表3，分别对比来自长英质母岩的沉积岩、镁铁质母岩的沉积岩以及上地壳的平均含量，可以发现，研究区元素比值均与上地壳长英质母岩沉积物比较接近，表明研究区沉积物母岩总体为属于长英质母岩。

Hf—La/Th图解[35]被广泛应用于沉积物物源的确定[19,36,37]。在Hf—La/Th图解中[图2(a)]，大部分样品点落在上地壳酸性母岩区域内，只有少数样品靠近被动大陆物源古老沉积物区，这表明研究区砂岩的母岩主要为来自上地壳的酸性火成岩。酸性火成岩相比镁铁质火成岩具有较高的REE与

Th含量，然而镁铁质火成岩的Co、Sc以及Cr含量相比前者更高，即Zr和Th等高场强元素在酸性火成岩中富集，而Sc和Co等相容元素则与铁镁质矿物相伴生，富集在中基性的火成岩中，因此这些元素的比值及其含量可以确定母岩类型[16,24,32]。根据Co/Th—La/Sc图解[16,38][图2(b)]，发现所有的样品均集中在酸性火山岩与花岗母岩区域内，表明中央峡谷沉积物的母岩为酸性岩。

表1 中央峡谷砂岩微量元素含量分析结果(×10⁻⁶)

Table 1 Trace elements contents of the sandstone from the Central Canyon(×10⁻⁶)

井名	L30-1	L30-2	L30-3	L30-4	L30-5	L30-6	L30-7	L30-8	L22-1	L22-2	L22-3	PAAS	UCC
Sc	5.0	6.5	5.9	6.1	6.9	7.1	7.2	7.3	8.3	8.4	8.0	16.0	14.0
V	37.8	48.7	45.9	47.5	49.6	54.7	51.9	52.3	65.0	67.7	61.6	150.0	97.0
Cr	45.1	47.8	45.5	49.7	58.2	61.1	70.0	68.5	65.4	75.0	75.0	110.0	92.0
Co	8.1	10.7	10.4	10.5	9.7	10.7	9.6	9.5	12.0	11.3	12.0	23.0	17.3
Ni	15.7	16.8	16.7	18.0	19.7	21.6	21.3	20.5	25.5	26.1	24.4	55.0	47.0
Cu	6.2	7.6	6.6	7.2	10.6	7.7	8.7	8.7	12.5	12.2	11.4	50.0	28.0
Zn	54.6	70.6	60.8	73.2	61.4	58.4	60.8	75.5	72.5	69.8	69.3	85.0	67.0
Rb	81.4	75.8	77.3	78.9	79.4	78.3	75.4	73.7	91.8	88.2	84.3	160.0	82.0
Sr	166.2	103.1	119.9	143.2	92.9	86.1	79.4	84.6	212.8	218.4	187.1	200.0	320.0
Y	21.0	23.8	21.8	19.1	19.5	19.3	23.2	24.7	23.7	24.4	24.8	27.0	21.0
Zr	341.9	334.0	288.2	268.6	234.6	273.0	419.3	474.7	320.2	309.1	359.4	210.0	193.0
Nb	8.8	10.2	8.8	9.0	11.5	12.5	13.4	14.4	11.6	12.4	12.9	19.0	12.0
Cs	2.0	2.4	2.4	2.6	2.9	2.9	2.8	2.7	4.3	4.0	3.6	15.0	4.9
Ba	824.4	335.9	459.1	389.7	367.0	337.6	341.8	413.1	2 562.0	4 446.0	3 762.0	650.0	628.0
La	28.3	32.4	31.7	29.0	29.3	31.5	37.0	39.2	33.1	35.2	38.0	38.2	31.0
Ce	64.4	74.7	73.1	67.4	65.0	69.7	80.1	84.9	71.9	75.8	83.1	79.6	63.0
Pr	6.9	7.9	7.8	7.1	7.1	7.6	8.7	9.3	7.9	8.3	9.1	8.8	7.1
Nd	26.5	30.4	29.9	27.2	26.6	28.6	32.5	34.6	29.8	31.2	34.6	33.9	27.0
Sm	5.5	6.3	6.1	5.5	5.3	5.5	6.4	6.8	6.0	6.2	6.8	5.6	4.7
Eu	1.0	1.2	1.1	1.0	1.0	1.0	1.1	1.1	1.3	1.4	1.4	1.1	1.0
Gd	5.0	5.7	5.5	4.8	4.6	4.7	5.4	5.7	5.4	5.6	6.0	4.7	4.0
Tb	0.7	0.8	0.8	0.7	0.7	0.7	0.8	0.9	0.8	0.8	0.9	0.8	0.7
Dy	4.1	4.7	4.4	3.9	3.8	3.8	4.5	4.7	4.5	4.6	4.8	4.7	3.9
Ho	0.8	0.9	0.8	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	1.0	0.8
Er	2.2	2.6	2.3	2.1	2.1	2.1	2.5	2.7	2.6	2.6	2.6	2.9	2.3
Tm	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3
Yb	2.2	2.4	2.2	2.0	2.0	2.0	2.4	2.6	2.5	2.5	2.5	2.8	2.0
Lu	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3
Hf	8.6	8.6	7.4	6.7	6.1	7.1	10.4	11.6	8.0	7.9	9.0	5.0	5.3
Ta	0.8	0.9	0.8	0.8	0.9	1.0	1.1	1.1	0.9	1.0	1.0	1.3	0.9
Pb	28.0	21.3	21.4	21.6	16.4	16.3	15.0	16.0	20.6	22.7	21.3	20.0	17.0
Th	13.3	11.6	11.2	10.7	10.8	11.8	13.6	14.5	11.2	12.0	12.8	14.6	10.5
U	2.0	1.7	1.6	1.5	1.6	1.8	2.2	2.4	2.0	2.1	2.1	3.1	2.7

沉积物中铁镁矿物微量元素(Cr、Ni及V)含量较高时，往往反映其母岩性质为镁铁质的[36,39-42]。Garver等[43]研究表明，沉积物中高含量的Cr(＞150×10⁻⁶)与Ni(＞100×10⁻⁶)往往与物源区镁铁质母岩有关。中央峡谷源头和峡谷中游Cr元素的平均含量分别为5.73×10⁻⁶与71.78×10⁻⁶，Ni元素的平均含量分别为18.79×10⁻⁶与25.29×10⁻⁶，这一含量与上地壳平均含量相一致，表明沉积物母岩绝非镁铁质的，应该属于酸性母岩。这一结论也在V—Ni—Th×10图解(图3)中得到了很好的证实，从该图解可以发现，中央峡谷砂岩样品点均集中在上地壳酸性母岩区(上地壳平均组成据文献[44])，表明

表 2　中央峡谷砂岩微量元素计算结果

Table 2　Calculated results of trace elements of the sandstone from the Central Canyon

井名	L30-1	L30-2	L30-3	L30-4	L30-5	L30-6	L30-7	L30-8	L22-1	L22-2	L22-3	PAAS	UCC
La/Sc	5.6	5.0	5.3	4.7	4.3	4.5	5.1	5.4	4.0	4.2	4.7	2.4	2.2
La/Co	3.5	3.0	3.1	2.8	3.0	3.0	3.9	4.1	2.8	3.1	3.2	1.7	1.8
Th/Sc	2.6	1.8	1.9	1.7	1.6	1.7	1.9	2.0	1.4	1.4	1.6	0.9	0.8
Cr/Th	3.4	4.1	4.1	4.7	5.4	5.2	5.1	4.7	5.8	6.3	5.9	7.5	8.8
La/Th	2.1	2.8	2.8	2.7	2.7	2.7	2.7	2.7	3.0	2.9	3.0	2.6	3.0
Co/Th	0.6	0.9	0.9	1.0	0.9	0.9	0.7	0.7	1.1	1.0	0.9	1.6	1.7
Zr/Sc	68.1	51.1	48.5	43.8	34.2	38.7	58.2	64.8	38.6	36.6	44.7	13.1	13.8
LREE	132.6	152.9	149.7	137.1	134.2	143.8	165.7	175.8	150.0	158.1	173.0	167.2	133.8
HREE	36.6	41.5	38.5	33.8	33.9	33.9	40.5	43.0	41.0	42.1	43.4	44.6	35.3
ΣREE	169.2	194.4	188.2	170.9	168.1	177.8	206.2	218.8	191.1	200.2	216.4	184.8	148.2
LREE/HREE	3.6	3.7	3.9	4.1	4.0	4.2	4.1	4.1	3.7	3.8	4.0	9.5	0.3
La/Yb	13.0	13.6	14.3	14.7	14.9	15.4	15.2	15.0	13.3	14.2	15.0	13.6	15.5
$(La/Yb)_N$	8.8	9.2	9.6	9.9	10.0	10.4	10.2	10.1	9.0	9.6	10.1	10.5	9.2
$(Gd/Yb)_N$	1.9	1.9	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.8	1.9	1.6	1.4
δEu	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.7	0.7	0.7	0.6	0.7
δCe	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0

表 3　中央峡谷砂岩微量元素比值与上地壳、长英质母岩的沉积岩以及镁铁母岩的沉积岩对比(平均上地壳比值据文献[24];长英质岩石及镁铁质岩石比值据文献[17,32,34];每一栏中的样品自上而下分别为 L30 井和 L22 井的样品)

Table 3　Range of distinctive elemental ratios of the sandstone from the Central Canyon compared to those in the average upper continental crust and sediments derived from felsic and mafic rocks

元素比值	中央峡谷砂岩	来自长英质母岩的沉积岩	来自镁铁质母岩的沉积岩	上地壳
Eu/Eu*	0.53～0.59(Av:0.57),0.66～0.71(Av:0.69)	0.40～0.94	0.71～0.95	0.63
La/Sc	4.26～5.64(Av:4.98),3.99～4.73(Av:4.30)	2.50～16.30	0.43～0.86	2.21
La/Co	2.76～4.11(Av:3.28),2.75～3.18(Av:3.01)	1.80～13.8	0.14～0.38	1.76
Th/Sc	1.58～2.64(Av:1.89),1.35～1.59(Av:1.45)	0.84～20.50	0.05～0.22	0.79
Cr/Th	3.40～5.37(Av:4.58),5.82～6.27(Av:5.99)	4.00～15.00	25～500	7.76

注:Av 为平均值

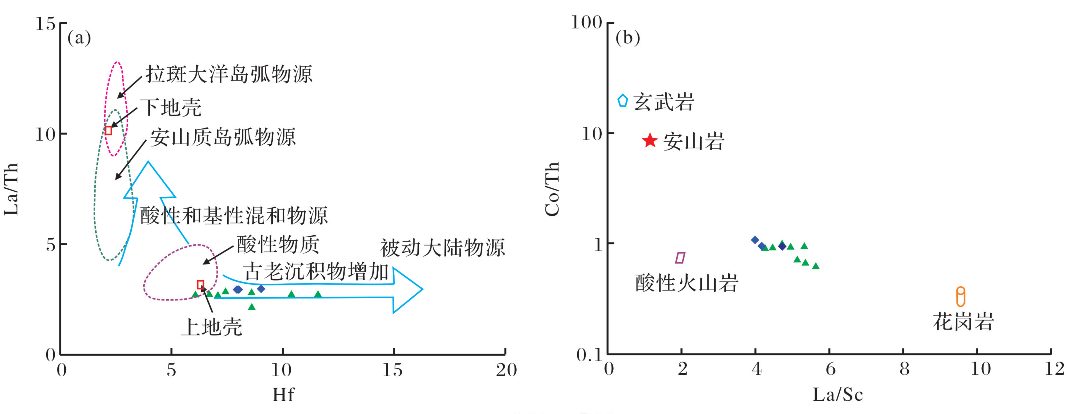

图 2　砂岩 Hf—La/Th 图解(a)(底图据文献[35])和 La/Sc—Co/Th 图解(b)(底图据文献[16])

Fig.2　The diagram of Hf-La(a) and La/Sc-Co/Th of sandstone(b)

其沉积物来自于酸性母岩区。

稀土元素球粒陨石标准化配分模式及 Eu 元素异常特征是判别碎屑沉积物母岩岩性的很好工具,多年来得到国内外学者的广泛应用[17,18,37,41,45]。总

体来说，镁铁质母岩如拉斑玄武岩轻稀土(LREE)相对较少，钙碱性母岩相对富集 LREE 并具有轻微的 Eu 异常，硅铝质母岩则富集轻稀土 LREE 并具有明显的负 Eu 异常[41]。中央峡谷砂岩稀土元素球粒陨石标准化配分模式见图 4(a)、图 4(b)。总体来看，研究区砂岩的稀土含量比较接近，总量介于 $(168.10\sim218.79)\times10^{-6}$ 之间，平均值为 191.01×10^{-6}，这些砂岩样品的稀土元素总量均接近于 PAAS 值而略高于 UCC 值。轻稀土(LREE)相对富集，La/Yb 值较高，介于 12.99～15.44 之间，平均值为 14.41。$(La/Yb)_N$ 值变化范围为 8.76～10.41，平均值为 9.72，LREE/HREE 值介于 3.62～4.24 之间，平均值为 3.91。铕具有明显的负异常，呈"V"字型，δEu $(\delta Eu=\omega(Eu)/(Eu^*)=2(Eu)_N/[\omega(Sm)_N+\omega(Gd)_N]$，δEu 值变化范围为 0.53～0.71，平均值为 0.6。铈异常不明显，δCe $(\delta Ce=\omega(Ce)/(Ce^*)=2(Ce)_N/[\omega(La)_N+\omega(Pr)_N]$，δCe 值变化范围为 1.03～1.10，平均值为 1.06。重稀土(HREE)相对平坦，$(Gd/Yb)_N$ 值变化范围为 1.74～2.01，平均值为 1.87。

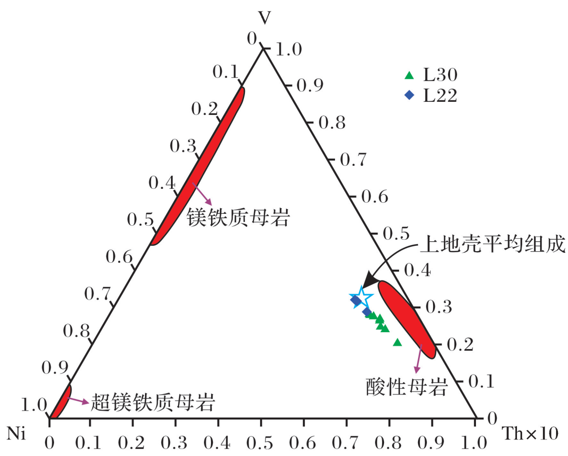

图 3　V—Ni—Th×10 母岩岩性判别三角图
(底图据文献[36,42])
Fig.3　V-Ni-Th×10 triangle diagram

综合以上研究，可以发现研究区砂岩的稀土元素球粒陨石标准曲线相互平行，轻稀土富集，重稀土平坦，明显的 Eu 负异常，Ce 无异常，并且与 UCC 和 PAAS 相一致，表明中央峡谷沉积物母岩为上地壳的酸性火成岩，这一特征与元素比值 Eu/Eu*、La/Sc、La/Co、Th/Sc、Cr/Th 以及岩性图解 La/Th—Hf、La/Sc—Co/Th、Ni—Th×10—V 相吻合。无论是元素比值还是各种源区岩性图解，以及稀土元素球粒陨石配分模式，均反映中央峡谷沉积物来自于上地壳的酸性母岩区。

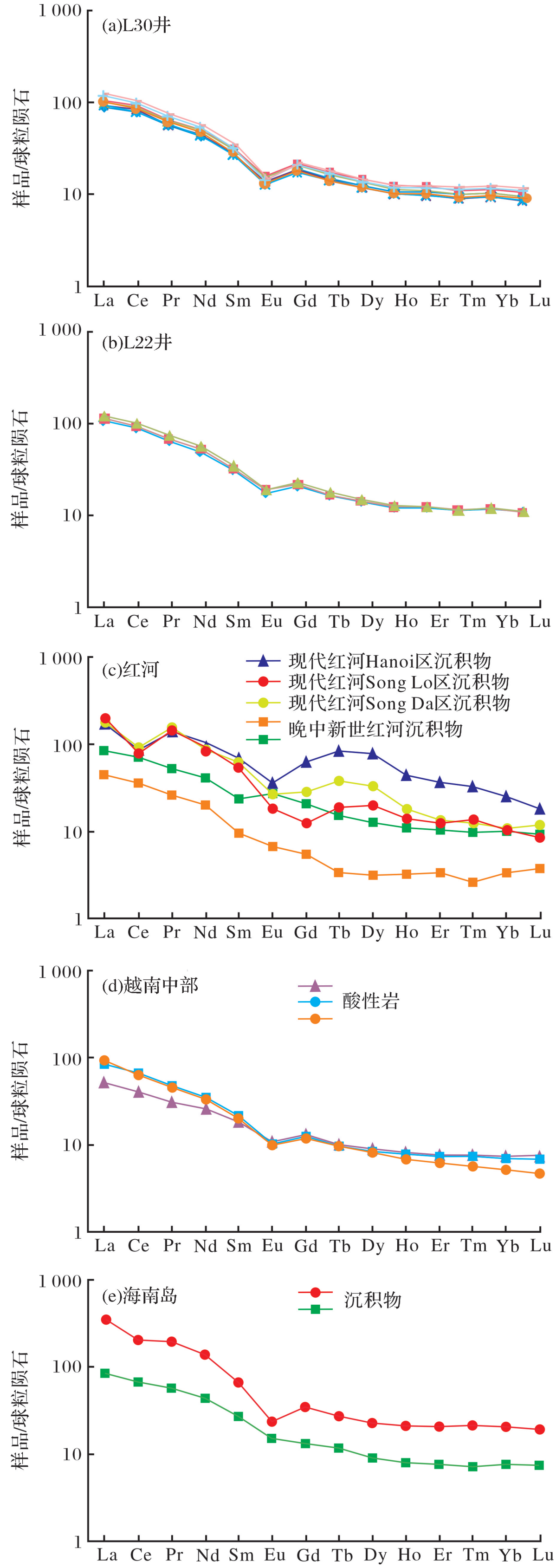

图 4　中央峡谷砂岩、红河、越南中部昆嵩隆起及海南岛稀土元素配分模式
Fig.4　REE distribution patterns of the sandstone from the Central Canyon, the Hainan Uplift, Red River, eastern Vietnam

4 沉积物来源分析

中央峡谷沉积物稀土元素特征相比红河物源具有明显差异，Clift 等[46]研究表明，现代红河流域 Hanoi 与 Song Da 地区的沉积物轻稀土相对富集，Eu、Ce 相对亏损，相对富集重稀土中的 Gd、Tb 以及 Dy，Song Lo 地区相比前 2 个地方有所不同的是无 Eu 异常，重稀土总体平坦，轻微富集 Tb、Dy 以及 Tm；晚中新世红河沉积物则具有轻稀土富集，重稀土相对平坦，Eu 轻微正异常或者无异常[图 4(c)]。王永凤等[13]研究表明，红河物源沉积物 δEu 值为 1.11，稀土元素球粒陨石标准化配分模式中 Eu 呈现正异常，表明母岩应以中基性岩/深部物质为主；越南中部酸性母岩的稀土元素总量为(176～182)×10^{-6}，轻稀土相对富集，$(La/Yb)_N$ 值介于 12.49～17.63 之间，重稀土相对平坦，Eu 呈略微宽缓“V”字型负异常，δEu 值变化范围为 0.61～0.64[47][图 4(d)]。海南岛沉积物稀土元素总量为(130.28～278.83)×10^{-6}，轻稀土相对富集，LREE/HREE 值介于 10.74～13.64 之间，$(La/Sm)_N$ 值介于 3.11～5.24之间，重稀土相对平坦，$(Gd/Yb)_N$ 值与 $(Gd/Lu)_N$ 值分别介于 1.70～1.72 与 1.76～1.82 之间，Eu 呈负异常，δEu 值变化范围为 0.46～0.75，表明母岩以酸性岩为主，这与海南隆起酸性岩广泛分布相一致[48,49][图 4(e)]。Zhao 等[50]研究表明，红河物源以基性—超基性变质岩和火成岩为主，显示 Eu 正异常特征，而海南岛物源以花岗岩及沉积岩为主，显示 Eu 负异常。综合红河、海南岛及越南中部三大物源区母岩岩性特征，可以发现中央峡谷沉积物母岩以来自上地壳的酸性岩为主，与越南中部及海南岛物源较为相似，首先可以确定红河物源并非主要物源区，而且海南岛物源稀土元素总量总体较高，这与中央峡谷沉积物有一定的差异，因此，中央峡谷沉积物稀土元素特征与越南中部物源最为接近。

本文研究应用了沉积岩重矿物组合及含量来进一步分析中央峡谷沉积物来源，中央峡谷的重矿物组合类型及相对含量见图 5。从重矿物组合图可以发现，总体以锆石、电气石、石榴子石、磁铁矿、赤褐铁矿以及白钛矿为主，绿帘石、角闪石、榍石、十字石以及独居石等矿物含量较低，除了峡谷源头的石榴子石与磁铁矿含量较低以外，整个中央峡谷砂岩主要重矿物含量一般都大于 4%，锆石、赤褐铁矿以及白钛矿含量高这一特征与越南中部沉积物重矿物特征相吻合[26]。前人研究表明，莺歌海盆地与琼东南盆地新生代沉积物具有三大潜在物源，分别为古红河、海南岛及越南中部[2-10,12]。结合元素地球化学及重矿物分析结果，可以发现，中央峡谷的物源主要为越南中部的酸性母岩区。

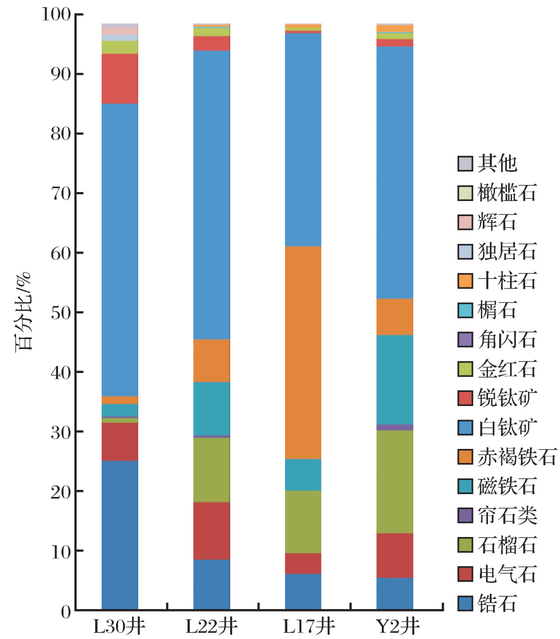

图 5 中央峡谷砂岩重矿物组合

(L22 井及 Y2 井数据来自文献[8])

Fig.5 Heavy mineral assemblages of the sandstone from the Central Canyon

在上述研究的基础上，本文也运用了碎屑锆石测年方法。结合前人研究成果，对比了中央峡谷与三大潜在物源区(红河、海南岛及越南中部)的碎屑锆石年龄(图 6)。中国在地史时期发生了一些大的构造运动，分别为喜马拉雅期(＜约 66Ma)、燕山期(66～205Ma)、印支期(205～300Ma)、海西期(300～360Ma)、加里东期(360～500Ma)、晋宁期(850～1 000Ma)、吕梁期(1 800～2 400Ma)及阜平期(2 400～2 600Ma)[9]。由锆石年龄谱图可以看出，红河物源存在 3 个主要的峰，分别为 246Ma、390Ma 以及 750Ma，另外还有 4 个次级峰：85Ma、520Ma、606Ma 以及 967Ma[图 6(a)]，主要对应于燕山期、印支期、加里东期以及晋宁期的岩浆活动。海南岛物源具有 3 个主要的锆石年龄峰，分别为 98Ma、158Ma 以及 246Ma[图 6(b)]，分别对应于燕山期和印支期的岩浆活动。越南中部物源具有 3 个主要的年龄峰，分别为 254Ma、450Ma 以及 1110Ma[图 6(c)]。中央峡谷的锆石年龄介于 30～2600Ma 之间，包括 4 个主要的年龄段：100～160Ma、230～250Ma、420～450Ma 以及 700～1100Ma[图 6(d)]。

总体来看，中央峡谷砂岩的碎屑锆石年龄对应主要的构造运动为燕山期、印支期、加里东期、晋宁期，与越南中部和红河物源较为相似，结合前文元素地球化学及重矿物的证据，可以确定中央峡谷的物源以越南中部为主，可能受到红河及海南岛物源的影响。

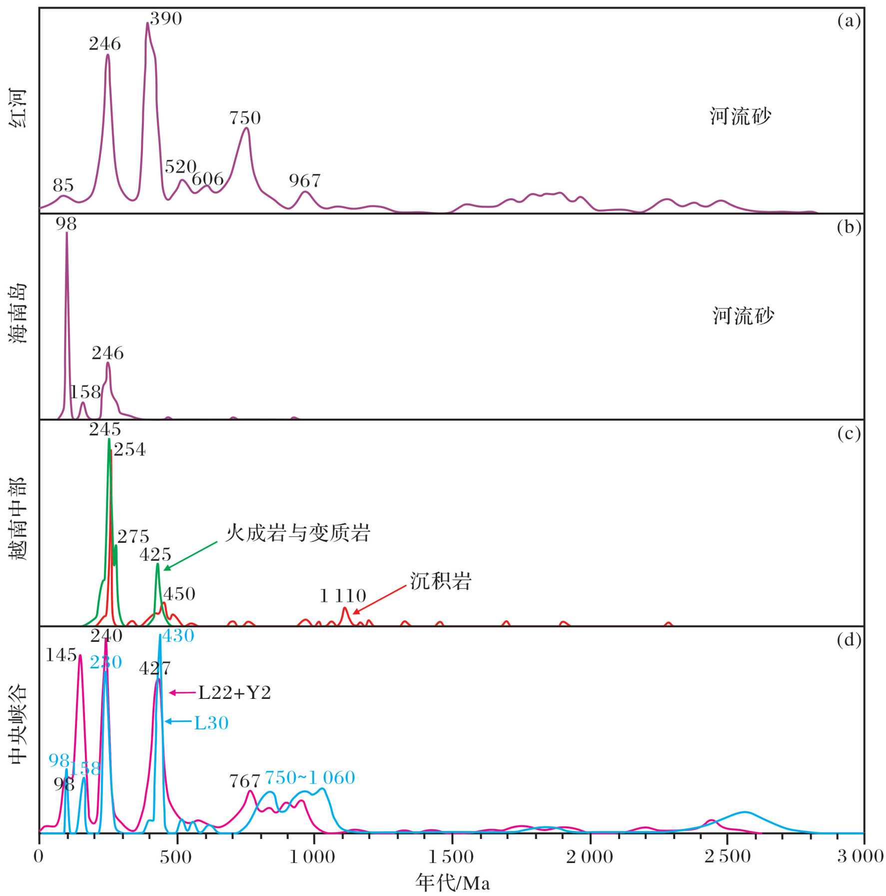

图 6　中央峡谷砂岩与三大物源区碎屑锆石年龄频谱

(红河砂岩数据引自文献[51,52]；越南中部火成岩与变质岩数据引自文献[47,53-56]；越南中部沉积岩数据引自文献[57]；中央峡谷中游(L22＋Y2)数据引自文献[8]，中央峡谷源头(L30)数据引自文献[6])

Fig.6　Kernel density estimation plots and pie charts for U-Pb ages of(a,b,c) potential source areas and(d) Central Canyon sandstones

上述结论与越南昆嵩隆起带发育的花岗岩锆石年龄相吻合，昆嵩隆起发育多种类型的花岗岩，而且分布范围广[58,59]，其锆石年龄分别为：前寒武纪时期1 717～1 368Ma[59]，760～723Ma[60]；早古生代时期428±5Ma[61,62]、早中生代时期248～245Ma[63]，253±2Ma[64]，晚中生代时期93.9±3.0Ma[65]，87.3±1.2Ma[63]；昆嵩隆起在新生代以超镁铁质—镁铁质喷出岩为主[66]，而红河剪切带周边花岗岩形成年龄集中在60～20Ma之间[67-69]。因此，中央峡谷沉积物主要来源于越南中部。

5　结论

(1)微量元素含量及其相关比值(Eu/Eu*、La/Sc、La/Co、Th/Sc以及Cr/Th)，Hf—La/Th、La/Sc—Co/Th与V—Ni—Th×10图解以及稀土元素球粒陨石标准化配分模式均显示中央峡谷沉积物母岩为上地壳的酸性岩。

(2)对比三大潜在物源区(红河、海南岛及越南中部)沉积物的稀土元素配分模式，发现中央峡谷沉积物稀土元素球粒陨石标准化配分模式与越南中部最为接近；重矿物中锆石、赤褐铁矿以及白钛矿含量高这一特征与越南中部沉积物重矿物特征相吻合；结合前人有关中央峡谷碎屑锆石测年的相关研究，发现中央峡谷的锆石年龄包括4个主要的年龄段：100～160Ma、230～250Ma、420～450Ma以及700～1 100Ma，对应主要的构造运动为：燕山期、印支期、加里东期、晋宁期，与越南中部和红河物源较为相

似;综合以上研究结果,确定中央峡谷的物源主要来自越南中部。

参考文献(References)

[1] Yang Jinhai,Li Cai,Li Tao,*et al*.Accumulation condition and model of gas reservoir in Central Caynon in deepwater area of northern South ChinaSea[J].Acta Geologica Sinica,2014,88(11):2141-2149.[杨金海,李才,李涛,等.琼东南盆地深水区中央峡谷天然气成藏条件与成藏模式[J].地质学报,2014,88(11):2141-2149.]

[2] Clift P D,Sun Z.The sedimentary and tectonic evolution of the Yinggehai-Song Hong Basin and the southern Hainan margin,South China Sea:Implications for Tibetan uplift and monsoon intensification[J].Journal of Geophysical Research Atmospheres,2006,111(B6):232-241.

[3] Yan Y,Carter A,Palk C,*et al*.Understanding sedimentation in the Song Hong-Yinggehai Basin,South China Sea[J].Geochemistry Geophysics Geosystems,2011,12(6):48-58.

[4] Wang C,Liang X Q,Xie Y H,*et al*.Provenance of Upper Miocene to Quaternary sediments in the Yinggehai-Song Hong Basin,South China Sea:Evidence from detrital zircon U-Pb ages[J].Marine Geology,2014,355(9):202-217.

[5] Wang C,Liang X Q,Xie Y H,*et al*.Late Miocene provenance change on the eastern margin of the Yinggehai-Song Hong Basin,South China Sea:Evidence from U-Pb dating and Hf isotope analyses of detrital zircons[J].Marine & Petroleum Geology,2015,61:123-139.

[6] Wang C,Liang X Q,Fu J G,*et al*.Detrital zircon provenance of Pliocene Yinggehai Formation in the Ledong Gasfield of the Yinggehai-Song Hong Basin[J].Acta Geologica Sinica,2015,89(s1):279-280.

[7] Wang C,Liang X Q,Foster D A,*et al*.Zircon U-Pb geochronology and heavy mineral composition constraints on the provenance of the Middle Miocene deep-water reservoir sedimentary rocks in the Yinggehai-Song Hong Basin,South China Sea[J].Marine & Petroleum Geology,2016,77:819-834.

[8] Cao L C,Jiang T,Wang Z F,*et al*.Provenance of Upper Miocene sediments in the Yinggehai and Qiongdongnan Basins,northwestern South China Sea:Evidence from REE,heavy minerals and zircon U-Pb ages[J].Marine Geology,2015,361:136-146.

[9] Chen H,Xie X N,Guo J L,*et al*.Provenance of Central Canyon in Qiongdongnan Basin as evidenced by detrital zircon U-Pb study of Upper Miocene sandstones[J].Chinese Science:Earth Science,2015,58(8):1-13.

[10] Jiang T,Cao L C,Xie X N,*et al*.Insights from heavy minerals and zircon U-Pb ages into the middle Miocene-Pliocene provenance evolution of the Yinggehai Basin,northwestern South China Sea[J].Sedimentary Geology,2015,327:32-42.

[11] Wang Yingmin,Xu Qiang,Li Dong,*et al*.Late Miocene Red River submarine fan,northwestern South China Sea[J].Chinese Science Bulletin,2011,56(10):781-787.[王英民,徐强,李冬,等.南海西北部晚中新世的红河海底扇[J].科学通报,2011,56(10):781-787.]

[12] Sun M,Wang H,Liao J H,*et al*.Sedimentary characteristics and model of gravity flow depositional system for the first member of Upper Miocene Huangliu Formation in Dongfang area,Yinggehai Basin,northwestern South China Sea[J].Journal of Earth Science,2014,25(3):506-518.

[13] Wang Yongfeng,Wang Yingmin,Li Dong,*et al*.Features and source analysis on Early Pliocene sedimentary Rare Earth Element(REE) in Central Canyon of Qiongdongnan Basin[J].Journal of Oil & Gas Technology,2011,33(6):50-52.[王永凤,王英民,李冬,等.琼东南盆地中央峡谷早上新世沉积物稀土元素特征及物源分析[J].石油天然气学报,2011,33(6):50-52.]

[14] Li Dong,Xu Qiang,Wang Yongfeng,*et al*.Provenance analysis of the Pliocene Central Canyon in Qiongdongnan Basin and its implications[J].Acta Sedimentologica Sinica,2015,33(4):659-664.[李冬,徐强,王永凤,等.琼东南盆地上新世中央峡谷物源分析及其意义[J].沉积学报,2015,33(4):659-664.]

[15] Zuo Qianmei,Zhang Daojun,He Weijun,*et al*.Provenance analysis of Huangliu Formation of the Central Canyon system in the deepwater area of the Qiongdongnan Basin[J].Journal of Oceanography,2015,37(5):15-23.[左倩媚,张道军,何卫军,等.琼东南盆地深水区中央峡谷黄流组物源特征[J].海洋学报,2015,37(5):15-23.]

[16] Mclennan S M,Hemming S,Mcdaniel D K,*et al*.Geochemical approaches to sedimentation,provenance,and tectonics[J].Special Paper of the Geological Society of America,1993,284:21-40.

[17] Cullers R L.The chemical signature of source rocks in size fractions of Holocene stream sediment derived from metamorphic rocks in the Wet Mountains region,Colorado,U.S.A[J].Chemical Geology,1994,113(3/4):327-343.

[18] Armstrong-Altrin J S,Yong I L,Kasper-Zubillaga J J,*et al*.Geochemistry of beach sands along the western Gulf of Mexico,Mexico:Implication for provenance[J].Chemie der Erde-Geochemistry,2012,72(4):345-362.

[19] Tao H F,Wang Q C,Yang X F,*et al*.Provenance and tectonic setting of Late Carboniferous clastic rocks in West Junggar,Xinjiang,China:A case from the Hala-alat Mountains[J].Journal of Asian Earth Sciences,2013,64:210-222.

[20] Talibi H E,Zaghloul M N,Perri F,*et al*.Sedimentary evolution of the siliciclastic Aptian-Albian Massylian flysch of the Chouamat Nappe(central Rif,Morocco)[J].Journal of African Earth Sciences,2014,100(100):554-568.

[21] Perri F.Composition,provenance and source weathering of Mesozoic sandstones from Western-Central Mediterranean

Alpine Chains[J].Journal of African Earth Sciences,2014,91(91):32-43.

[22] Perri F,Critelli S,Dominici R,*et al*.Provenance and accommodation pathways of Late Quaternary sediments in the deep-water northern Ionian Basin,southern Italy[J].Sedimentary Geology,2012,280(4):244-259.

[23] Perri F,Critelli S,Dominici R,*et al*.Sourceland controls and dispersal pathways of Holocene muds from boreholes of the Ionian Basin,Calabria,southern Italy[J].Geological Magazine,2015a,152(6):1-6.

[24] Taylor S R,McLennan S M.The Continental Crust:Its Composition and Evolution[M].Oxford:Blackwell Scientific Publishers,1985.

[25] Mclennan S M.Rare earth elements and sedimentary rocks:Influence of provenance and sedimentary processes[J].Reviews in Mineralogy,1989,21(8):169-200.

[26] Zhong Zehong,Liu Jinghuan,Zhang Daojun,*et al*.Origin and sedimentary reservoir characteristics of a large submarine fan in Dongfang area,Yinggehai Basin[J].Acta Petrolei Sinica,2013,34(S2):102-111.[钟泽红,刘景环,张道军,等.莺歌海盆地东方区大型海底扇成因及沉积储层特征[J].石油学报,2013,34(S2):102-111.]

[27] Liu C H,Liu F L,Shi J R,*et al*.Depositional age and provenance of the Wutai Group:Evidence from zircon U-Pb and Lu-Hf isotopes and whole-rock geochemistry[J].Precambrian Research,2016,281:269-290.

[28] Wu S G,Sun Q L,Wu T U,*et al*.Polygonal fault and oil-gas accumulation in deep-water area of Qiongdongnan Basin[J].Acta Petrolei Sinica,2009,30(1):22-26,32.

[29] Lei Chao.Structure and Evolution of Yinggehai and Qiongdongnan Basins,South China Sea:Implications for Cenozoic Tectonics in Southeast Asia[D].Beijing:China University Of Geosciences,2012.[雷超.南海北部莺歌海—琼东南盆地新生代构造变形格局及其演化过程分析[D].北京:中国地质大学,2012.]

[30] Zhu Weilin,Mi Lijun.Atlas of Oil and Gas Basins,China Sea[M].Beijing:Petroleum Industry Press,2010:3-316.[朱伟林,米立军.中国海域含油气盆地图集[M].北京:石油工业出版社,2010:3-316.]

[31] Ma Ming,Chen Guojun,Lv Chengfu,*et al*.Eocene-Low Oligocene sedimentary environment and mudstone provenance in Baiyun Sag,Pearl River Mouth Basin[J].Acta Petrolei Sinica,2016,37(5):610-621.[马明,陈国俊,吕成福,等.珠江口盆地白云凹陷始新统-下渐新统沉积环境与泥岩物源[J].石油学报,2016,37(5):610-621.]

[32] Armstrong-Altrin J S,Yong I L,Verma S P,*et al*.Geochemistry of sandstones from the Upper Miocene Kudankulam Formation,southern India:Implications for provenance,weathering,and tectonic setting[J].Journal of Sedimentary Research,2004,74(2):285-297.

[33] Shynu R,Rao V P,Parthiban G,*et al*.REE in suspended particulate matter and sediment of the Zuari estuary and adjacent shelf,western India:Influence of mining and estuarine turbidity[J].Marine Geology,2013,346(7):326-342.

[34] Cullers R L.The geochemistry of shales,siltstones and sandstones of Pennsylvanian-Permian age,Colorado,USA:Implications for provenance and metamorphic studies[J].Lithos,2000,51(3):181-203.

[35] Floyd P A,Leveridge B E.Tectonic environment of the Devonian Gramscatho Basin,south Cornwall:Framework mode and geochemical evidence from turbidite sandstones[J].Journal of the Geological Society,1987,144(4):531-542.

[36] Etemad-Saeed N,Hosseini-Barzi M,Armstrong-Altrin J S,*et al*.Petrography and geochemistry of clastic sedimentary rocks as evidences for provenance of the Lower Cambrian Lalun Formation,Posht-e-badam block,Central Iran[J].Journal of African Earth Sciences,2011,61(2):142-159.

[37] Tao H F,Sun S,Wang Q C,*et al*.Petrography and geochemistry of lower carboniferous greywacke and mudstones in northeast Junggar,China:Implications for provenance,source weathering,and tectonic setting[J].Journal of Asian Earth Sciences,2015,87(12):11-25.

[38] Sun W H,Zhou M F,Yan D P,*et al*.Provenance and tectonic setting of the Neoproterozoic Yanbian Group,western Yangtze Block(SW China)[J].Precambrian Research,2008,167(1):213-236.

[39] Perri F,Caracciolo L,Cavalcante F,*et al*.Sedimentary and thermal evolution of the Eocene-Oligocene mudrocks from the southwestern Thrace Basin(NE Greece)[J].Basin Research,2016,28(3):199-211.

[40] Cullers R,Chaudhuri S,Kilbane N,*et al*.Rare-earths in size fractions and sedimentary rocks of Pennsylvanian-Permian age from the mid-continent of the U.S.A[J].Geochimica Et Cosmochimica Acta,1979,43(8):1285-1301.

[41] Cullers R L,Bock B,Guidotti C,*et al*.Elemental distributions and neodymium isotopic compositions of Silurian metasediments,western Maine,USA:Redistribution of the rare earth elements[J].Geochimica Et Cosmochimica Acta,1997,61(9):1847-1861.

[42] Bracciali L,Marroni M,Luca P,*et al*.Geochemistry and petrography of western Tethys Cretaceous sedimentary covers(Corsica and Northern Apennines):From source areas to configuration of margins[J].Special Paper of the Geological Society of America,2007,420:73-93.

[43] Garver J I,RoycePR,Smick T A,*et al*.Chromium and nickel in shale of the Taconic Foreland:A case study for the provenance of fine-grained sediments with an ultramafic source[J].Journal of Sediment Research,1996,66(1):100-106.

[44] Plank T,Langmuir C H.The chemical composition of subducting sediment and its consequences for the crust and mantle

[J].Chemical Geology,1998,145(3):325-394.

[45] Armstrong-Altrin J S,Machain-Castillo M L,Rosales-Hoz L,*et al*.Provenance and depositional history of continental slope sediments in the Southwestern Gulf of Mexico unraveled by geochemical analysis[J].Continental Shelf Research,2015,95:15-26.

[46] Clift P D,Long H V,Hinton R,*et al*.Evolving East Asian river systems reconstructed by trace element and Pb and Nd isotope variations in modern and ancient Red River-Song Hong sediments[J].Geochemistry Geophysics Geosystems,2013,9(4):540-549.

[47] Liu J L,Tran M D,Yuan Tang,*et al*.Permo-Triassic granitoids in the northern part of the Truong Son belt,NW Vietnam:Geochronology,geochemistry and tectonic implications[J].Gondwana Research,2012,22(2):628-644.

[48] Shao Lei,Li Ang,Wu Guoxuan,*et al*.Evolution of sedimentary environment and provenance in Qiongdongnan Basin in the northern South China Sea[J].Acta petroleum Sinica,2010,31(4):548-552.[邵磊,李昂,吴国瑄,等.琼东南盆地沉积环境及物源演变特征[J].石油学报,2010,31(4):548-552.]

[49] Cao Licheng. Provenance Evolution Since Neogene in the YinggehaiandQiongdongnan Basins: Evidence from REE, Heavy Mineral and Zircon U-Pb Ages[D].Beijing:China University of Geosciences,2014.[曹立成.莺歌海—琼东南盆地区新近纪物源演化研究[D].北京:中国地质大学,2014.]

[50] Zhao M,Shao L,Liang J S,*et al*.No Red River capture since the Late Oligocene:Geochemical evidence from the northwestern South China Sea[J].Deep Sea Research Part II Topical Studies in Oceanography,2015,122:185-194.

[51] Clift P D,Carter A,Campbell I H,*et al*.Thermochronology of mineral grains in the Red and Mekong Rivers,Vietnam:Provenance and exhumation implications for Southeast Asia[J].Geochemistry Geophysics Geosystems,2006,7(10):207-208.

[52] Hoang L V,Wu F Y,Clift P D,*et al*.Evaluating the evolution of the Red River system based on in situ U-Pb dating and Hf isotope analysis of zircons[J].Geochemistry Geophysics Geosystems,2009,10(11):292-310.

[53] Carter A,Roques D,Bristow C,*et al*.Understanding Mesozoic accretion in Southeast Asia:significance of Triassic thermotectonism (Indosinian orogeny) in Vietnam[J]. Geology, 2001, 29(3): 211-214.

[54] Usuki T,Lan C Y,Yui T F,*et al*.Early Paleozoic medium-pressure metamorphism in central Vietnam: evidence from SHRIMP U-Pb zircon ages[J].Geosciences Journal,2009,13(3):245-256.

[55] Nakano N,Osanai Y,Owada M,*et al*.Tectonic evolution of high-grade metamorphic terranes in central Vietnam:Constraints from large-scale monazite geochronology[J].Journal of Asian Earth Sciences,2013,73(8):520-539.

[56] Hai T T,Zaw K,Halpin J A,*et al*.The Tam Ky-Phuoc Son Shear Zone in central Vietnam:Tectonic and metallogenic implications[J].Gondwana Research,2013,26(1):144-164.

[57] Burrett C,Zaw K,Meffre S,*et al*.The configuration of greater Gondwana-Evidence from LA ICPMS,U-Pb geochronology of detrital zircons from the Palaeozoic and Mesozoic of Southeast Asia and China[J].Gondwana Research,2014,26(1):31-51.

[58] Wu Liangshi.Geological structure and regional metallogeny in Socialist Republic of Vietnam[J].Mineral Deposits,2009,28(5):725-727.[吴良士.越南社会主义共和国地质构造与区域成矿[J].矿床地质,2009,28(5):725-727.]

[59] Xie Yuhong,Tong Chuanxin,Pei Jianxiang,*et al*.Detrital zircon ages and reservoir source of the second member of the Huangliu Formation in the Yinggehai Basin[J].Geotectonica et Metallogenia,2016,40(3):517-530.[谢玉洪,童传新,裴健翔,等.莺歌海盆地黄流组二段碎屑锆石年龄与储层物源分析[J].大地构造与成矿学,2016,40(3):517-530.]

[60] Wang P L,Lo C H,Lan C Y,*et al*.Thermochronology of the PoSen complex,northern Vietnam:Implications for tectonic evolution in SE Asia[J].Journal of Asian Earth Sciences,2011,40(5):1044-1055.

[61] Roger F,Leloup P H,Jolivet M,*et al*.Long and complex thermal history of the Song Chay metamorphic dome(Northern Vietnam) by multi-system geochronology[J].Tectonophysics,2000,321(4):449-466.

[62] Roger F,Maluski H,Leyreloup A,*et al*.U-Pb dating of high temperature metamorphic episodes in the Kon Tum Massif (Vietnam)[J].Journal of Asian Earth Sciences,2007,30(3):565-572.

[63] Roger F,Maluski H,Lepvrier C,*et al*.LA-ICPMS zircons U/Pb dating of Permo-Triassic and Cretaceous magmatisms in Northern Vietnam-Geodynamical implications[J].Journal of Asian Earth Sciences,2012,48(6):72-82.

[64] Nagy E A,Maluski H,Lepvrier C,*et al*.Geodynamic Significance of the Kontum Massif in Central Vietnam:Composite $^{40}Ar/^{39}Ar$ and U-Pb Ages from Paleozoic to Triassic[J].The Journal of Geology,2001,109(6):755-770.

[65] Wang Dongsheng,Liu Junlai,Mydung T,*et al*.Geochronology,geochemistry and tectonic significance of granites in the Tinh Túc W-Sn ore deposits,Northeast Vietnam[J].Acta Petrologica Sinica,2011,27(9):2795-2808.[王东升,刘俊来,TRAN My Dung,等.越南东北部静足(Tinh Túc)钨锡矿区花岗岩年代学、地球化学与区域构造意义[J].岩石学报,2011,27(9):2795-2808.]

[66] Xie Yuhong,Zhang Yingchao,Li Xushen,*et al*.Main controlling factors and formation models of natural gas reservoirs with high-temperature and overpressure in Yinggehai Basin[J].Acta Petrolei Sinica,2012,33(4):601-609.[谢玉洪,张迎朝,李绪深,等.莺歌海盆地高温超压气藏控藏要素与成藏模式[J].石油学报,2012,33(4):601-609.]

[67] Leloup P H,Lacassin R,Tapponnier P,*et al*.The Ailao Shan-

Red River shear zone (Yunnan, China), Tertiary transform boundary of Indochina[J]. Tectonophysics, 1995, 251(1-4): 3-10.

[68] Zhang L S, Schärer U. Age and origin of magmatism along the Cenozoic Red River shear belt, China[J]. Contributions to Mineralogy and Petrology, 1999, 134(1): 67-85.

[69] Liu F L, Wang F, Liu P H, *et al*. Multiple metamorphic events revealed by zircons from the Diancang Shan-Ailao Shan metamorphic complex, southeastern Tibetan Plateau[J]. Gondwana Research, 2013, 24(1): 429-450.

Provenance of Central Canyon in the Upper Miocene to the Pliocene in the Qiongdongnan Basin

Yin Na[1,2], Yang Hai-zhang[3], Ma Ming[1], Zhang Gong-cheng[3], Lü Cheng-fu[1], Zhao Zhao[3], Li Chao[1]

(1. *Key Laboratory of Petroleum Resources, Gansu Province / Key Laboratory of Petroleum Resources Research, Institute of Geology and Geophysics, Chinese Academy of Sciences, Lanzhou* 730000, *China*; 2. *University of Chinese Academy of Sciences, Beijing* 100049, *China*; 3. *CNOOC Research Institute, Beijing* 100027, *China*)

Abstract: In this paper, trace and Rare Earth Elements (REE), heavy mineral data and detrital zircon U-Pb ages were used to determine the provenance of Central Canyon in the Upper Miocene to the Pliocene in the Qiongdongnan Basin. The results show that the total REE contents range from 168.10×10^{-6} to 218.79×10^{-6}, with a mean value of 191.01×10^{-6}, whereas the samples show values similar to those of PAAS and higher than that of UCC. These sandstone samples are characterized by the enrichment of Light Rare Earth Elements (LREE), with high ratios of La/Yb=12.99-15.44 (Av. 14.41), $(La/Yb)_N$=8.76-10.41 (Av. 9.72) and $\sum$LREE/$\sum$HREE=3.62-4.24 (Av. 3.91), a negative Eu anomaly (δEu=Eu/Eu* range from 0.53 to 0.71, average 0.6) and normal amounts of Ce (δCe=Ce/Ce* range from 1.03 to 1.10, average 1.06). Heavy Rare Earth Elements (HREE) show an almost flat distribution, with $(Gd/Yb)_N$ ratios ranging from 1.74 to 2.01 (average 1.87). The comparison of REE patterns suggest that the sandstones from Central Canyon System were derived from an old upper continental crust mainly composed of felsic igneous source rocks, as also shown by the ratios of Eu/Eu*, La/Sc, La/Co, Th/Sc and Cr/Th and the diagram of La/Th-Hf, La/Sc-Co/Th and Ni-Th×10-V. These characteristics are similar to the felsic igneous source rocks in the Central Vietnam. Zircon, hematite and limonite, and leucoxene are the most frequent heavy mineral and are associated with the sediments in Central Vietnam. The zircon U-Pb ages of sandstone samples from the Central Canyon System have a range of 30-2 600Ma, including four peak groups: 100-160Ma, 230-250Ma, 420-450Ma and 700-1 100Ma. All these characteristics are associated with the zircon U-Pb ages of the felsic igneous source rocks in the Kontum massif in the eastern Indo-china Block.

Key words: Qiongdongnan Basin; Upper Miocene; Pliocene; Central Canyon; Provenance