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中国新近纪构造－地层区划及地层格架

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摘　要:新近纪是中国地貌地形和气候环境格局最终奠定的关键时期,如青藏高原强烈抬升和现代高原地貌最终成型、中国南海海盆扩张结束、东亚现今大型水系格局最终建立、中国西高东低的地势最终确立以及东亚季风系统开始形成并逐渐增强.通过对中国新近纪大地构造、沉积盆地(群)、火山岩、隆起带和大型变形构造等的综合研究,共厘定一级构造－地层单元(大区)10个,二级构造－地层单元27个(区),包含各类沉积盆地94个.通过综合各个地层分区内盆地的盆地类型、沉积序列、沉积时代及地层接触关系的研究,重新厘定了中国新近纪岩石地层对比格架,并对中国新近纪时期沉积－构造－气候耦合历史进行了系统总结.

关键词:新近纪;构造－地层区划;地层对比;沉积盆地;地层学.

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Neogene Tectonic-Stratigraphic Realms and Sedimentary Sequence in China

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Abstract: Neogene is the key period for the establishment of geomorphology and pattern of climate changes in China, involving the significant uplift of Tibetan Plateau and final formation of modern plateau landform, the termination of seafloor spreading for the South China Sea, the final establishment of the present large river system in East Asia, the final establishment of the west-tilting topography of China, the formation and enhancement of East Asian monsoon system. Through the comprehensive study of Neogene tectonics, sedimentary basins (groups), volcanic rocks, uplifting belts and large deformation structures in China, 10 first-order tectonic-stratigraphic units (super-realms) and 27 second-order tectonic-stratigraphic units (realms) have been subdivided, including 94 basins. Through the research of the types of basins in each unit, sedimentary sequence, sedimentary age and stratigraphic contact, the Neogene lithostratigraphic correlation framework in China was established and the sedimentary-tectonic-

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climate history was summarized.

Key words: Neogene; tectonic-stratigraphic division; stratigraphic correlation; sedimentary basin; stratigraphy.

新近纪是地球新生代的第2个纪.在构造尺度上,新近纪是中国构造、地貌和气候发展演变历程中的一个重要的时期:青藏高原整体在新近纪时期表现为强烈隆升并向外扩展,高原现今的构造和地貌格局在该时期基本定型(Zhang *et al*., 2010; Wang *et al*., 2011; 张克信等,2013;Wang *et al*., 2014);青藏高原系列大型断裂构造的强烈变形调整和大型水系系统格局的建立主要在中新世完成(付碧宏等,2009);青藏高原新近纪显著隆升造就东亚地区大尺度上的地貌反转,中国现今西高东低的宏观地貌地形格局在新近纪最终奠定(汪品先,2005;Zhang *et al*., 2010);青藏高原的形成所制约的东亚季风系统在新近纪以来开始形成并逐渐增强(An *et al*., 2001);东亚气候由古近纪时期行星风系主控的带状气候模式向季风主控的气候模式转换(刘东生等,1998;施雅风等,1999;Sun and Wang, 2005);现今中国西北内陆干旱而东部地区湿润的气候格局在晚上新世最终奠定(Guo *et al*., 2008).此外,新近纪期间发生了多次重要的全球性生物和气候事件,包括渐新世－中新世之交全球珊瑚的大规模灭绝、晚中新世C4植被的大规模扩展以及原始人类的出现(图1,Zachos *et al*., 2001).新近纪同时是全球气候与环境发生变化的重要转折期,发生的重要气候事件包括(图1,Zachos *et al*., 2001, 2008):①中中新世气候适宜期(MMCO,17～14 Ma),代表了中新世气候最温暖的时期,14 Ma之后伴随着全球CO_2浓度降低事件,全球气候迅速变冷,地球南极冰盖扩展到近似现今的规模;②晚中新世(～8 Ma)亚洲季风增强和C4植被扩张事件,发生于约8 Ma;③晚上新世气候转型事件(～3 Ma),北半球大冰盖开始快速扩张,气候持续变冷,陆地植被向低纬收缩,显著改变了全球气候和陆地生态系统.因此,建立中国新近纪构造－地层区划及地层对比格架,是进一步深入研究新近纪时期地球表层岩石圈－水圈－大气圈－生物圈等多圈层耦合演化的基石,意义十分重大.

1 构造－地层区划

本文对中国新近纪构造地层区划遵循先前订立的地层区划原则(张克信等,2015,2017,2020),在先前开展的有关中国古近纪构造－地层区划研究中已经详细描述(宋博文等,2020),故本文不再赘述.以上述划分原则为指导,划分出中国新近纪各类盆地94个(图2),归属为(1)西北压陷区、(2)羌塘－三江压陷－走滑区、(3)冈底斯陆缘弧区、(4)喜马拉雅汇聚挤压区、(5)秦祁昆挤压区、(6)华北伸展断陷－坳陷区、(7)东北裂陷区、(8)华南隆起区、(9)中国东部陆缘裂谷－盆岭区和(10)东南亚多岛弧盆系区共10个构造－地层大区,进一步细分为27个构造－地层区(图2).

2 各构造－地层大区特征概述

2.1 西北压陷区

西北压陷区根据盆地类型和盆地沉积充填序列特征,划分为阿尔泰隆起区、准噶尔－吐哈压陷区、天山－北山逆冲－走滑区、塔里木压陷区和阿尔金－阿拉善隆起区(图2,图3).

阿尔泰隆起区新近纪期间主体为剥蚀区,没有沉积记录.

准噶尔－吐哈压陷区包含布尔津盆地、塔城盆地、伊宁盆地、准噶尔盆地和吐哈盆地.以准噶尔盆地为代表,该盆地南部新近纪整体表现为较稳定的沉积期,为均衡沉降区,以塔西河组、独山子组和西域组沉积为代表(图3,Ji *et al*., 2008);盆地北部新近纪地层序列由老到新依次为索索泉组、哈拉玛盖组、可可买登组和西域组(图3,李云通等,1984;叶捷等,2012).而其中西域组(或称西域砾岩)在该区域的分布显示其底界具有穿时性,其年代在前陆盆地不同构造部位存在差异,其底界年龄可跨越中新世到第四纪(Chen *et al*., 2002; 李冰晶等,2019).

天山－北山逆冲－走滑区包含北山盆地,新近纪主要沉积了一套以苦泉组为代表的北西－南东走向的山间盆地沉积(图3,李云通等,1984).

塔里木压陷区即为塔里木盆地.新近纪时期副特提斯海已经整体向西退出塔里木盆地,塔里木盆地主体为陆相沉积,塔西南地区地层沉积序列从老到新依次为克孜洛依组上段、安居安组、帕卡布拉克组、阿图什组和西域组(图3,贾承造等,2004).而目前学界对于塔西南地区新近纪各组的沉积时代,特别是阿图什组和西域组的磁性地层时代依然存

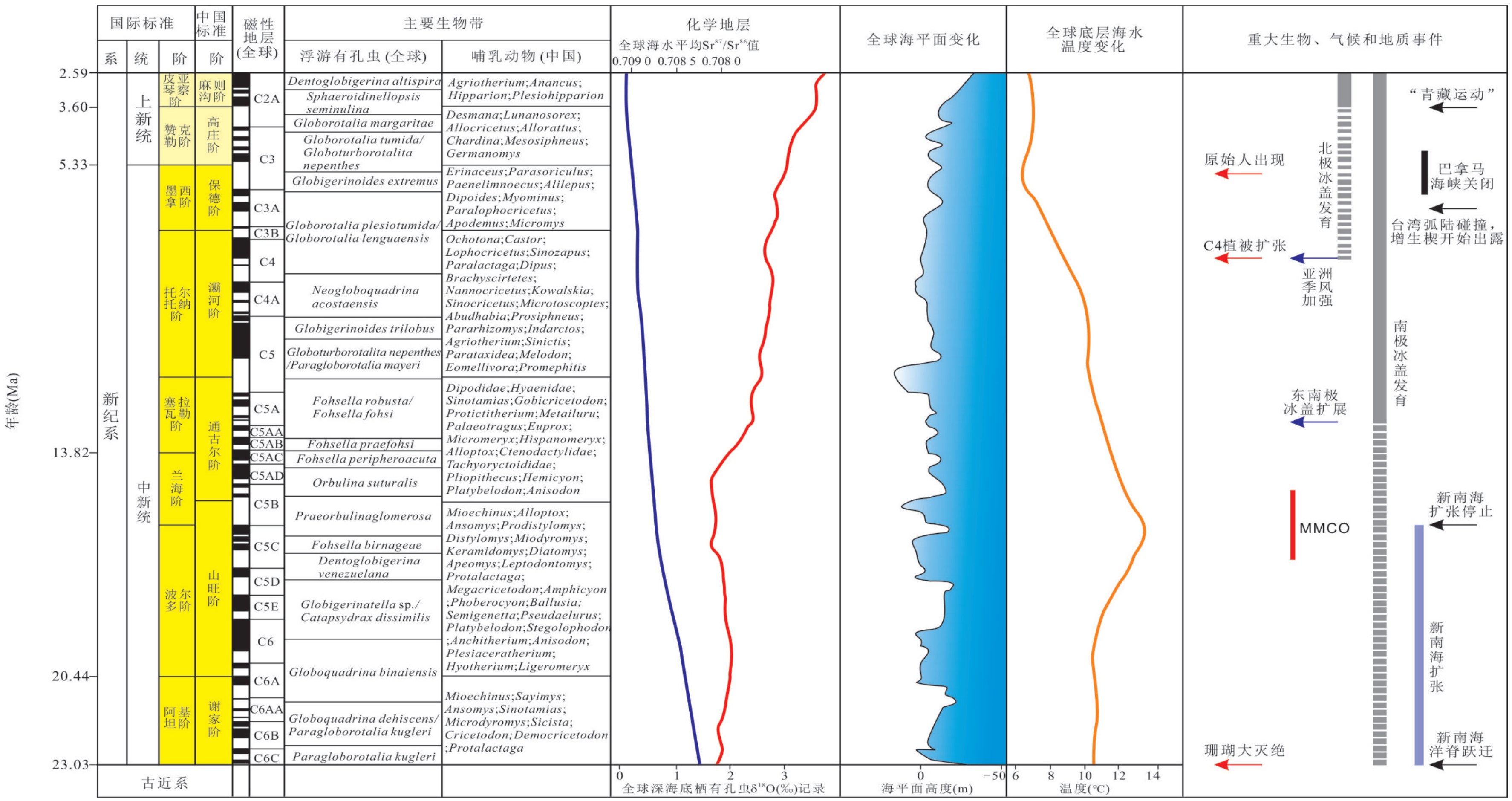

图 1 中国新近纪年代—磁性—生物—化学—气候等综合地层格架与全球地质事件序列

Fig.1 Neogene multidisciplinary stratigraphic correlation in China and global geological events

磁性地层据 Gradstein *et al*.(2012);主要生物带据 Wade *et al*.(2011)、Deng *et al*.(2019);化学地层据 Zachos *et al*.(2001)、McArthur *et al*.(2012);全球海平面变化据 Miller *et al*.(2005);全球底层海水温度变化据 Lear *et al*.(2000);重大生物、气候和地质事件据 Briais *et al*.(1993)、Zachos *et al*.(2001, 2008)、Li *et al*.(2015)、黄奇瑜(2017)和 Wang and Jian(2019)

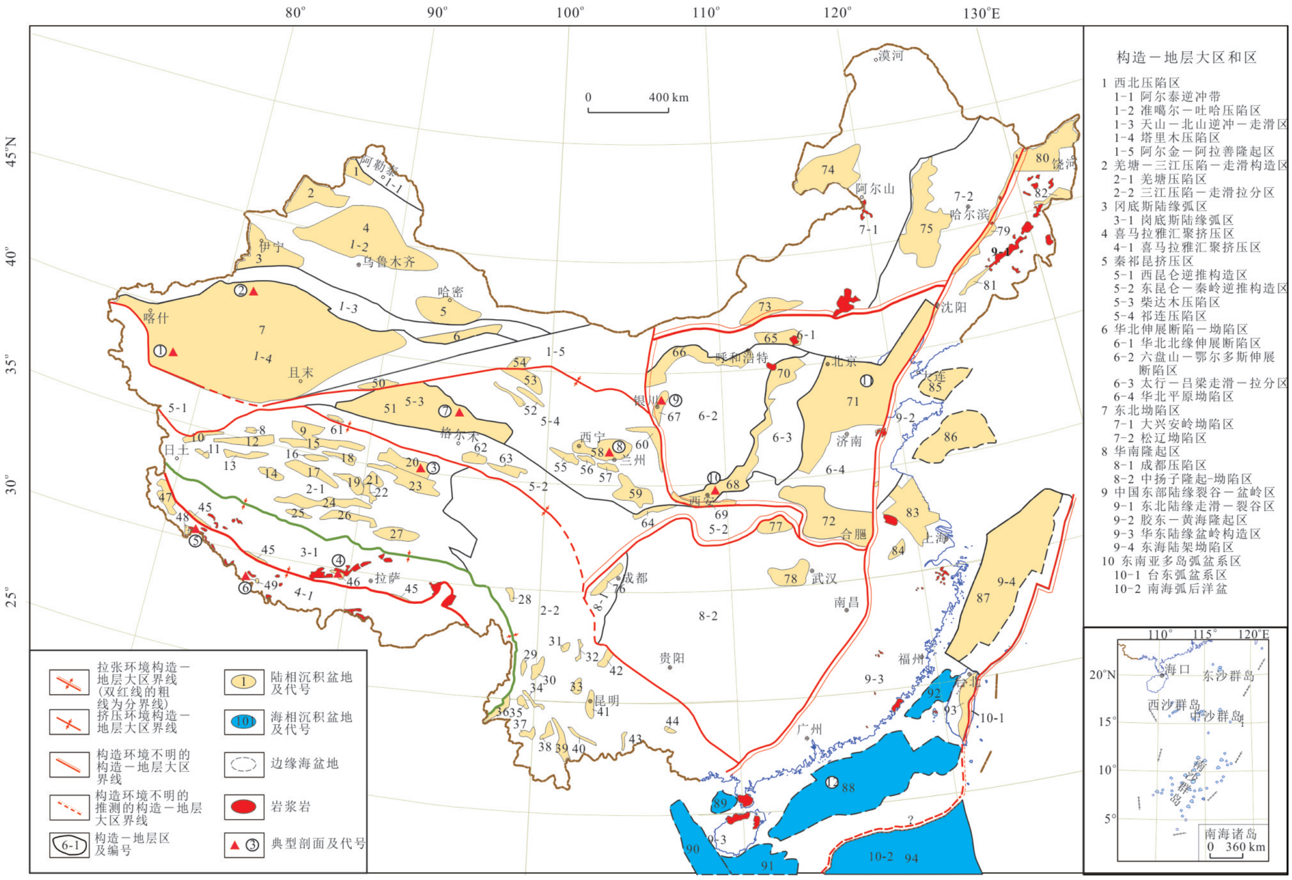

图 2 中国新近纪构造－地层分区及盆地分布

Fig.2 Neogene tectonic-stratigraphic regimes and sedimentary basins in China

地理底图据 http://www.mnr.gov.cn/sj/sjfw/,审图号为 GS(2016)2923 号;1.布尔津断陷盆地;2.塔城压陷盆地;3.伊宁压陷盆地;4.准噶尔压陷盆地;5.吐哈压陷盆地;6.北山压陷盆地;7.塔里木压陷盆地;8.黑石北湖含火山压陷盆地;9.西可可西里含火山压陷盆地;10.松西压陷盆地;11.鲁玛江东措压陷盆地;12.拜惹布措含火山压陷盆地;13.温泉湖含火山压陷盆地;14.查多岗日含火山压陷盆地;15.强措含火山压陷盆地;16.石坪顶含火山压陷盆地;17.玛尔果茶卡压陷盆地;18.鲸鱼湖含火山压陷盆地;19.多格措仁含火山压陷盆地;20.可可西里压陷盆地;21.唐古拉压陷盆地;22.米提将占木错压陷盆地;23.沱沱河压陷盆地;24.洞措压陷盆地;25.尼玛断陷盆地;26.南双湖断陷盆地;27.伦坡拉断坳盆地;28.芒康走滑拉分盆地;29.兰坪－剑川走滑拉分盆地;30.丽江断陷盆地;31.盐源走滑拉分盆地;32.西昌－攀枝花走滑拉分盆地;33.楚雄断陷盆地;34.昌宁走滑拉分盆地;35.保山断陷盆地;36.腾冲断陷盆地;37.耿马断陷盆地;38.景谷断陷盆地;39.思茅走滑拉分盆地;40.元江走滑拉分盆地;41.昆明断坳盆地;42.昭通断陷盆地;43.马关走滑拉分盆地;44.百色断陷盆地;45.大竹卡断陷盆地;46.乌郁断陷盆地;47.札达断陷盆地;48.普兰断陷盆地;49.吉隆断陷盆地;50.索尔库里走滑拉分盆地;51.柴达木压陷盆地;52.疏勒南山压陷盆地;53.酒泉压陷盆地;54.金塔－花海压陷盆地;55.贵德压陷盆地;56.循化压陷盆地;57.临夏压陷盆地;58.西宁－兰州压陷盆地;59.陇西－天水断陷盆地;60.宁南断陷盆地;61.阿亚克库木湖压陷盆地;62.秀河压陷盆地;63.玛多压陷盆地;64.成县压陷盆地;65.汉诺坝陆内裂谷;66.贺兰山－河套断陷盆地;67.银川断陷盆地;68.渭河断陷盆地;69.宝鸡－南洛断陷盆地;70.山西断陷盆地;71.渤海湾坳陷盆地;72.南华北坳陷盆地;73.二连坳陷盆地;74.海拉尔坳陷盆地;75.松辽坳陷盆地;76.成都压陷盆地;77.南襄坳陷盆地;78.江汉坳陷盆地;79.依兰－伊通走滑－拉分盆地;80.三江走滑－拉分盆地;81.辽源东走滑拉分盆地;82.虎林断陷－坳陷盆地;83.苏北坳陷盆地;84.芜湖坳陷盆地;85.北黄海坳陷盆地;86.南黄海坳陷盆地;87.东海陆架坳陷盆地;88.珠江口坳陷盆地;89.北部湾坳陷盆地;90.莺歌海坳陷盆地;91.琼东南坳陷盆地;92.台湾西坳陷盆地;93.台湾东坳陷盆地;94.南海中央海盆

在较大争议,尚未取得共识(Sun and Liu,2006;Heermance *et al.*, 2007; Zheng *et al.*, 2015).塔里木北部地区在库车坳陷发育了另一套新近纪沉积序列,由老到新依次为吉迪克组上段、康村组和库车组(图 3,图 4,贾承造等,2004;Zhang *et al.*, 2014).

阿尔金－阿拉善隆起区主体为剥蚀区,发育索尔库里盆地、金塔－花海盆地等山间盆地.其中索尔库里盆地的形成发育与阿尔金断裂密切相关,新近纪沉积序列与其东侧的柴达木盆地一致(陈正乐等,2003).

2.2 羌塘－三江压陷－走滑区

羌塘－三江压陷－走滑区根据盆地类型和盆地沉积充填序列特征,划分为羌塘压陷区和三江走

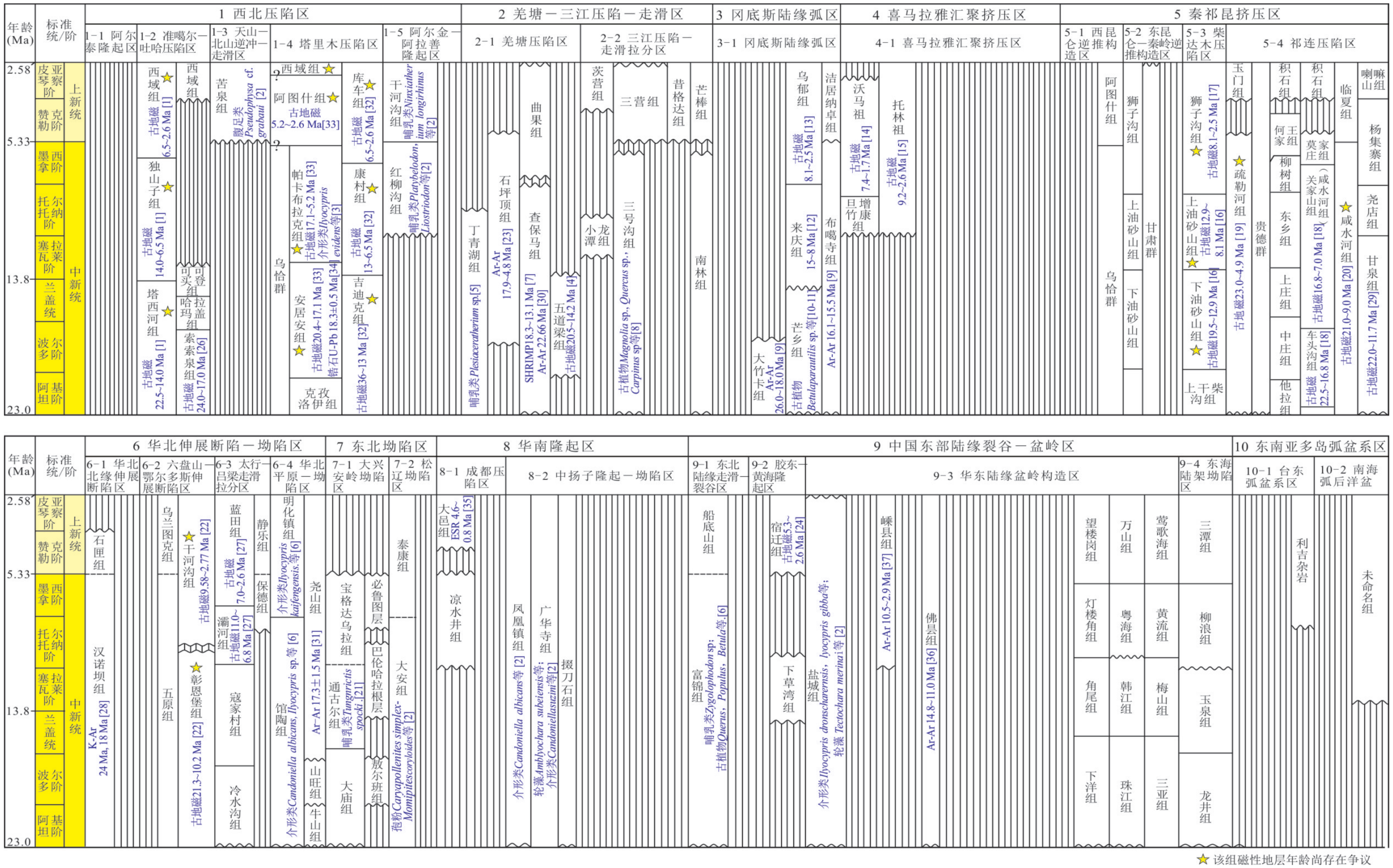

图 3 中国新近纪构造－地层区划与岩石地层格架对比

Fig.3 Neogene tectonic-stratigraphc regimes and correlation of lithostratigraphc units in China

参考文献:[1]Ji *et al.*, 2008; [2]李云通等, 1984; [3]蒋显庭等, 2015; [4]李军鹏, 2008; [5]Deng *et al.*, 2012; [6] 汪啸风和陈孝红, 2005; [7] 魏启荣等, 2007; [8] 云南省地质矿产局, 1996; [9] Leary *et al.*, 2016; [10]赵政璋等, 2001; [11] Spicer *et al.*, 2003; [12] 刘耕武和李建国, 2016; [13] 陈贺海等, 2007; [14] 岳乐平等, 2004; [15] Saylor *et al.*, 2009; [16] Ji *et al.*, 2017; [17] Fang *et al.*, 2007; [18] Fang *et al.*, 2019; [19] 宋春晖, 2006; [20] Zhang *et al.*, 2014; [21] Wang, 2004; [22] Liu *et al.*, 2019; [23] 刘荣等, 2006; [24] Jiang *et al.*, 2019; [25] Wan *et al.*, 2014; [26] 叶捷等, 2012; [27] Kaakinen and Lunkka, 2003; [28] 王慧芬等, 1985; [29] Li *et al.*, 2014; [30] 赵振明等, 2009; [31] He *et al.*, 2011; [32] Zhang *et al.*, 2014; [33]陈新伟, 2016; [34] Cao *et al.*, 2014; [35] 王凤林等, 2003; [36] 孙东霞等, 2019; [37] Ho *et al.*, 2003; [38] 陈建林等, 2006

滑－拉分区(图2,图3).

羌塘压陷区新近纪盆地群包含黑石北湖盆地、西可可西里盆地、松西盆地、鲁玛江东措盆地、拜惹布措盆地、温泉湖盆地、查多岗日盆地、强措盆地、石坪顶盆地、玛尔果茶卡盆地、鲸鱼湖盆地、多格措仁盆地、可可西里盆地、唐古拉盆地、米提将占木错盆地、沱沱河盆地、洞措盆地、尼玛盆地、南双湖盆地和伦坡拉盆地.以伦坡拉盆地和可可西里－沱沱河盆地为代表叙述如下.伦坡拉盆地新近纪沉积主要为丁青湖组(赵政璋等,2001),主体沉积以页岩、泥岩为主,夹砂岩、油页岩与泥灰岩.该组沉积时代一直备受争议,近年来随着该组地层中的火山岩夹层锆石定年、砂岩碎屑最年轻锆石定年和哺乳动物化石综合研究,其沉积上限被限定为中新世(图3, Deng *et al.*, 2012;Han *et al.*, 2019;赵珍等,2020).可可西里－沱沱河盆地新近纪时期主体发育五道梁组和曲果组沉积(图3,李军鹏,2008;Wang *et al.*, 2008),同时该盆地可见大量以查保马组为代表的新近纪火山岩产出(魏启荣等,2007;赵振明等,2009).

三江走滑－拉分区新近纪时期主要发育的盆地包括芒康盆地、兰坪－剑川盆地、丽江盆地、木里西盆地、盐源盆地、西昌－攀枝花盆地、楚雄盆地、昌宁盆地、保山盆地、腾冲盆地、耿马盆地、景谷盆地、思茅盆地、元江盆地、昆明盆地、昭通盆地、马关盆地和百色盆地.以兰坪－剑川盆地为代表,先前对于该盆地新生代包括新近纪地层的沉积时代多有争议,近年来学者们基于盆地构造、古生物学和盆内新生代火山岩等的综合研究,将先前归属于新近纪的双河组和剑川组的沉积时代重新厘定为晚始新世(Gourbet *et al.*, 2017),古近纪地层与新近纪地层之间存在显著的地层间断.新近纪时期该盆地主体发育三营组河湖相沉积(图3,沈青强等,2017),盆地沉积分布范围相比古近纪时期大幅萎缩.

2.3 冈底斯陆缘弧区

冈底斯陆缘弧区在新近纪时期主体为剥蚀区,仅在其南侧发育新近纪沉积盆地,包括大竹卡盆地和乌郁盆地(图2,图3).以大竹卡盆地和乌郁盆地为代表.大竹卡盆地新近纪沉积即为大竹卡组(冈仁波齐砾岩),该组沉积在晚渐新世以来沿雅鲁藏布江缝合带呈东西向带状分布,绵延近1 500 km,沉积厚度变化巨大(图2,Zhang *et al.*, 2010;张克信等,2013).大竹卡组作为雅鲁藏布缝合带中重要的地质单元,记录了来自缝合带两侧物源区,冈底斯岩浆弧和喜马拉雅造山带丰富的隆升和剥蚀的历史,同时也提供了古雅鲁藏布江演化的信息(Aitchison *et al.*, 2002; Wang *et al.*, 2013;Li *et al.*, 2017).近年来通过该组地层中的火山岩夹层锆石定年、砂岩碎屑最年轻锆石定年和磁性地层学研究,将大竹卡组的沉积时代约束为晚渐新世－早中新世(DeCelles *et al.*, 2011; Leary *et al.*, 2016; Ai *et al.*, 2019).乌郁盆地位于冈底斯山南麓,南邻雅鲁藏布缝合带,新近纪地层序列由老到新依次为芒乡组、来庆组和乌郁组(图3,图4)(Spicer *et al.*, 2003;朱迎堂等,2006;陈贺海等,2007).该分区新近纪火山岩地层十分发育,以布嘎寺组为代表(图3),主要为粗面岩及粗面质火山集块岩、火山角砾岩和凝灰质砾岩组成的多个火山喷发韵律,时代为中新世(Zhang *et al.*, 2010).

2.4 喜马拉雅汇聚挤压构造区

新近纪时期,新特提斯洋完全退出藏南,喜马拉雅地区无海相沉积发育,主体为陆相剥蚀区,仅发育以札达盆地、普兰盆地和吉隆盆地为代表的一系列裂谷盆地.这些盆地的发育均与藏南地区中新世中晚期发育的一系列近南北向地堑有关(Yin and Harrison, 2000;Wang *et al.*, 2014).以札达盆地和吉隆盆地为代表细述如下.札达盆地为受东北侧的北西－南东向喀喇昆仑断裂和西南侧近东西向的藏南拆离系控制的半地堑盆地,该盆地新近纪地层主要发育以托林组为代表的河湖相沉积(图3,图4,王世锋等,2008),垂向序列上呈现出由粗变细、再变粗的三段式结构(Saylor *et al.*, 2009).吉隆盆地为受藏南拆离系和主中央逆冲断裂之间的南北向断裂带控制的小型断陷盆地,该盆地新近纪地层主要发育以旦增竹康组和沃马组为代表的河湖相沉积(图3,图4,岳乐平等,2004;陈奋宁等,2010;Xu *et al.*, 2012).

2.5 秦祁昆挤压变形区

秦祁昆挤压变形区根据盆地类型和盆地沉积充填序列特征,划分为西昆仑逆推构造区、东昆仑－秦岭逆推构造区、柴达木压陷区和祁连压陷区(图2,图3).

西昆仑逆推构造区新近纪主体为剥蚀区.

东昆仑－秦岭逆推构造区包含阿亚克库木湖盆地、秀河盆地、玛多盆地和成县盆地.

柴达木压陷区主要为柴达木盆地,该盆地新近纪地层序列由老至新依次为上干柴沟组上段、下油砂山组、上油砂山组和狮子沟组(图 3,图 4,Fang *et al*., 2007;Lu and Xiong, 2009;Ji *et al*., 2017).柴达木盆地新生代磁性地层学年龄约束尚存在较大争议(Wang *et al*., 2017; Song *et al*., 2020),本文我们仍然遵循柴达木盆地传统地层年龄认识(宋春晖,2006;Zhang *et al*., 2010).

祁连压陷区主要包含疏勒南山盆地、酒泉盆地、贵德盆地、循化盆地、临夏盆地、西宁-兰州盆地、宁南盆地和天水盆地.以酒泉盆地、西宁-兰州盆地、循化盆地、临夏盆地和陇西-天水盆地为代表.酒泉盆地新近纪地层序列由老到新依次为疏勒河组和玉门组(图 3,宋春晖,2006).西宁盆地新近纪地层序列由老到新依次为谢家组顶部,车头沟组、关家山组(咸水河组)、莫家庄组和积石组(图 3,Fang *et al*., 2019).循化盆地和临夏盆地新近系的地层序列相同,由老到新依次分为他拉组、中庄组、上庄组、东乡组、柳树组、何王家组和积石组(Fang *et al*., 2003;季军良等,2010).兰州盆地新近纪地层序列由老到新依次为咸水河组和临夏组(图 3, Zhang *et al*., 2010, 2014).陇西-天水盆地位于青藏高原东北缘挤压隆升区与鄂尔多斯伸展区的过渡部位(马收先等,2016),其新近纪地层序列由老到新依次为甘泉组、尧店组、杨集寨组和喇嘛山组(图 3,Li *et al*., 2014).

2.6　华北伸展断陷-坳陷区

华北伸展断陷-坳陷区根据盆地类型和盆地沉积充填序列特征(图 3), 划分为华北北缘伸展断陷区、六盘山-鄂尔多斯伸展断陷区、太行-吕梁走滑-拉分区和华北平原坳陷区(图 2,图 3).

华北北缘伸展断陷区新近纪期间主体为剥蚀区,仅发育汉诺坝陆内裂谷,其中主体发育汉诺坝组层状火山喷发岩夹碎屑岩系,与上覆石匣组呈平行不整合接触(图 3).

六盘山-鄂尔多斯伸展断陷区包含贺兰山-河套盆地和银川盆地.以银川盆地为代表,该盆地新近纪地层序列与宁南盆地一致,由老到新依次为彰恩堡组和干河沟组(图 3,Liu *et al*., 2019).

太行-吕梁走滑-拉分区新近纪盆地主要为汾渭裂谷系,该裂谷系呈"S"型, 自北而南由一系列次级断陷盆地组成(图 2),其中以渭河断陷盆地为代表.该盆地新近系与下伏古近系序列之间存在明显地层缺失,由老到新依次为冷水井组、寇家村组、灞河组和蓝田组(图 3,图 4,Kaakinen and Lunkka, 2003; 鹿化煜等,2018).

华北平原坳陷区包含渤海湾盆地和南华北盆地.以渤海湾盆地为代表,该盆地新近纪由先前的断陷盆地主体转变为坳陷盆地发育,地层序列由老到新依次为馆陶组和明化镇组(图 3,Liang *et al*., 2016).

2.7　东北坳陷区

东北坳陷区根据盆地类型和盆地沉积充填序列特征(图 3), 划分为大兴安岭坳陷区和松辽坳陷区(图 2,图 3).大兴安岭坳陷区包含二连盆地和海拉尔盆地.以二连盆地为代表,该盆地新近纪以来全区抬升剥蚀,直到中新世晚期-上新世中东部地区才继续沉降接受沉积,沉积范围相比古近纪大幅萎缩消减(李洪军等,2012),地层序列由老到新依次为大庙组、通古尔组和宝格达乌拉组(图 3,汪啸风和陈孝红,2005;Wang *et al*., 2014).

松辽坳陷区包含松辽盆地,该盆地新近纪地层主要为大安组上段和泰康组(图 3,李云通等,1984).

2.8　华南隆起区

华南隆起区根据盆地类型和盆地沉积充填序列特征(图 3), 划分为成都压陷区和中扬子隆起-坳陷区(图 2,图 3).成都压陷区包含成都盆地,成都盆地新近纪地层由老到新依次为凉水井组和大邑组(图 3, Zhang *et al*., 2010);中扬子隆起-坳陷区包含南襄盆地和江汉盆地,南襄盆地新近纪地层主要为凤凰镇组(图 3,李云通等,1984),江汉盆地新近纪地层主要为广化寺组和掇刀石组(图 3,李云通等,1984).

2.9　中国东部陆缘裂谷-盆岭区

中国东部陆缘裂谷区根据盆地类型和盆地沉积充填序列特征(图 3), 划分为东北陆缘走滑-裂谷区、胶东-黄海隆起区、华东陆缘盆岭构造区和东海陆架伸展区(图 2,图 3).

东北陆缘走滑-裂谷区包含依兰-伊通盆地、三江盆地、辽源东盆地和虎林盆地.以依兰-伊通盆地为代表,该断陷盆地新近纪主体受依兰-伊通断裂控制,沉积主体为富锦组和船底山组(图 3,汪啸风和陈孝红,2005).

胶东-黄海隆起区新近纪主体为剥蚀区,仅在郯庐断裂带泗洪段一带可见新近纪地层发育,以中中新统下草湾组和上新统宿迁组为代表(图 3,Jiang *et al*., 2019).

华东陆缘盆岭构造区包含苏北盆地、芜湖盆地、北黄海盆地、南黄海盆地、东海陆架盆地、珠江口盆地、北部湾盆地、莺歌海盆地、琼东南盆地、台湾西盆地和台湾东盆地.以苏北盆地和南海北部次级盆地群为例细述之.苏北盆地在渐新世末三垛运动之后由断陷转入坳陷发育阶段(杨琦和陈红宇,2003),不整合面之上发育了以盐城组为代表的一套河流泛滥平原沉积(图3,邱海峻等,2006);南海北部次级盆地群分别为珠江口盆地、琼东南盆地、北部湾盆地和莺歌海盆地,呈NE-EW-NW向弧形分布,4个盆地均充填新近纪地层序列(解习农等,2015).南海北部的次级盆地以珠江口盆地为代表,其新近纪地层序列由老到新依次为珠江组、韩江组、粤海组和万山组(图3,图4,解习农等,2015).东海陆架坳陷区包含东海陆架盆地,其新近纪地层序列由老到新依次为龙井组、玉泉组、柳浪组和三潭组(图3,Su *et al*., 2014).

2.10 东南亚多岛弧盆系

东南亚多岛弧盆系根据盆地类型和盆地沉积充填序列特征(图3),划分为台东弧盆系和南海弧后洋盆(图2,图3).

台东弧盆系新近纪可见东台湾蛇绿岩出露于台湾岛海岸山脉残留弧前盆地内,与晚中新世—上新世利吉混杂岩紧密共生(Huang *et al*., 2000);南海弧后洋盆新近纪地层目前研究程度较低,相关地层资料主要通过国际大洋钻探计划(ODP)获取(Wang *et al*., 2003;Wang and Jian, 2019).

3 中国新近纪沉积—构造—气候耦合演化历史

通过对中国新近纪地层区开展详细区划(图2),以及对各个构造—地层区内盆地类型及展布、岩石地层序列和地层接触关系的讨论(图3,图4),笔者对中国新近纪沉积—构造—气候耦合演化历史进行系统总结如下:

新近纪,中国西部地区构造—地貌演化进入了一个全新的阶段.新近纪印度板块与欧亚板块的碰撞进入陆内演化阶段,青藏高原构造活动强烈,陆内汇聚作用加剧,形成大规模的冲断、推覆构造及滑脱系和走滑,表现为强烈隆升(李廷栋,1995;Wang *et al*., 2014).晚渐新世—早中新世的强构造抬升是青藏高原重大构造变革期(刘池洋等,2009;张克信等,2013;Lu *et al*., 2018):晚渐新世—早中新世,随着印度板块向北的持续俯冲,西昆仑—帕米尔构造结地壳不断加厚,变形广泛和强烈,表现为大型断裂的强烈活动、岩石快速剥露冷却和岩浆变质作用(Robinson *et al*., 2004;Sobel *et al*., 2006;曹凯等,2018);冈底斯—唐古拉带在渐新世—中新世之交的强构造抬升剥露,其南侧伴随喜马拉雅山系在早中新世的显著抬升(Ding *et al*., 2017),形成现今的雅鲁藏布江谷地雏形(王二七等,2002);晚渐新世—中中新世,青藏高原中北部地区地壳浅层呈现出普遍的以褶皱和逆冲断层为代表的缩短压扁变形,可可西里—沱沱河地区区域性的角度不整合面发育和盆地内古近纪地层发生变形抬升(Wang *et al*., 2008),阿尔金断裂在此期间表现为强烈活动,伴随着阿尔金山的快速抬升和强烈缩短(Yue *et al*., 2004;陈正乐等,2006);青藏高原东北缘地区在23~21 Ma发生强烈的挤压变形,拉脊山构造带在中新世初期约22 Ma开始发生大规模的加速构造隆升剥蚀(Lease *et al*., 2011;Zhang *et al*., 2015),~21 Ma之后拉脊山作为独立山系开始显现,成为分割西宁—兰州盆地与南部的贵德—循化盆地的屏障(方小敏等,2007;Zhang *et al*., 2016);柴达木盆地北部新生代沉积物源变化记录显示南祁连山在晚渐新世—早中新世(~25~21 Ma)发生显著隆升剥蚀(Song *et al*., 2019);晚渐新世(26 Ma)哀牢山—红河剪切带及其周缘地区发生了强烈的构造体制转换,从走滑伸展变形转换为简单剪切变形(任龙龙等,2020).晚渐新世—早中新世青藏高原的扩展隆升对该地区的生态系统和气候格局产生了重大影响:青藏高原生态系统在古近纪/新近纪之交经历了由热带、亚热带生态体系向高原型生物群落的重大转折(邓涛等,2019;Deng *et al*., 2021);晚渐新世—早中新世帕米尔构造节和天山山脉的显著隆升,阻挡了来自西风带所携带的新特提斯洋暖湿气流,加剧了中国西部内陆地区的干旱化(Wang *et al*., 2020),准噶尔盆地在~24 Ma开始出现风尘堆积(Sun *et al*., 2010);晚渐新世—早中新世黄土高原连续风尘堆积的出现所指示的亚洲内陆干旱化(Guo *et al*., 2002;Qiang *et al*., 2011)与同时期青藏高原的显著隆升存在密切的耦合(An *et al*., 2014; Liu *et al*., 2015).中新世中晚期(~15~8 Ma)藏南地区的构造变形体制发生了重大转变,在高原内部及南部广大地区总体形成为伸展

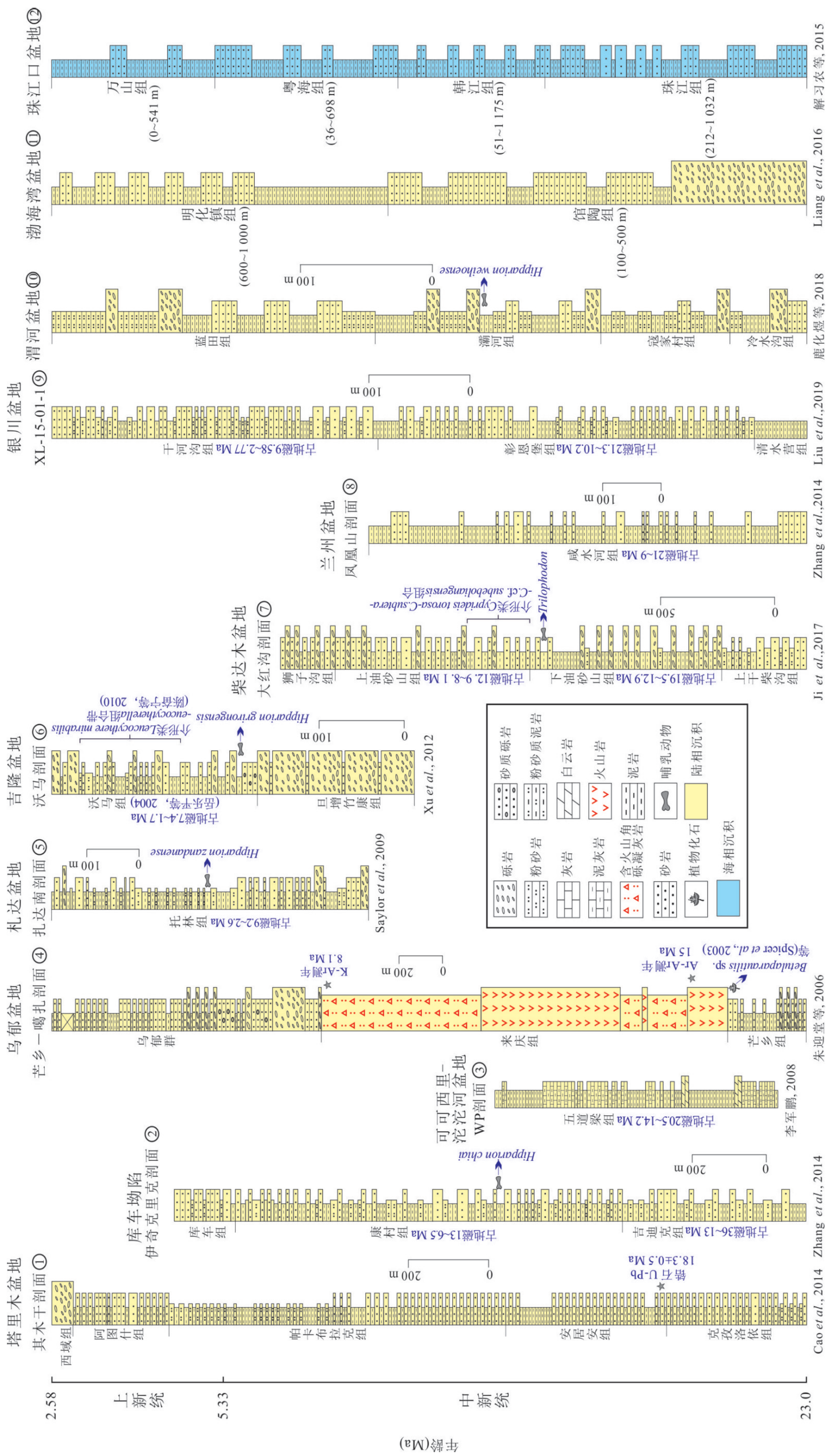

图 4 中国新近纪构造—地层区代表性盆地沉积充填序列

Fig.4 Sedimentary filling sequences of representative basins in the Neogene tectonic-stratigraphic realms of China

松弛的构造面貌(Wang *et al.*, 2014),构造变形由挤压逆冲转变为伸展和走滑作用控制下的变形,在东西向伸展作用的影响下,高原内部发育近南北向裂谷系、藏南拆离系等伸展构造(Yin and Harrison, 2000),同时在川西－藏东地区发育一系列受走滑断裂控制的走滑－拉分盆地(Zhang *et al.*, 2010);中新世中晚期青藏高原东北缘最大主压应力方位从NNE向变为NEE向(Lease *et al.*, 2011; Yuan *et al.*, 2013),高原东北缘表现为显著隆升,祁连山以及东昆仑山等系列山脉该时期的隆升具有广泛的耦合性(Jolivet *et al.*, 2001);高原东部藏东和川滇西部地区在13～9 Ma间表现出快速的河流下切(Clark *et al.*, 2005),反映存在快速的地表抬升.晚中新世(8 Ma)以来印度板块继续向欧亚大陆俯冲,青藏高原向北部和东部扩展,高原周缘山系快速隆升剥蚀并向盆地方向扩展,盆地沉积范围显著缩小,地貌反差加剧,中国西部地区现代盆山地貌格局基本成型(Zheng *et al.*, 2006; Wang *et al.*, 2011; Li *et al.*, 2014).与之相耦合的是,晚中新世(～8 Ma)我国黄土高原地区广泛发育风尘堆积(An *et al.*, 2001; Lu *et al.*, 2019),同时由西风环流携带至北太平洋的亚洲内陆风尘沉积速率显著增大(Rea *et al.*, 1998),海陆记录的一致性指示了亚洲内陆干旱区的扩大和干旱程度的显著加剧.3.6 Ma以来整个青藏高原发生快速构造抬升事件,导致了高原周边一系列盆地内沉积速率的加快和磨拉石建造的发育(Li *et al.*, 2015),青藏高原周边的主要山川地貌、河流水系以及气候格局最终奠定.

23 Ma以后,太平洋俯冲系统持续向东后撤,印度板块和菲律宾海板块向北运移作用,华北地区西缘形成EW向拉张(万天丰,2007),鄂尔多斯地块西北缘(银川－河套裂谷系)和南缘强烈的伸展断陷作用在中新世继续发展(Zhang *et al.*, 2019),上新世之后,伸展断陷作用进一步扩展到鄂尔多斯地块的东缘,发育汾渭裂谷系,并加速沉降,环鄂尔多斯地堑盆地系主体形成(图2,邢作云等,2005;张岳桥等,2019);新近纪以来,受菲律宾海板块向北运移影响,中国东部构造应力场发生重大转变,渤海湾盆地表现为强烈挤压,伸展作用停止,裂后不整合界面形成,并进入整体热沉降阶段,形成开阔的坳陷盆地(任建业,2018);东北地区新近纪为后裂谷坳陷阶段,松辽等盆地平原化,辽吉东部和三江平原为红杂色碎屑沉积和玄武岩沉积(王五力等,2012);中中新世(15～13 Ma)北部日本海盆开裂并继续沿NW－SE向扩张,并在东亚边缘产生强烈的拉张应力,沿早期的NE－NNE向走滑断裂(如敦密断裂、依兰－伊通断裂)产生以碱性玄武岩为主的陆缘裂谷火山岩浆喷发,形成新生代裂谷型火山活动的高峰(邢光福等,2017);华南地区先前广布的系列断陷盆地(江汉盆地、南襄盆地等)在新近纪时期大幅萎缩并遭受剥蚀,如江汉盆地新近纪广华寺组与古近系之间发育不整合面,存在明显地层缺失,进入新近纪之后逐步坳陷萎缩(王必金等,2006);中国东部盆岭区的众多古近纪盆地进入新近纪之后坳陷萎缩并遭受剥蚀(图3),主体发育河流泛滥平原沉积;与此同时,南京地区“长江砾石层”的年代学与物源分析研究显示,最晚在渐新世/中新世之交,长江上游的沉积物就已经到达苏北盆地的西南缘,贯通东流的长江水系在这个时期可能已经建立(Zheng *et al.*, 2013),而该时间节点与渐新世末中国东部开始主体处于“季风主控型”环境相一致,季风环流的加强使中国东部地区在新近纪时期显著湿润化(张仲石和郭正堂,2005;Guo *et al.*, 2008).在23 Ma以后,中国东部陆缘的南黄海盆地、南海北部盆地群、东海陆架盆地等均由断陷转为坳陷过程,其中东海陆架盆地在渐新世末至中新世早期经历花港运动,使得盆地发生挤压变形与整体性隆升剥蚀形成了中新统与下伏地层之间的区域性角度不整合(赵志刚等,2016;刘金水等,2020);中中新世以后,受澳大利亚板块不断向北推挤作用的影响,菲律宾海板块持续向北西俯冲,东亚陆缘处于挤压或左旋压扭的构造背景(索艳慧等,2012),冲绳海槽开始孕育与发展,东海陆架盆地现今构造格局开始成型(刘金水等,2020).24～23 Ma,新南海发生洋脊跃迁事件,南海洋中脊从东部次海盆向西南次海盆跃迁(Briais *et al.*, 1993),同时期南海北部大陆边缘盆地的裂陷终止,形成破裂不整合界面,自此南海北部大陆边缘盆地全面进入海相沉降环境(解习农等,2015);16～15 Ma洋中脊活动停止,新南海停止扩张,洋盆规模基本稳定(Wang and Jian, 2019);6.5 Ma开始随着北吕宋火山岛弧与华南大陆边缘发生斜向弧－陆碰撞造山,增生楔开始出露形成台湾岛雏形,台湾造山运动开始(Huang *et al.*, 2000;黄奇瑜,2017);上新世以来,中国东部海域普遍进入稳定沉降期(王振峰等,

2004),现今构造格局逐渐形成,同时随着晚上新世北半球进入大冰期时代,中国现代季风—干旱环境的格局最终奠定.

4 结论

(1)在建立中国新近纪构造—地层区划的基础上,通过综合各个地层分区中盆地的类型、沉积序列,沉积时代及地层接触关系的研究,本文重新厘定了中国新近纪岩石地层对比格架.

(2)通过对中国新近纪时期沉积、构造与气候耦合过程的总结,表明中国现今地貌地形、海陆分布和气候格局在新近纪最终奠定成型.

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References

Ai, K.K., Shi, G.L., Zhang, K.X., et al., 2019. The Uppermost Oligocene Kailas Flora from Southern Tibetan Plateau and Its Implications for the Uplift History of the Southern Lhasa Terrane. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 515: 143—151. https: //doi.org/10.1016/j.palaeo.2018.04.017

Aitchison, J.C., Davis, A.M., Badengzhu, et al., 2002. New Constraints on the India-Asia Collision: The Lower Miocene Gangrinboche Conglomerates, Yarlung Tsangpo Suture Zone, SE Tibet. *Journal of Asian Earth Sciences*, 21(3): 251—263. https: //doi. org/10.1016/S1367-9120(02)00037-8

An, Z. S., 2014. Late Cenozoic Climate Change in Asia: Loess, Monsoon and Monsoon-Arid Environment Evolution. Springer, London.

An, Z.S., Kutzbach, J.E., Prell, W.L., et al., 2001. Evolution of Asian Monsoons and Phased Uplift of the Himalaya-Tibetan Plateau since Late Miocene Times. *Nature*, 411 (6833): 62—66. https: //doi.org/10.1038/35075035

Briais, A., Patriat, P., Tapponnier, P., 1993. Updated Interpretation of Magnetic Anomalies and Seafloor Spreading Stages in the South China Sea: Implications for the Tertiary Tectonics of Southeast Asia. *Journal of Geophysical Research: Solid Earth*, 98(B4): 6299—6328. https: //doi.org/10.1029/92jb02280

Bureau of Geology and Mineral Resources of Yunnan Province, 1996. Stratigraphy (Lithostratic) of Yunnan Province. China University of Geosiences Press, Wuhan (in Chinese).

Cao, K., Mai, H.T., Wang, G.C., et al., 2018. Mesozoic-Cenozoic Tectonic and Topographic Development of the Pamir Syntaxis and Its Potential Effects on the Sea Retreat in the Tarim Basin, *Quaternary Science*, 38(1): 15—38(in Chinese with English abstract).

Cao, K., Xu, Y.D., Wang, G.C., et al., 2014. Neogene Source-to-Sink Relations between the Pamir and Tarim Basin: Insights from Stratigraphy, Detrital Zircon Geochronology, and Whole-Rock Geochemistry. *The Journal of Geology*, 122(4): 433—454. https: //doi. org/10.1086/676478

Chen, F.N., Xu, Y.D., Jiang, S.S., et al., 2010. Late Miocene-Early Pleistocene Ostracoda Fauna of Oma Formation in Gyirong Basin, Southern Tibet. *Earth Science*, 35(5): 821—827(in Chinese with English abstract).

Chen, H.H., Han, J.T., Ding, Z.L., et al., 2007. The Sedimentary Sequence Era of Wuyu Basin in the Southern Tibet since the Late Cenozoic and Its Tectonic Significance. *Science in China* (*Series D*), 37(12): 1617—1624(in Chinese).

Chen, J., Burbank, D.W., Scharer, K.M., et al., 2002. Magnetochronology of the Upper Cenozoic Strata in the Southwestern Chinese Tian Shan: Rates of Pleistocene Folding and Thrusting. *Earth and Planetary Science Letters*, 195(1/2): 113—130. https: //doi. org/10.1016/S0012-821X(01)00579-9

Chen, J.L., Xu, J.F., Kang, Z.Q., et al., 2006. Origin of the Miocene Bugasi Group Volcanic Rocks in the Cuoqin County, Western Tibetan Plateau. *Acta Petrologica Sinica*, 22(3): 585—594(in Chinese with English abstract).

Chen, X.W., 2016. Sedimentary Records of Cenozoic Tectonic Events in the Pamir and South Tian Shan(Dissertation). Zhejiang University, Hangzhou(in Chinese with English abstract).

Chen, Z.L., Bai, Y.F., Chen, B.L., et al., 2003. Sedimentation and Tectonic Evolution of the North Xorkol Basin in the Altyn Tagh Range. *Regional Geology of China*, 22(6): 405—411(in Chinese with English abstract).

Chen, Z.L., Gong, H.L., Li, L., et al., 2006. Cenozoic Uplifting and Exhumation Process of the Altyn Tagh Mountains. *Earth Science Frontiers*, 13(4): 91—102(in Chinese with English abstract).

Clark, M.K., House, M.A., Royden, L.H., et al., 2005. Late Cenozoic Uplift of Southeastern Tibet. *Geology*, 33(6):

525－528. https://doi.org/10.1130/g21265.1

DeCelles, P.G., Kapp, P., Quade, J., et al., 2011. Oligocene-Miocene Kailas Basin, Southwestern Tibet: Record of Postcollisional Upper-Plate Extension in the Indus-Yarlung Suture Zone. *Geological Society of America Bulletin*, 123(7/8): 1337－1362. https://doi.org/10.1130/b30258.1

Deng, T., Hou, S.K., Wang, S.Q., 2019. Neogene Integrative Stratigraphy and Timescale of China. *Science China Earth Sciences*, 62(1): 310－323. https://doi.org/10.1007/s11430-017-9155-4

Deng, T., Wang, S.Q., Xie, G.P., et al., 2012. A Mammalian Fossil from the Dingqing Formation in the Lunpola Basin, Northern Tibet, and Its Relevance to Age and Paleo-Altimetry. *Chinese Science Bulletin*, 57(2/3): 261－269. https://doi.org/10.1007/s11434-011-4773-8

Deng, T., Wu, F.X., Wang, S.Q., et al., 2019. Significant Shift in the Terrestrial Ecosystem at the Paleogene/Neogene Boundary in the Tibetan Plateau. *Chinese Science Bulletin*, 64(27): 2894－2906(in Chinese).

Deng, T., Wu, F.X., Wang, S.Q., et al., 2021. Major Turnover of Biotas across the Oligocene/Miocene Boundary on the Tibetan Plateau. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 567: 110241. https://doi.org/10.1016/j.palaeo.2021.110241

Ding, L., Spicer, R.A., Yang, J., et al., 2017. Quantifying the Rise of the Himalaya Orogen and Implications for the South Asian Monsoon. *Geology*, 45(3): 215－218. https://doi.org/10.1130/g38583.1

Fang, X.M., Garzione, C., van der Voo, R., et al., 2003. Flexural Subsidence by 29 Ma on the NE Edge of Tibet from the Magnetostratigraphy of Linxia Basin, China. *Earth and Planetary Science Letters*, 210(3/4): 545－560. https://doi.org/10.1016/S0012-821X(03)00142-0

Fang, X.M., Fang, Y.H., Zan, J.B., et al., 2019. Cenozoic Magnetostratigraphy of the Xining Basin, NE Tibetan Plateau, and Its Constraints on Paleontological, Sedimentological and Tectonomorphological Evolution. *Earth-Science Reviews*, 190: 460－485. https://doi.org/10.1016/j.earscirev.2019.01.021

Fang, X.M., Song, C.H., Dai, S., et al., 2007. Cenozoic Deformation and Uplift of the NE Qinghai-Tibet Plateau: Evidence from High-Resolution Magnetostratigraphy and Basin Evolution. *Earth Science Frontiers*, 14(1): 230－242(in Chinese with English abstract).

Fang, X.M., Zhang, W.L., Meng, Q.Q., et al., 2007. High-Resolution Magnetostratigraphy of the Neogene Huaitoutala Section in the Eastern Qaidam Basin on the NE Tibetan Plateau, Qinghai Province, China and Its Implication on Tectonic Uplift of the NE Tibetan Plateau. *Earth and Planetary Science Letters*, 258(1/2): 293－306. https://doi.org/10.1016/j.epsl.2007.03.042

Fu, B.H., Shi, P.L., Jia, Y.Y., 2009. Late Cenozoic Tectono-Geomorphic Growth and Drainage Response along the Large-Scale Strike-Slip Fault System, Tibetan Plateau. *Chinese Journal of Geology (Scientia Geologica Sinica)*, 44(4): 1343－1363(in Chinese with English abstract).

Gourbet, L., Leloup, P.H., Paquette, J.L., et al., 2017. Reappraisal of the Jianchuan Cenozoic Basin Stratigraphy and Its Implications on the SE Tibetan Plateau Evolution. *Tectonophysics*, 700/701: 162－179. https://doi.org/10.1016/j.tecto.2017.02.007

Gradstein, F.M., Ogg, J.G., Schmitz, M.D., et al., 2012. The Geological Time Scale 2012(vol. 2). Elsevier, Waltham, Massachusetts.

Guo, Z.T., Ruddiman, W.F., Hao, Q.Z., et al., 2002. Onset of Asian Desertification by 22 Myr ago Inferred from Loess Deposits in China. *Nature*, 416(6877): 159－163. https://doi.org/10.1038/416159a

Guo, Z.T., Sun, B., Zhang, Z.S., et al., 2008. A Major Reorganization of Asian Climate by the Early Miocene. *Climate of the Past*, 4(3): 153－174. https://doi.org/10.5194/cp-4-153-2008

Han, Z.P., Sinclair, H.D., Li, Y.L., et al., 2019. Internal Drainage has Sustained Low-Relief Tibetan Landscapes since the Early Miocene. *Geophysical Research Letters*, 46(15): 8741－8752. https://doi.org/10.1029/2019gl083019

He, H.Y., Deng, C.L., Pan, Y.X., 2011. New $^{40}Ar/^{39}Ar$ Dating Results from the Shanwang Basin, Eastern China: Constraints on the Age of the Shanwang Formation and Associated Biota. *Physics of the Earth and Planetary Interiors*, 187(1/2): 66－75. https://doi.org/10.1016/j.pepi.2011.05.002

Heermance, R.V., Chen, J., Burbank, D.W., et al., 2007. Chronology and Tectonic Controls of Late Tertiary Deposition in the Southwestern Tian Shan Foreland, NW China. *Basin Research*, 19(4): 599－632. https://doi.org/10.1111/j.1365-2117.2007.00339.x

Ho, K.S., Chen, J.C., Lo, C.H., et al., 2003. ^{40}Ar-^{39}Ar Dating and Geochemical Characteristics of Late Cenozoic Basaltic Rocks from the Zhejiang-Fujian Region, SE China: Eruption Ages, Magma Evolution and Petrogenesis. *Chemical Geology*, 197(1－4): 287－318. https://doi.org/10.1016/S0009-2541(02)00399-6

Huang, C.Y., Yuan, P.B., Lin, C.W., et al., 2000. Geodynamic Processes of Taiwan Arc-Continent Collision and Comparison with Analogs in Timor, Papua New Guinea, Urals and Corsica. *Tectonophysics*, 325(1/2): 1—21. https: //doi.org/10.1016/S0040-1951(00)00128-1

Huang, Q.Y., 2017. Geological Ages of Taiwan Stratigraphy and Tectonic Events. *Scientia Sinica (Terrae)*, 47(4): 394—405(in Chinese).

Ji, J.L., Luo, P., White, P., et al., 2008. Episodic Uplift of the Tianshan Mountains since the Late Oligocene Constrained by Magnetostratigraphy of the Jingou River Section, in the Southern Margin of the Junggar Basin, China. *Journal of Geophysical Research Atmospheres*, 113 (B5): B05102. https: //doi.org/10.1029/2007jb005064

Ji, J.L., Zhang, K.X., Clift, P.D., et al., 2017. High-Resolution Magnetostratigraphic Study of the Paleogene-Neogene Strata in the Northern Qaidam Basin: Implications for the Growth of the Northeastern Tibetan Plateau. *Gondwana Research*, 46: 141—155. https: //doi.org/10.1016/j.gr.2017.02.015

Ji, J.L., Zhang, K.X., Qiang, T., et al., 2010. Magnetostratigraphy of the Neogene Strata in Xunhua Basin, Qinghai Province. *Earth Science*, 35(5): 803—810(in Chinese with English abstract).

Jia, C.Z., Zhang, S.B., Wu, S.Z., 2004. Stratigraphy of the Tarim Basin and Adjacent Areas. Science Press, Beijing (in Chinese).

Jiang, R., Cao, K., Zeng, J.W., et al., 2019. Late Cenozoic Tectonic Evolution of the Southern Segment of the Tan-Lu Fault Zone, Eastern China. *Journal of Asian Earth Sciences*, 182: 103932. https: //doi.org/10.1016/j.jseaes.2019.103932

Jiang, X.T., Zhou, W.F., Lin, S.P., 1995. Stratigraphy and Ostracods of Xinjiang in China. Geological Publishing House, Beijing(in Chinese).

Jolivet, M., Brunel, M., Seward, D., et al., 2001. Mesozoic and Cenozoic Tectonics of the Northern Edge of the Tibetan Plateau: Fission-Track Constraints. *Tectonophysics*, 343(1/2): 111—134. https: //doi. org/10.1016/S0040-1951(01)00196-2

Kaakinen, A., Lunkka, J.P., 2003. Sedimentation of the Late Miocene Bahe Formation and Its Implications for Stable Environments Adjacent to Qinling Mountains in Shaanxi, China. *Journal of Asian Earth Sciences*, 22(1): 67—78. https: //doi. org/10.1016/S1367-9120(03)00044-0

Lear, C.H., Elderfield, H., Wilson, P.A., 2000. Cenozoic Deep-Sea Temperatures and Global Ice Volumes from Mg/Ca in Benthic Foraminiferal Calcite. *Science*, 287 (5451): 269—272. https: //doi. org/10.1126/science.287.5451.269

Leary, R., Orme, D.A., Laskowski, A.K., et al., 2016. Along-Strike Diachroneity in Deposition of the Kailas Formation in Central Southern Tibet: Implications for Indian Slab Dynamics. *Geosphere*, 12(4): 1198—1223. https: //doi.org/10.1130/ges01325.1

Lease, R.O., Burbank, D.W., Clark, M.K., et al., 2011. Middle Miocene Reorganization of Deformation along the Northeastern Tibetan Plateau. *Geology*, 39(4): 359—362. https: //doi.org/10.1130/g31356.1

Li, B.J., Wu, D.Y., Pang, L.C., et al., 2019. Stratigraphic Attribute and Origin of the Xiyu Conglomerates in NW China: Progress and Prospect. *Journal of Earth Environment*, 10(5): 427—440(in Chinese with English abstract).

Li, H.J., Shen, K.F., Nie, F.J., et al., 2012. Sedimentary Evolution in Meso-Cenozoic and Uranium Mineralization of Erlian Basin. *Journal of East China Institute of Technology (Natural Science)*, 35(4): 301—308(in Chinese with English abstract).

Li, J.J., Fang, X.M., Song, C.H., et al., 2014. Late Miocene-Quaternary Rapid Stepwise Uplift of the NE Tibetan Plateau and Its Effects on Climatic and Environmental Changes. *Quaternary Research*, 81(3): 400—423. https: //doi.org/10.1016/j.yqres.2014.01.002

Li, J.J., Zhou, S.Z., Zhao, Z.J., et al., 2015. The Qingzang Movement: The Major Uplift of the Qinghai-Tibetan Plateau. *Science China Earth Sciences*, 58(11): 2113—2122. https: //doi.org/10.1007/s11430-015-5124-4

Li, J.P., 2008. Miocene Wudaoliang Formation Magnetostratigraphy and Paleoenvironmental Evolution in the Tuotuohe Area of the Qinghai-Tibetan Plateau(Dissertation). Chengdu University of Technology, Chengdu(in Chinese with English abstract).

Li, S., Ding, L., Xu, Q., et al., 2017. The Evolution of Yarlung Tsangpo River: Constraints from the Age and Provenance of the Gangdese Conglomerates, Southern Tibet. *Gondwana Research*, 41: 249—266. https: //doi.org/10.1016/j.gr.2015.05.010

Li, T.D., 1995. The Uplifting Process and Mechanism of the Qinhai-Tibet Plateau. *Acta Geoscientia Sinica*, 16(1): 1—9(in Chinese with English abstract).

Li, Y.T., 1984. Stratigraphy of China (13)•Chinese Tertiary. Geological Publishing House, Beijing (in Chinese).

Liang, J.T., Wang, H.L., Bai, Y., et al., 2016. Cenozoic Tectonic Evolution of the Bohai Bay Basin and Its Coupling Relationship with Pacific Plate Subduction. *Journal of*

Asian Earth Sciences, 127: 257—266. https: //doi.org/10.1016/j.jseaes.2016.06.012

Liu, C.Y., Zhao, H.G., Zhang, C., et al., 2009. The Important Turning Period of Evolution in the Tibet-Himalayan Tectonic Domain. *Earth Science Frontiers*, 16(4): 1—12 (in Chinese with English abstract).

Liu, D.S., Zheng, M.P., Guo, Z.T., 1998. Initiation and Evolution of the Asian Monsoon System Timely Coupled with the Ice-Sheet Growth and the Tectonic Movements in Asia. *Quaternary Sciences*, 18(3): 194—204(in Chinese with English abstract).

Liu, G.W., Li, J.G., 2016. Miocene Fossil Floral Horizons in the Oiyug Basin, Southern Central Tibet, and Related Stratigraphic Problems. *Journal of Stratigraphy*, 40(1): 92—99(in Chinese with English abstract).

Liu, J.S., Xu, H.Z., Jiang, Y.M., et al., 2020. Mesozoic and Cenozoic Basin Structure and Tectonic Evolution in the East China Sea Basin. *Acta Geologica Sinica*, 94(3): 675—691(in Chinese with English abstract).

Liu, R., Lu, J.G., Wu, X.Z., 2006. Time and Environment of Formation and Geochemical Characteristics of the Chenyuhu to Xiangyanghu Shipingding Group Volcanic Rocks in Northern Tibet. *Xinjiang Geology*, 24(2): 109—114(in Chinese with English abstract).

Liu, X.B., Shi, W., Hu, J.M., et al., 2019. Magnetostratigraphy and Tectonic Implications of Paleogene-Neogene Sediments in the Yinchuan Basin, Western North China Craton. *Journal of Asian Earth Sciences*, 173: 61—69. https: //doi.org/10.1016/j.jseaes.2019.01.016

Liu, X.D., Sun, H., Miao, Y.F., et al., 2015. Impacts of Uplift of Northern Tibetan Plateau and Formation of Asian Inland Deserts on Regional Climate and Environment. *Quaternary Science Reviews*, 116: 1—14. https: //doi.org/10.1016/j.quascirev.2015.03.010

Lu, H.J., Tian, X.B., Yun, K., et al., 2018. Convective Removal of the Tibetan Plateau Mantle Lithosphere by ～26 Ma. *Tectonophysics*, 731/732: 17—34. https: //doi.org/10.1016/j.tecto.2018.03.006

Lu, H.J., Xiong, S.F., 2009. Magnetostratigraphy of the Dahonggou Section, Northern Qaidam Basin and Its Bearing on Cenozoic Tectonic Evolution of the Qilian Shan and Altyn Tagh Fault. *Earth and Planetary Science Letters*, 288(3/4): 539—550. https: //doi. org/10.1016/j.epsl.2009.10.016

Lu, H.Y., Wang, X.Y., Wang, X.Y., et al., 2019. Formation and Evolution of Gobi Desert in Central and Eastern Asia. *Earth-Science Reviews*, 194: 251—263. https: //doi.org/10.1016/j.earscirev.2019.04.014

Lu, H.Y., Zhang, H.Z., Wang, Y.C., et al., 2018. Cenozoic Depositional Sequence in the Weihe Basin (Central China): A Long-Term Record of Asian Monsoon Precipitation from the Greenhouse to Icehouse Earth. *Quaternary Sciences*, 38(5):1057—1067 (in Chinese with English abstract).

Ma, S.X., Li, H.L., Zhang, Y.Q., et al., 2016. The Neogene Extension of the Tianshui Basin: Evidence from Sedimentary and Structural Records. *Geological Bulletin of China*, 35(8): 1314—1323(in Chinese with English abstract).

McArthur, J. M., Howarth, R. J., Shields, G. A., 2012. Strontium Isotope Stratigraphy. The Geologic Time Scale. Elsevier, Amsterdam, 127—144. https: //doi.org/10.1016/b978-0-444-59425-9.00007-x

Miller, K.G., Kominz, M.A., Browning, J.V., et al., 2005. The Phanerozoic Record of Global Sea-Level Change. *Science*, 310(5752): 1293—1298. https: //doi. org/10.1126/science.1116412

Qiang, X.K., An, Z.S., Song, Y.G., et al., 2011. New Eolian Red Clay Sequence on the Western Chinese Loess Plateau Linked to Onset of Asian Desertification about 25 Ma Ago. *Science China Earth Sciences*, 54(1): 136—144. https: //doi.org/10.1007/s11430-010-4126-5

Qiu, H.J., Xu, Z.Q., Qiao, D.W., 2006. Progress in the Study of the Tectonic Evolution of the Subei Basin, Jiangsu, China. *Geological Bulletin of China*, 25(Z2): 1117—1120(in Chinese with English abstract).

Rea, D.K., Snoeckx, H., Joseph, L.H., 1998. Late Cenozoic Eolian Deposition in the North Pacific: Asian Drying, Tibetan Uplift, and Cooling of the Northern Hemisphere. *Paleoceanography*, 13(3): 215—224. https: //doi.org/10.1029/98pa00123

Ren, J.Y., 2018. Genetic Dynamics of China Offshore Cenozoic Basins. *Earth Science*, 43(10): 3337—3361(in Chinese with English abstract).

Ren, L.L., Zhang, B., Zheng, D.W., et al., 2020. Tectonic Transformation and Its Exhumation History of the Ailao Shan-Red River Shear Zone in Oligocene: Evidences from Apatite Fission Track Thermochronology of the Southern Segment of the Ailao Shan Range. *Acta Petrologica Sinica*, 36(6): 1787—1802(in Chinese with English abstract).

Robinson, A.C., Yin, A., Manning, C. E., et al., 2004. Tectonic Evolution of the Northeastern Pamir: Constraints from the Northern Portion of the Cenozoic Kongur Shan Extensional System, Western China. *Geological Society of America Bulletin*, 116(7): 953—973. https: //doi.

org/10.1130/b25375.1

Saylor, J.E., Quade, J., Dettman, D.L., et al., 2009. The Late Miocene through Present Paleoelevation History of Southwestern Tibet. *American Journal of Science*, 309 (1): 1—42. https: //doi.org/10.2475/01.2009.01

Shen, Q.Q., Cao, K., Wang, G.C., et al., 2017. Paleogene Sedimentary and Structural Evolution of the Jianchuan-Lanping Basins, Western Yunnan and Its Regional Tectonic Implications. *Geotectonica et Metallogenia*, 41(1): 23—41(in Chinese with English abstract).

Shi, Y.F., Li, J.J., Li, B.Y., et al., 1999. Uplift of the Qinghai-Xizang (Tibetan) Plateau and East Asia Environmental Change during Late Cenozoic. *Acta Geographica Sinica*, 54(1): 10—21(in Chinese with English abstract).

Sobel, E.R., Chen, J., Heermance, R. V., 2006. Late Oligocene-Early Miocene Initiation of Shortening in the Southwestern Chinese Tian Shan: Implications for Neogene Shortening Rate Variations. *Earth and Planetary Science Letters*, 247(1/2): 70—81. https: //doi. org/10.1016/j.epsl.2006.03.048

Song, B.W., Spicer, R.A., Zhang, K. X., et al., 2020. Qaidam Basin Leaf Fossils Show Northeastern Tibet was High, Wet and Cool in the Early Oligocene. *Earth and Planetary Science Letters*, 537: 116175. https: //doi. org/10.1016/j.epsl.2020.116175

Song, B.W., Zhang, K.X., Hou, Y. F., et al., 2019. New Insights into the Provenance of Cenozoic Strata in the Qaidam Basin, Northern Tibet: Constraints from Combined U-Pb Dating of Detrital Zircons in Recent and Ancient Fluvial Sediments. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 533: 109254. https: //doi. org/10.1016/j.palaeo.2019.109254

Song, B.W., Zhang, K.X., Xu, Y.D., et al., 2020. Paleogene Tectonic-Stratigraphic Realms and Sedimentary Sequence in China. *Earth Science*, 45(12): 4352—4369(in Chinese with English abstract).

Song, C.H., 2006. Tectonic Uplift and Cenozoic Sedimentary Evolution in the Northern Margin of the Tibetan Plateau (Dissertation). Lanzhou University, Lanzhou(in Chinese with English abstract).

Spicer, R.A., Harris, N.B.W., Widdowson, M., et al., 2003. Constant Elevation of Southern Tibet over the Past 15 Million Years. *Nature*, 421(6923): 622—624. https: //doi.org/10.1038/nature01356

Su, J.B., Zhu, W.B., Chen, J., et al., 2014. Cenozoic Inversion of the East China Sea Shelf Basin: Implications for Reconstructing Cenozoic Tectonics of Eastern China. *International Geology Review*, 56(12): 1541—1555. https: //doi.org/10.1080/00206814.2014.951004

Sun, D.X., Lü, T.Y., Shen, X.L., et al., 2019. High-Precision Laser $^{40}Ar/^{39}Ar$ Age of Volcanic Rocks in Longhai-Zhangpu Area, Fujian Province. *Geological Bulletin of China*, 38(9): 1511—1520(in Chinese with English abstract).

Sun, J.M., Liu, T.S., 2006. The Age of the Taklimakan Desert. *Science*, 312(5780): 1621. https: //doi.org/10.1126/science.1124616

Sun, J.M., Ye, J., Wu, W.Y., et al., 2010. Late Oligocene-Miocene Mid-Latitude Aridification and Wind Patterns in the Asian Interior. *Geology*, 38(6): 515—518. https: //doi.org/10.1130/g30776.1

Sun, X.J., Wang, P.X., 2005. How Old is the Asian Monsoon System?—Palaeobotanical Records from China. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 222(3/4): 181—222. https: //doi. org/10.1016/j. palaeo.2005.03.005

Suo, Y.H., Li, S.Z., Dai, L.M., et al., 2012. Cenozoic Tectonic Migration and Basin Evolution in East Asia and Its Continental Margins. *Acta Petrologica Sinica*, 28(8): 2602—2618(in Chinese with English abstract).

Wade, B.S., Pearson, P.N., Berggren, W. A., et al., 2011. Review and Revision of Cenozoic Tropical Planktonic Foraminiferal Biostratigraphy and Calibration to the Geomagnetic Polarity and Astronomical Time Scale. *Earth-Science Reviews*, 104(1/2/3): 111—142. https: //doi. org/10.1016/j.earscirev.2010.09.003

Wan, C.B., Sun, Y.W., Xue, Y. F., et al., 2014. Neogene Palynological Assemblages in the West Slope of Songliao Basin and Their Geological Implications. *Science China Earth Sciences*, 57(10): 2486—2497. https: //doi.org/10.1007/s11430-014-4846-z

Wan, T.F., 2004. The Tectonics Compendium in China. Geological Publishing House, Beijing (in Chinese).

Wang, J. G., Hu, X. M., Garzanti, E., et al., 2013. Upper Oligocene-Lower Miocene Gangrinboche Conglomerate in the Xigaze Area, Southern Tibet: Implications for Himalayan Uplift and Paleo-Yarlung-Zangbo Initiation. *The Journal of Geology*, 121(4): 425—444. https: //doi. org/10.1086/670722

Wang, P. X., 2005. Cenozoic Deformation and History of Sea-Land Interactions in Asia. *Earth Science*, 30(1): 1—18(in Chinese with English abstract).

Wang, B.J., Lin, C.S., Chen, Y., et al., 2006. Episodic Tectonic Movement and Evolutional Character in Jianghan Basin. *Oil Geophysical Prospecting*, 41(2): 226—230, 248, 19－20(in Chinese with English abstract).

Wang, C.S., Dai, J.G., Zhao, X.X., et al., 2014. Outward-Growth of the Tibetan Plateau during the Cenozoic: A Review. *Tectonophysics*, 621: 1－43. https://doi.org/10.1016/j.tecto.2014.01.036

Wang, C.S., Zhao, X.X., Liu, Z.F., et al., 2008. Constraints on the Early Uplift History of the Tibetan Plateau. *Proceedings of the National Academy of Sciences*, 105(13): 4987－4992. https://doi.org/10.1073/pnas.0703595105

Wang, E.Q., Chen, L.Z., Chen, Z.L., 2002. Tectonic and Climatic Element-Controlled Evolution of the Yalungzangbu River in Southern Tibet. *Quaternary Sciences*, 22(4): 365－373(in Chinese with English abstract).

Wang, F.L., Li, Y., Li, Y.Z., et al., 2003. Sedmentary Characteristics of the Cenozoic Dayi Conglomerate in Chengdu Basin. *Journal of Chengdu University of Technology (Science & Technology Edition)*, 30(2): 139－146(in Chinese with English abstract).

Wang, G.C., Cao, K., Zhang, K.X., et al., 2011. Spatio-Temporal Framework of Tectonic Uplift Stages of the Tibetan Plateau in Cenozoic. *Science China Earth Sciences*, 54(1): 29－44. https://doi.org/10.1007/s11430-010-4110-0

Wang, H.F., Dai, T.M., Fan, S.K., et al., 1985. K-Ar Dating of Hannuoba Basalts at Zhangjiakou. *Geochimica*, 14(3): 206－215(in Chinese with English abstract).

Wang, P.X., Jian, Z.M., 2019. Exploring the Deep South China Sea: Retrospects and Prospects. *Science China Earth Sciences*, 62(10): 1473－1488. https://doi.org/10.1007/s11430-019-9484-4

Wang, P.X., Zhao, Q.H., Jian, Z.M., 2003. Thirty Million Year Deep Sea Records in the South China Sea. *Chinese Science Bulletin*, 48: 2524－2535 (in Chinese).

Wang, S.F., Zhang, W.L., Fang, X.M., et al., 2008. Magnetic Stratigraphic Characteristics of Zhada Basin in the Southwest of the Tibet and Its Tectonic Significance. *Chinese Science Bulletin*, 53(6): 676－683(in Chinese).

Wang, W.L., Fu, J.Y., Yang, Y.J., 2012. Tectonic Evolution and Genesis of the Late Mesozoic-Cenozoic Basin-and-Mountain System of Northeast China. *Geology and Resources*, 21(1): 17－26(in Chinese with English abstract).

Wang, W.T., Zheng, W.J., Zhang, P.Z., et al., 2017. Expansion of the Tibetan Plateau during the Neogene. *Nature Communications*, 8(1): 1－12. https://doi.org/10.1038/ncomms15887

Wang, X., Carrapa, B., Sun, Y., et al., 2020. The Role of the Westerlies and Orography in Asian Hydroclimate since the Late Oligocene. *Geology*, 48(7): 728e732. https://doi.org/10.1130/G47400.1

Wang, X.F., Chen, X.H., 2005. Stratigraphic Subdivision and Correlation of Each Geologic Period in China. Geological Publishing House, Beijing (in Chinese).

Wang, X.M., 2004. New Materials of Tungurictis (Hyaenidea, Carnivora) from Tunggur Formation, Neimongol. *Vertebrata Palasiatica*, 42(2): 144－153.

Wang, Z.F., He, J.X., Xie, X.N, 2004. Heat Flow Action and Its Control on Natural Gas Migration and Accumulation in Mud-Fluid Diapir Areas in Yinggehai Basin. *Earth Science*, 29(2): 203－210(in Chinese with English abstract).

Wei, Q.R., Li, D.W., Wang, G.C., et al., 2007. Zircon SHRIMP U-Pb Dating and Geochemical Characteristics of Chabaoma Formation Volcanic Rocks in Northern Tibetan Plateau and Its Petrogenesis. *Acta Petrologica Sinica*, 23(11): 2727－2736(in Chinese with English abstract).

Xie, X.N., Ren, J.Y., Wang, Z.F., et al., 2015. Difference of Tectonic Evolution of Continental Marginal Basins of South China Sea and Relationship with SCS Spreading. *Earth Science Frontiers*, 22(1): 77－87(in Chinese with English abstract).

Xing, G.F., Feng, Y.M., Yu, M.G., et al., 2017. The Volcanic Tectonic of China. Geological Publishing House, Beijing (in Chinese).

Xing, Z.Y., Zhao, B., Tu, M.Y., et al., 2005. The Formation of the Fenwei Rift Valley. *Earth Science Frontiers*, 12(2): 247－262(in Chinese with English abstract).

Xu, Y.D., Zhang, K.X., Wang, G.C., et al., 2012. Extended Stratigraphy, Palynology and Depositional Environments Record the Initiation of the Himalayan Gyirong Basin (Neogene China). *Journal of Asian Earth Sciences*, 44: 77－93. https://doi.org/10.1016/j.jseaes.2011.04.007

Yang, Q., Chen, H.Y., 2003. Tectonic Evolution of the North Jiangsu-South Yellow Sea Basin. *Petroleum Geology & Experiment*, 25(S1): 562－565(in Chinese with English abstract).

Ye, J., Wu, W.Y., Ni, X.J., et al., 2012. The Duolebulejin Section of Northern Junggar Basin and Its Stratigraphic and Environmental Implication. *Scientia Sinica (Terrae)*, 42(10): 1523－1532(in Chinese).

Yin, A., Harrison, T.M., 2000. Geologic Evolution of the Himalayan-Tibetan Orogen. *Annual Review of Earth and Planetary Sciences*, 28(1): 211－280. https://doi.org/10.1146/annurev.earth.28.1.211

Yuan, D.Y., Ge, W.P., Chen, Z.W., et al., 2013. The

Growth of Northeastern Tibet and Its Relevance to Large-Scale Continental Geodynamics: A Review of Recent Studies. *Tectonics*, 32(5): 1358−1370. https: //doi. org/10.1002/tect.20081

Yue, L.P., Deng, T., Zhang, R., et al., 2004. Paleomagnetic Chronology and Records of Himalayan Uplift on the Longgugou Section of Gyirong-Oma Basin in Xizang(Tibet). *Chinese Journal of Geophysics*, 47(6): 1009−1016 (in Chinese with English abstract).

Yue, Y.J., Ritts, B. D., Hanson, A. D., et al., 2004. Sedimentary Evidence against Large Strike-Slip Translation on the Northern Altyn Tagh Fault, NW China. *Earth and Planetary Science Letters*, 228(3/4): 311−323. https: //doi.org/10.1016/j.epsl.2004.10.008

Zachos, J., Pagani, M., Sloan, L., et al., 2001. Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present. *Science*, 292(5517): 686−693. https: //doi. org/10.1126/science.1059412

Zachos, J.C., Dickens, G. R., Zeebe, R. E., 2008. An Early Cenozoic Perspective on Greenhouse Warming and Carbon-Cycle Dynamics. *Nature*, 451(7176): 279−283. https: //doi.org/10.1038/nature06588

Zhang, J., Wang, Y.N., Zhang, B. H., et al., 2015. Evolution of the NE Qinghai-Tibetan Plateau, Constrained by the Apatite Fission Track Ages of the Mountain Ranges around the Xining Basin in NW China. *Journal of Asian Earth Sciences*, 97: 10−23. https: //doi.org/10.1016/j. jseaes.2014.10.002

Zhang, J., Wang, Y.N., Zhang, B. H., et al., 2016. Tectonics of the Xining Basin in NW China and Its Implications for the Evolution of the NE Qinghai-Tibetan Plateau. *Basin Research*, 28(2): 159−182. https: //doi. org/10.1111/ bre.12104

Zhang, K.X., He, W.H., Luo, M.S., et al., 2017. Sedimentary Formation and Tectonic Evolution of China. Geological Publishing House, Beijing (in Chinese).

Zhang, K.X., He, W.H., Xu, Y.D., et al., 2020. Principles and Methods to Division of Tectonostratigraphic Regions for Geochronologic Periods: Exemplified by Cambrian Period. *Earth Science*, 45(12): 4267−4290(in Chinese with English abstract).

Zhang, K.X., Pan, G.T., He, W.H., et al., 2015. New Division of Tectonic-Strata Superregion in China. *Earth Science*, 40(2): 206−233(in Chinese with English abstract).

Zhang, K.X., Wang, G.C., Ji, J.L., et al., 2010. Paleogene-Neogene Stratigraphic Realm and Sedimentary Sequence of the Qinghai-Tibet Plateau and Their Response to Uplift of the Plateau. *Science China Earth Sciences*, 53(9): 1271−1294. https: //doi. org/10.1007/ s11430-010-4048-2

Zhang, K.X., Wang, G.C., Luo, M.S., et al., 2013. Cenozoic Tectonic Lithofacies Paleogeographic Map with Instructions in the Tibetan Plateau and Adjacent Regions (1∶3 000 000). Geological Publishing House, Beijing (in Chinese).

Zhang, T., Fang, X. M., Song, C. H., et al., 2014. Cenozoic Tectonic Deformation and Uplift of the South Tian Shan: Implications from Magnetostratigraphy and Balanced Cross-Section Restoration of the Kuqa Depression. *Tectonophysics*, 628: 172−187. https: //doi. org/ 10.1016/j.tecto.2014.04.044

Zhang, Y.Q., Dong, S. W., Li, J. H, 2019. Late Paleogene Sinistral Strike-Slip System along East Qinling and in Southern North China: Implications for Interaction between Collision-Related Block Trans-rotation and Subduction-Related Back-Arc Extension in East China. *Tectonophysics*, 769: 228181. https: //doi.org/10.1016/ j.tecto.2019.228181

Zhang, Y.Q., Shi, W., Dong, S.W., 2019. Neotectonics of North China: Interplay between Far-Field Effect of India-Eurasia Collision and Pacific Subduction Related Deep-Seated Mantle Upwelling. *Acta Geologica Sinica*, 93(5): 971 - 1001(in Chinese with English abstract).

Zhang, Z.S., Guo, Z.T., 2005. Spatial Character Reconstruction of Different Periods in Oligocene and Miocene. *Quaternary Sciences*, 25(4): 523−530(in Chinese with English abstract).

Zhao, Z., Wu, Z.H., Yang, Y.Z., et al., 2020. Establishing the Chronostratigraphic Framework of the Continental Red Beds in Central Qiangtang Basin: Constrained by Zircon U-Pb Ages. *Geological Review*, 66(5): 1155−1171(in Chinese with English abstract).

Zhao, Z.G., Wang, P., Qi, P., et al., 2016. Regional Background and Tectonic Evolution of East China Sea Basin. *Earth Science*, 41(3): 546−554(in Chinese with English abstract).

Zhao, Z.M., Ji, W.H., Li, R.S., et al., 2009. Geochemical Characteristics and Petrogenesis of Volcanic Rocks since the Neogene in the Bayankala and East Kunlun Region, Northern Tibetan Plateau. *Geochimica*, 38(3): 205−230 (in Chinese with English abstract).

Zhao, Z.Z., Li, Y.T., Ye, H.F., et al., 2001. Stratigraphy of Qinghai-Tibet Plateau. Science Press, Beijing (in Chinese).

Zheng, D.W., Zhang, P. Z., Wan, J. L., et al., 2006. Rapid Exhumation at ∼8 Ma on the Liupan Shan Thrust Fault from Apatite Fission-Track Thermochronology: Implications for Growth of the Northeastern Tibetan Plateau Margin. *Earth and Planetary Science Letters*, 248(1－2): 198－208. https: //doi. org/10.1016/j.epsl.2006.05.023

Zheng, H. B., Clift, P. D., Wang, P., et al., 2013. Pre-Miocene Birth of the Yangtze River. *Proceedings of the National Academy of Sciences*, 110(19): 7556－7561. https: //doi.org/10.1073/pnas.1216241110

Zheng, H. B., Wei, X. C., Tada, R., et al., 2015. Late Oligocene-Early Miocene Birth of the Taklimakan Desert. *PNAS*, 112(25): 7662－7667. https: //doi. org/10.1073/pnas.1424487112

Zhu, Y. T., Fang, X. M., Gao, J. P., et al., 2006. Oligo-Mioence Depositional Facies of the Wuyu Basin, Southern Tibetan Plateau. *Acta Sedimentologica Sinica*, 24(6): 775－782(in Chinese with English abstract).

附中文参考文献

曹凯,麦洪涛,王国灿,等,2018. 帕米尔构造结中新生代构造地貌演化及对塔里木盆地海退的影响. 第四纪研究, 38(1):15－38

陈奋宁, 徐亚东, 江尚松, 等, 2010. 西藏南部吉隆盆地晚中新世－早更新世沃马组介形虫动物群 . 地球科学, 35(5): 821－827.

陈贺海, 汉景泰, 丁仲礼, 等, 2007. 藏南乌郁盆地晚新生代沉积序列的时代及其区域构造意义 . 中国科学(D辑: 地球科学),37(12): 1617－1624.

陈建林, 许继峰, 康志强, 等, 2006. 青藏高原西部措勤县中新世布嘎寺组钾质火山岩成因 . 岩石学报,22(3): 585－594.

陈新伟, 2016. 帕米尔南天山新生代构造事件的沉积响应研究(博士学位论文). 杭州: 浙江大学 .

陈正乐, 白彦飞, 陈柏林, 等, 2003. 阿尔金山索尔库里北盆地沉积与构造演化 . 地质通报,22(6): 405－411.

陈正乐, 宫红良, 李丽, 等, 2006. 阿尔金山脉新生代隆升－剥露过程 . 地学前缘,13(4): 91－102.

邓涛, 吴飞翔, 王世骐, 等, 2019. 古近纪/新近纪之交青藏高原陆地生态系统的重大转折 . 科学通报, 64(27): 2894－2906.

方小敏, 宋春晖, 戴霜, 等, 2007. 青藏高原东北部阶段性变形隆升: 西宁、贵德盆地高精度磁性地层和盆地演化记录 . 地学前缘,14(1): 230－242.

付碧宏, 时丕龙, 贾营营, 2009. 青藏高原大型走滑断裂带晚新生代构造地貌生长及水系响应 . 地质科学, 44(4): 1343－1363.

黄奇瑜, 2017. 台湾岛的年龄 . 中国科学: 地球科学, 47(4): 394－405.

季军良, 张克信, 强泰, 等, 2010. 青海循化盆地新近纪磁性地层学 . 地球科学, 35(5): 803－810.

贾承造,张师本,吴绍祖,2004. 塔里木盆地及周边地层 . 北京:科学出版社 .

蒋显庭,周维芬,林树,2015. 新疆地层及介形类化石 . 北京: 地质出版社 .

解习农, 任建业, 王振峰, 等, 2015. 南海大陆边缘盆地构造演化差异性及其与南海扩张耦合关系 . 地学前缘, 22(1): 77－87.

李冰晶, 武登云, 逄立臣, 等, 2019. 西域砾岩的地层属性与成因: 进展与展望 . 地球环境学报, 10(5): 427－440.

李洪军, 申科峰, 聂逢君, 等, 2012. 二连盆地中新生代沉积演化与铀成矿 . 东华理工大学学报(自然科学版), 35(4): 301－308.

李军鹏, 2008. 青藏高原沱沱河地区中新世五道梁组磁性地层与古环境演变研究(硕士学位论文). 成都: 成都理工大学 .

李廷栋, 1995. 青藏高原隆升的过程和机制 . 地球学报,16(1): 1－9.

李云通,雷奕振,王大宁,等,1984. 中国地层－中国的第三系 . 北京:地质出版社 .

刘池洋, 赵红格, 张参,等, 2009. 青藏－喜马拉雅构造域演化的转折时期 . 地学前缘, 16(4): 1－12.

刘东生, 郑绵平, 郭正堂, 1998. 亚洲季风系统的起源和发展及其与两极冰盖和区域构造运动的时代耦合性 . 第四纪研究,18(3): 194－204.

刘耕武, 李建国, 2016. 西藏南木林乌郁盆地中新世植物化石层位及相关地层问题 . 地层学杂志, 40(1): 92－99.

刘金水, 许怀智, 蒋一鸣, 等, 2020. 东海盆地中、新生代盆架结构与构造演化 . 地质学报, 94(3): 675－691.

刘荣, 吕金刚, 吴新忠, 2006. 藏北沉鱼湖—向阳湖一带石坪顶组火山岩特征、形成时代及环境 . 新疆地质,24(2): 109－114.

鹿化煜,张瀚之,王逸超,等,2018. 渭河盆地新生代沉积序列与亚洲季风气候起源演化 . 第四纪研究,38(3):1057－1067.

马收先, 李海龙, 张岳桥, 等, 2016. 天水盆地新近纪伸展构造: 来自沉积与构造变形方面的证据 . 地质通报, 35(8): 1314－1323.

邱海峻, 许志琴, 乔德武, 2006. 苏北盆地构造演化研究进展 . 地质通报,25(Z2): 1117－1120.

任建业, 2018. 中国近海海域新生代成盆动力机制分析 . 地球科学, 43(10): 3337－3361.

任龙龙, 张波, 郑德文, 等, 2020. 哀牢山－红河剪切带渐新世的构造体制转换与剥露历史: 来自哀牢山南段磷灰石裂变径迹的证据 . 岩石学报, 36(6): 1787－1802.

沈青强, 曹凯, 王国灿, 等, 2017. 剑川－兰坪盆地古近纪沉积－构造变革及其区域构造意义 . 大地构造与成矿学,

41(1): 23−41.

施雅风, 李吉均, 李炳元, 等, 1999. 晚新生代青藏高原的隆升与东亚环境变化. 地理学报,54(1): 10−21.

宋博文, 张克信, 徐亚东, 等, 2020. 中国古近纪构造—地层区划及地层格架. 地球科学, 45(12): 4352−4369.

宋春晖, 2006. 青藏高原北缘新生代沉积演化与高原构造隆升过程(博士学位论文). 兰州: 兰州大学.

孙东霞, 吕同艳, 沈晓丽, 等, 2019. 福建龙海—漳浦沿海地区火山岩激光 $^{40}Ar/^{39}Ar$ 年龄. 地质通报, 38(9): 1511−1520.

索艳慧, 李三忠, 戴黎明, 等, 2012. 东亚及其大陆边缘新生代构造迁移与盆地演化. 岩石学报, 28(8): 2602−2618.

万天丰, 2007. 中国大地构造学纲要. 北京: 地质出版社.

汪品先, 2005. 新生代亚洲形变与海陆相互作用. 地球科学, 30(1): 1−18.

汪啸风, 陈孝红, 2005. 中国各地质时代地层划分与对比. 北京: 地质出版社.

王必金, 林畅松, 陈莹, 等, 2006. 江汉盆地幕式构造运动及其演化特征. 石油地球物理勘探, 41(2): 226−230, 248, 19−20.

王二七, 陈良忠, 陈智樑, 2002. 在构造和气候因素制约下的雅鲁藏布江的演化. 第四纪研究,22(4): 365−373.

王凤林, 李勇, 李永昭, 等, 2003. 成都盆地新生代大邑砾岩的沉积特征. 成都理工大学学报(自然科学版), 30(2): 139−146.

王慧芬, 戴橦谟, 范嗣昆, 等, 1985. 张家口汉诺坝玄武岩K-Ar年龄计时. 地球化学,14(3): 206−215.

王世锋, 张伟林, 方小敏, 等, 2008. 藏西南札达盆地磁性地层学特征及其构造意义. 科学通报, 53(6): 676−683.

王五力, 付俊彧, 杨雅军, 2012. 中国东北晚中生代—新生代盆山体系构造演化及成因探讨. 地质与资源, 21(1): 17−26.

王振峰, 何家雄, 解习农, 2004. 莺歌海盆地泥—流体底辟带热流体活动对天然气运聚成藏的控制作用. 地球科学,29(2): 203−210.

魏启荣, 李德威, 王国灿, 等, 2007. 青藏高原北部查保马组火山岩的锆石SHRIMP U-Pb定年和地球化学特点及其成因意义. 岩石学报,23(11): 2727−2736.

邢光福,冯益民,余明刚,等,2017. 中国火山岩大地构造. 北京:地质出版社.

邢作云, 赵斌, 涂美义, 等, 2005. 汾渭裂谷系与造山带耦合关系及其形成机制研究. 地学前缘,12(2): 247−262.

杨琦, 陈红宇, 2003. 苏北—南黄海盆地构造演化. 石油实验地质,25(S1): 562−565.

叶捷, 吴文裕, 倪喜军, 等, 2012. 新疆准噶尔盆地北缘夺勒布勒津剖面的地层学及环境意义. 中国科学: 地球科学, 42(10): 1523−1532.

岳乐平, 邓涛, 张睿, 等, 2004. 西藏吉隆—沃马盆地龙骨沟剖面古地磁年代学及喜马拉雅山抬升记录. 地球物理学报,47(6): 1009−1016.

云南省地质矿产局,1996. 云南省岩石地层. 武汉: 中国地质大学出版社.

张克信, 何卫红, 徐亚东, 等, 2020. 论断代构造—地层区划的原则与方法: 以中国寒武纪构造—地层区划为例. 地球科学, 45(12): 4267−4290.

张克信, 潘桂棠, 何卫红, 等, 2015. 中国构造—地层大区划分新方案. 地球科学, 40(2): 206−233.

张克信,2017. 中国沉积岩建造与沉积大地构造. 北京: 地质出版社.

张克信,王国灿,骆满生,等,2013. 青藏高原及邻区新生代构造—岩相古地理图及说明书(1:3 000 000). 北京:地质出版社.

张岳桥, 施炜, 董树文, 2019. 华北新构造: 印欧碰撞远场效应与太平洋俯冲地幔上涌之间的相互作用. 地质学报, 93(5): 971−1001.

张仲石, 郭正堂, 2005. 根据地质记录恢复渐新世和中新世不同时期环境空间特征及其意义. 第四纪研究, 25(4): 523−530.

赵珍, 吴珍汉, 杨易卓,等, 2020. 羌塘中部陆相红层时代的U-Pb年龄约束. 地质论评, 66(5): 1155−1171.

赵振明, 计文化, 李荣社, 等, 2009. 青藏高原北部巴颜喀拉与东昆仑地区新近纪以来火山岩的地球化学特征及其成因. 地球化学, 38(3): 205−230.

赵政璋,李永铁,叶和飞,等,2001. 青藏高原地层. 北京:科学出版社.

赵志刚, 王鹏, 祁鹏, 等, 2016. 东海盆地形成的区域地质背景与构造演化特征. 地球科学, 41(3): 546−554.

朱迎堂, 方小敏, 高军平, 等, 2006. 青藏高原南部乌郁盆地渐新世—上新世地层沉积相分析. 沉积学报,24(6): 775−782.