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喜马拉雅前渊和孟加拉湾盆地形成演化

王　茜[1,2],辛仁臣[3*],董瑞杰[3],樊啸天[3]

(1 中国地质大学(北京)地球科学与资源学院,北京 100083;
2 中国华电集团清洁能源有限公司,北京 100160;
3 中国地质大学(北京)海洋学院,北京 100083)

摘　要:通过区域地质、地球物理、板块重建及地球动力学背景综合研究,揭示了喜马拉雅前渊和孟加拉湾盆地形成演化及动力学背景。喜马拉雅前渊与孟加拉湾盆地被西隆(Shillong)高原分隔。喜马拉雅前渊位于西隆高原北侧,主要以拉萨地块前白垩系为基底,晚白垩世—早始新世为新特提斯洋向洋内岛弧、拉萨板块俯冲形成的弧前和弧后盆地;中始新世—中新世早期,新特提斯洋逐渐俯冲消亡,印度板块与拉萨地块的陆陆碰撞逐渐加剧,形成前陆盆地;中新世中期以来,随着印度板块与欧亚板块陆陆碰撞的加剧,喜马拉雅前陆盆地隆升、剥蚀,只保留了前陆盆地的前渊。孟加拉湾(Bengal)盆地位于西隆高原南侧,其西北部以印度板块的前寒武系为基底,石炭—二叠纪为裂谷盆地,三叠纪为剥蚀区,侏罗纪—早白垩世以火山作用为主,晚白垩世—早始新世为被动大陆边缘盆地,中始新世以来随着印度板块向拉萨板块俯冲加剧,印度洋板块向缅甸大陆俯冲,孟加拉湾盆地演化为陆缘碎屑供应逐渐增强的残留洋盆。孟加拉湾东南部的基底为前古近系洋壳,始新世以来形成巨厚的残留洋盆充填序列。

关键词:喜马拉雅前渊;孟加拉湾盆地;弧后盆地;前陆盆地;残留洋盆

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喜马拉雅前渊盆地和孟加拉湾盆地是重要的含油气盆地,仅孟加拉湾盆地面积就达 40.5×10^4 km^2,据 IHS 能源公司预测,其油气可采储量达 3×10^8 m^3。由于其独特的地质属性和巨大的资源效应,长期以来受到学术界和产业界学者的高度关注,发表了大量资料详实的研究成果[1-24]。喜马拉雅前渊盆地和孟加拉湾盆地的成因形成了较为统一的认识:喜马拉雅前渊盆地是印度板块与欧亚大陆碰撞形成的前陆盆地残留[5,6,11-13,23,24];孟加拉湾盆地的主体是新特提斯洋关闭后,印度大陆板块及印度洋板块与欧亚板块碰撞俯冲形成的残留洋盆[1,3,4,8,10,14-17,21,22]。关于印度板块与欧亚大陆的开始碰撞的时间最具争议:Gaetani 和 Garzanti[25] 基于藏斯卡(Zanskar)地区靠近印度缝合带的沉积序列研究认为碰撞开始于 54 Ma;Beck 等[26]根据巴基斯坦境内缝合带地层学证据认为碰撞开始于 66.0～55.5 Ma;Leech 等[27]根据放射性定年数据认为喜马拉雅西部的碰撞时间开始于 57±1 Ma;Najman 等[28]基于西藏地区地质、生物地层及古地磁证据认为在 50 Ma 开始碰撞;Hu 等[29]基于藏南地区的研究

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作者简介:王　茜(1990—),女,在读博士,主要从事含油气盆地构造分析方面的研究工作. E-mail:944085175@qq.com

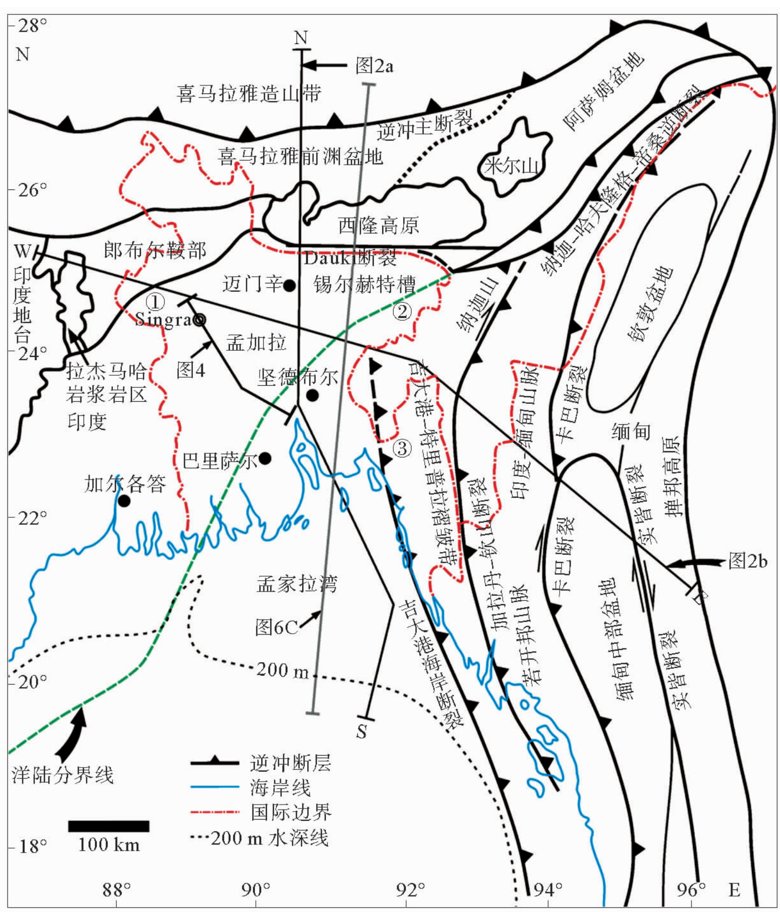
*通讯作者:辛仁臣(1964—),男,博士,副教授,主要从事沉积与油气方面的研究工作. E-mail:xinrenchen@163.com

认为碰撞时间在 66～58 Ma 之间。由此可见，尽管不同学者基于不同地区、不同数据得出的印度板块与欧亚大陆的开始碰撞的时间有差异，但均限定在白垩纪晚期至古近纪早期，喜马拉雅前陆盆地大规模发育开始于古近纪早期以后。

本文根据大量文献资料，编绘了研究区构造简图、地质剖面简图、重点地区地层序列及对比图，在此基础上，结合东特提斯古地理再造研究成果，编绘了喜马拉雅前渊至孟加拉湾盆地演化剖面、喜马拉雅前渊和孟加拉湾盆地形成演化过程。

1　地质背景

喜马拉雅前渊—孟加拉湾盆地北接喜马拉雅造山带，东接印缅山脉，向西过渡为印度台地，南部面向印度洋（图 1）。区域地质研究表明：喜马拉雅前渊主要是晚白垩世以来，新特提斯洋关闭，印度地块向拉萨—喜马拉雅地块之下俯冲（图 2a）形成的前陆盆地残留，下白垩统为被动大陆边缘碎屑岩和远洋火山岩、泥岩、灰岩[30]；东北部阿萨姆（Assam）盆地（图 1）则是印度地块、拉萨—喜马拉雅地块、缅甸地块三者俯冲、拼贴、碰撞形成的前陆盆地残留[31-34]。孟加拉湾盆地西北部为陆壳基底，在前寒武系基底之上发育石炭—二叠系冈瓦纳群含煤岩系和白垩系拉结马哈火山岩系[2-4]，东南部为洋壳基底（图 1），西北部的印度地台太古代陆壳向东南减薄，逐渐过渡为白垩纪洋壳[3,4,8,10,14-17,21-22]（图 2）。孟加拉湾盆地洋壳向东俯冲，形成一系列逆冲断裂、走滑断裂和弧前、弧后盆地[3,4,10,14-16]。本文讨论的重点对象是喜马



①孟加拉湾盆地西北地区；②孟加拉湾盆地东北地区；③孟加拉湾盆地吉大港地区

图 1　喜马拉雅前渊—孟加拉湾盆地及围区构造简图（据文献[2,4,17]资料编绘）

Fig. 1　Simplified tectonic map of the Himalayan foredeep—the Bengal Bay Basin and surrounding area (modified from references [2,4,17])

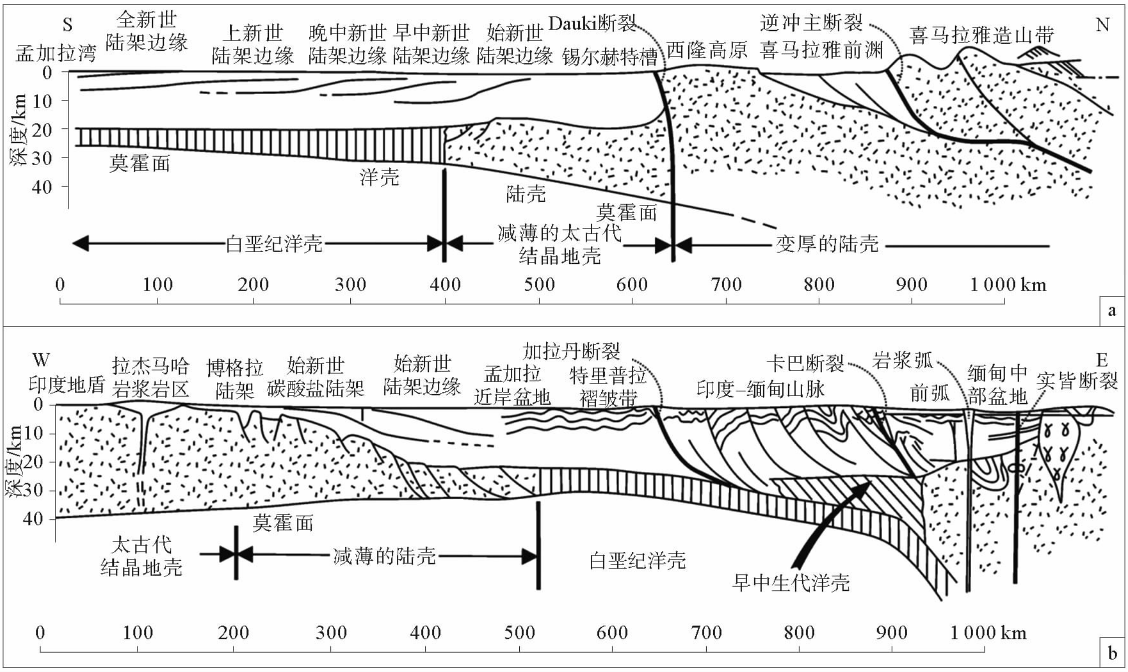


图 2 喜马拉雅前渊—孟加拉湾盆地及围区地质剖面简图(剖面位置见图 1,据文献[2,4,5,17]资料编绘)

Fig. 2 Simplified geological profiles of the Himalayan foredeep—the Bengal Bay Basin and surrounding areas (see Fig. 1 for profile positions modified from references[2,4,5,17])

拉雅前渊和孟加拉湾盆地,限于篇幅,阿萨姆盆地和孟加拉湾盆地洋壳向东俯冲的形成逆冲断裂、走滑断裂和弧前、弧后盆地不予讨论。

2 晚白垩世以来的沉积记录

2.1 喜马拉雅造山带

喜马拉雅造山带的藏斯卡(Zanskar)和藏南地区出露了上白垩统和古近系沉积地层[30]。藏斯卡地区的 Dibling 露头自下而上出露了:①上白垩统 Turonian-Campanian 阶 Chikkim 组灰色及杂色薄层灰岩,含浮游有孔虫,为远洋沉积;②上白垩统 Maastrichtian 阶 Kangi La 组泥岩、泥灰岩、含砂泥灰岩,底部富含浮游有孔虫,顶部陆源碎屑增多,构成向上水深变浅的沉积序列,为远洋—外陆架沉积;③上白垩统 Maastrichtian 阶 Marpo 组泥岩、砂质泥岩、泥灰岩、泥灰质灰岩、灰岩、砂质灰岩,底栖有孔虫、藻类、珊瑚、棘皮动物、介形类化石,为进积碳酸盐岩斜坡沉积;④古近系 Danian 阶 Stumpata 组砂岩、泥灰岩和砂质灰岩,具生物碎屑和生物潜穴,为混积海岸带沉积;⑤古近系 Selandian 阶 Dibling 组厚层灰岩,含广盐性生物化石,为潟湖沉积(图 3)。

2.2 喜马拉雅前陆盆地

喜马拉雅前陆盆地的发育始于古近纪[6,11,12],发育了古近系古新统、始新统、渐新统,新近系中新统、上新统及第四系,不同地区地层特征及岩性地层单位命名有差异(图 3)。

印度查谟(Jammu)地区出露了古近系和新近系沉积地层[11,12,35],自下而上依次为 Subathu 组、Murree 群和 Siwalik 群(图 3)。

(1)Subathu 组

该地岩层序列自下而上为:①横向厚度变化大的硅质角砾岩,角砾为硅化的灰岩碎块;②薄层状和波纹层状粉砂岩及粉砂质泥岩和铝土矿,泥质粉砂岩中见沿纹层分布的棱角状石英碎屑;③黑色泥岩,夹煤层;④灰绿色泥岩与泥质内碎屑灰岩不等厚互层,内碎屑灰岩含多种有孔虫和贝类化石,内碎屑和生物贝壳有序排列,见丘状交错层理,灰绿色泥岩发育水平层理;⑤黄色泥岩与纹层

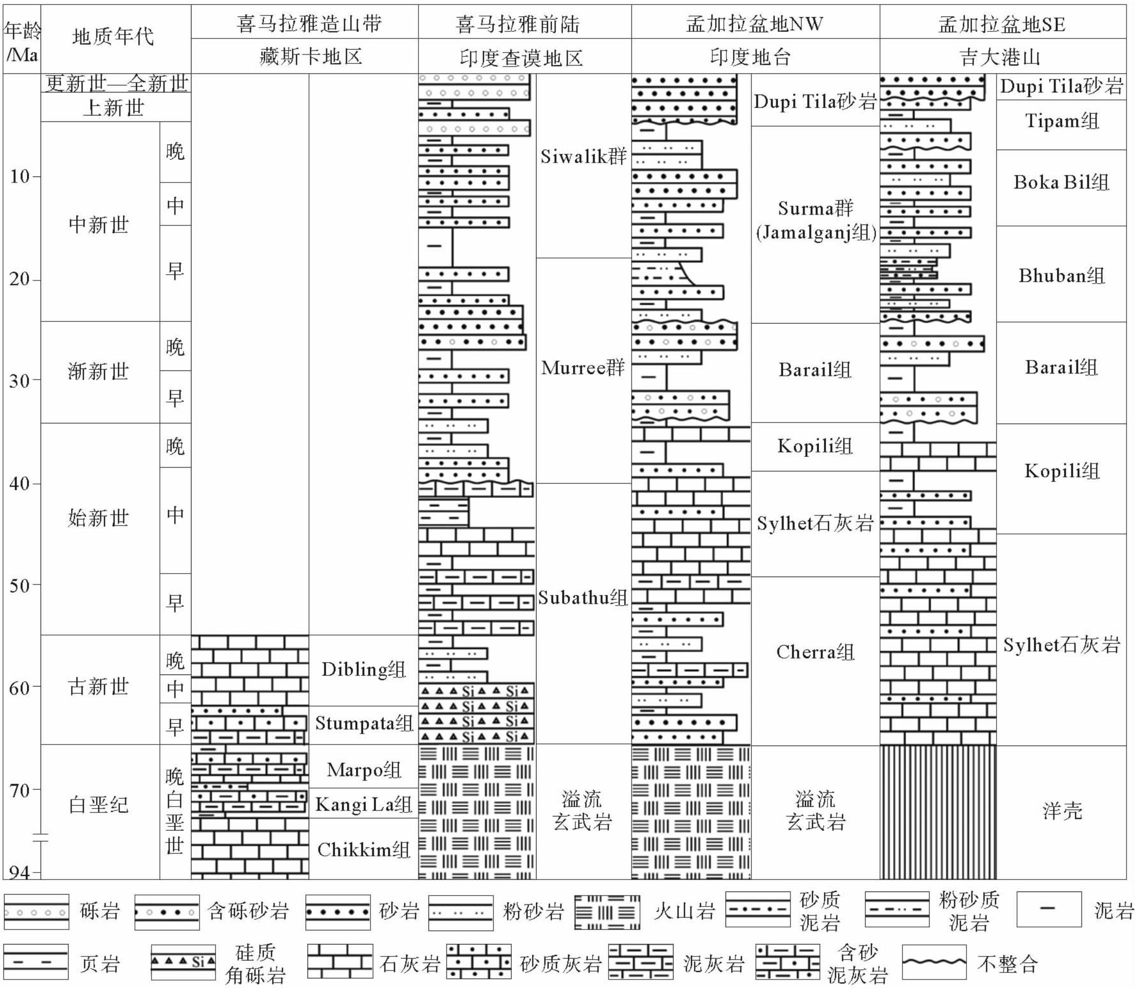


图 3　喜马拉雅—孟加拉湾盆地重点地区地层序列及对比(据文献[2-4,6,11,12,14,30,31]资料编绘)

Fig. 3　The stratigraphic sequences and correlation of the key areas of the Himalayan foredeep—the Bengal Bay Basin (modified from references [2-4,6,11,12,14,30,31])

状灰岩不等厚互层,见水平层理;⑥含牡蛎灰岩,见丘状交错层理和波纹交错层理;⑦紫色页岩和泥灰岩,发育水平层理,具植物化石,其上与 Murree 群以侵蚀面接触。其中,①②③为晚古新世前寒武纪刚性基底之上的河流相—沼泽相沉积;④⑤⑥为障壁—潟湖—浅海—滨岸沉积;⑦为潮上带沉积(图 3)。

(2)Murree 群

该群岩层序列自下而上为:①灰色岩屑砂岩,具交错层理;②褐色、棕色泥岩夹纹层状粉砂岩,泥岩层段见钙质结核土壤层;③棕色泥岩夹砂岩,砂岩具交错层理或波纹交错层理;④含泥砾交错层理砂岩;⑤波纹交错层理砂岩;⑥褐色、棕色泥岩夹纹层状粉砂岩,顶部为钙质结核土壤层。总体上为潮坪体系沉积(图 3)。

(3)Siwalik 群

该群底界年龄约为 18.3 Ma,分为下、中、上 3 部分:①下部为灰色中细粒砂岩与浅色钙质泥岩不等厚互层,底部泥岩厚度较大;②中部为灰白色块状中砂岩夹含钙质结核、植物化石砂质泥岩;③上部为砾岩,夹中粗粒砂岩透镜体及少量泥岩。总体上为河流—冲积扇沉积(图 3)。

2.3　孟加拉湾盆地

孟加拉湾盆地西北部印度地台的钻井资料、吉大港山、锡尔赫特槽翼部的露头资料[2,3]和孟加拉湾盆地北部的钻井和地震资料[4,14],揭示孟加拉湾盆地西北部和东南部的地层序列存在显著

差异(图 3、4)。

孟加拉湾盆地西北部在前寒武系基底之上发育的地层有:石炭—二叠系冈瓦纳群含煤岩系,白垩系拉结马哈火山岩系,古近系 Cherra 组、Sylhet 灰岩、Kopili、Barail 组,新近系 Surma 群、Tipam 群、DupiTila 砂岩。孟加拉湾盆地东南部在白垩纪洋壳基底之上发育的地层有:古近系 Sylhet 灰岩、Kopili、Barail 组,新近系 Surma 群、Tipam 群、DupiTila 砂岩[2-4,14],见图 3、4。

孟加拉湾盆地西北部印度地台的钻井揭示前寒武系基底主要为片麻岩、片岩、斜长角闪岩、混合岩、辉绿岩、花岗岩、花岗闪长岩、石英闪长岩。基底之上发育石炭—二叠系冈瓦纳群含煤岩系,最大厚度约 1 000 m,分布不均衡,厚度变化大,为克拉通内断陷盆地沉积。冈瓦纳群含煤岩系之上覆盖了白垩纪拉结马哈火山岩系,厚度约 500 m,相当于印度西部的德干(Deccan)火山岩系,主要由角闪石玄武岩、橄榄玄武岩、安山岩组成,夹红色铁质泥岩、黏土岩、暗红砂岩,是印度地块从冈瓦纳裂离时期的产物。

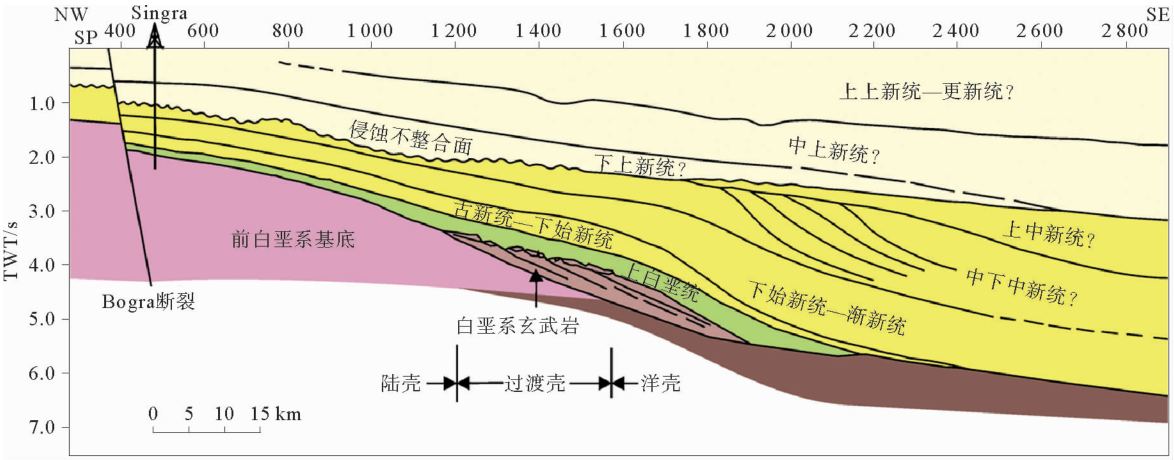


图 4 孟加拉盆地北部地震资料地质解释剖面(剖面位置见图 1。据文献[2-4,14]资料编绘)

Fig. 4 Geological profiles interpreted from seismic data of the northern Bengal Bay Basin

(see Fig. 1 for profile positions, modified from references [2-4,14])

古近系古新统—下始新统 Cherra 组厚度一般在 169~360 m,主要由分选差的砂岩、泥岩、泥灰岩组成,夹少量灰岩,为滨浅海沉积。上覆中始新统 Sylhet 灰岩岩系厚 250 m,夹少量砂岩,为浅海沉积。Sylhet 灰岩岩系之上的上始新统 Kopili 组厚度在 40~600 m,主要由深灰—黑色富含化石泥岩、海绿石砂岩和灰岩组成,为滨浅海沉积。渐新统 Barail 组厚度多在 200~1 600 m,主要为含内源砾石具交错层理的中—粗砂岩,夹灰色粉砂岩和泥岩(图 3),以滨浅海及三角洲沉积为主。

新近系中新统中下部 Surma 群与印度地台的 Jamalganj 组相当,厚度一般在 150~1 300 m,为滨浅海和三角洲沉积。Surma 群下部称 Bhuban 组,上部称 BokaBil 组。Bhuban 组底部和顶部主要为浅灰—浅黄色细砂岩、粉砂岩与蓝灰色泥岩不等厚互层,中部主要为蓝色、黄灰色粉砂质泥岩和砂质泥岩(图 3)。

BokaBil 组下部为薄层纹层状泥岩夹浅棕色砂岩,中部为黄色块状砂岩,上部为纹层状粉砂岩、砂岩,见钙质结核,顶部为泥岩(图 3)。上中新统—上新统下部 Tipam 群划分为 Tipam 砂岩和 Girujan 泥岩 2 个次级地层单元;Tipam 砂岩主要为黄棕色到橙色粗粒交错、块状层理砂岩,见石英质鹅卵石、炭化植物化石(包括树干)、煤夹层(图 3);Tipam 砂岩厚度在 76~2 565 m,锡尔赫特槽厚度最大;Tipam 砂岩为河流相沉积。Girujan 泥岩主要由棕色、蓝色、紫色和灰色泥岩组成(图 3),厚 168~1 077 m,锡尔赫特地区厚度最大,为湖泊、河漫滩沉积。

上新统上部—更新统 DupiTila 砂岩不整合于 Tipam 群之上,厚 92~2 393 m。下部为灰色、黄色、红色、粉色、紫色、白色中粗块状—槽状层状

砂岩含结晶岩卵石，上部为粉砂岩、泥岩，见硅化木和褐煤(图 3)，为曲流河沉积。

3　地球动力学背景及盆地演化

3.1　地球动力学背景

喜马拉雅前渊和孟加拉湾盆地形成演化的地球动力学背景与新特提斯洋的关闭、印度地块与欧亚大陆拼贴、碰撞历史密切相关。

晚三叠世—早侏罗世拉萨地块从冈瓦纳边缘分离，新特提斯洋开始形成[14,37]。自白垩纪(135～120 Ma)开始[38,39]，随着印度板块从冈瓦纳分离、印度洋的形成和扩张，新特提斯洋逐渐关闭，印度板块逐渐与欧亚大陆汇聚、拼贴、碰撞，控制了喜马拉雅前渊和孟加拉湾盆地形成演化。

印度—雅鲁藏布缝合带主要是新特提斯的残迹。其中，绝大多数蛇绿岩具有洋内超级俯冲带的地球化学特征，其最老地质年龄为早白垩世[40]，表明自早白垩世开始，新特提斯洋壳向洋内岛弧俯冲(图 5A)；硅质岩系中最老的放射虫组合是中晚三叠世(Ladinian-Carnian 期)，代表了裂谷边缘深水盆地[41]；蛇绿杂岩中深水硅质岩的最新地质年代为晚白垩世[42]，表明直到晚白垩世在拉萨地块与印度板块间一直存在新特提斯深水洋盆(图 5B)。印度地块与新特提斯洋内岛弧碰撞主要是在 60～55 Ma，中始新世(约 45 Ma)开始，印度地块与欧亚大陆发生陆陆碰撞[37](图 5C)。中新世(21 Ma)以来，印度地块向拉萨地块俯冲加剧，同时印度洋壳向缅甸地块强烈俯冲，导致喜马拉雅和印缅山脉急剧隆升[14]。

上述板块相互作用的地球动力学背景，决定了喜马拉雅前渊和孟加拉湾盆地形成演化。

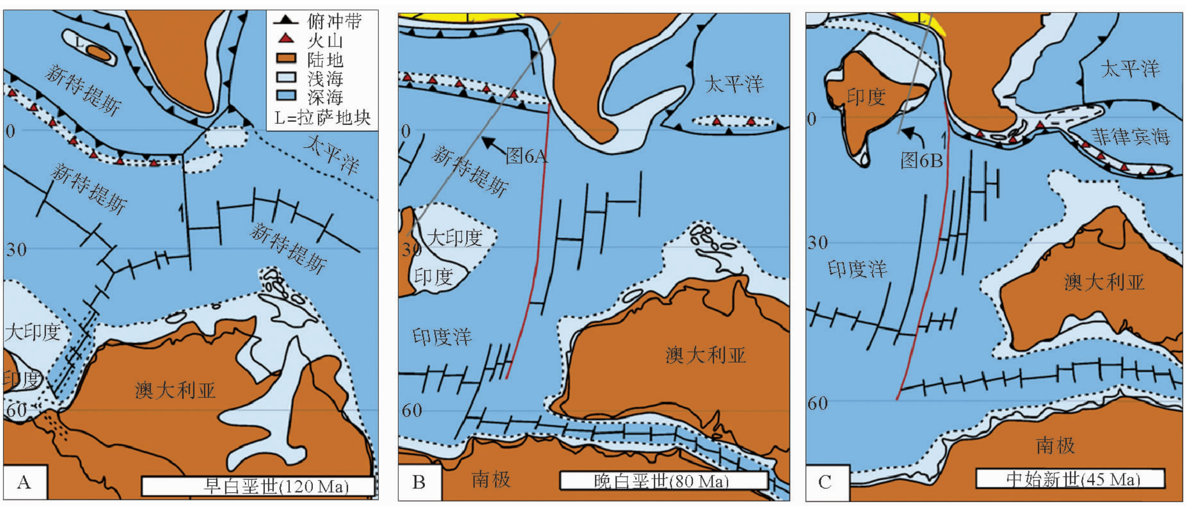


图 5　东特提斯古地理再造：A-早白垩世，B-晚白垩世，C-中始新世(据文献[14,37])

Fig. 5　Palaeogeographic evolution of eastern Tethys: maps A-Early Cretaceous, B-Late Cretaceous, C-Middle Eocene(modified from references [14,37])

3.2　喜马拉雅前渊和孟加拉湾盆地形成演化

喜马拉雅前渊盆地处于印度板块面向欧亚大陆一侧，而孟加拉湾盆地处于印度板块面向印度洋一侧。根据上述沉积记录和地球动力学背景分析，自晚白垩世印度板块从冈瓦纳分离、印度洋打开以来，喜马拉雅前渊和孟加拉湾盆地的形成演化既有同步性，又有差异性，总体上可分为 3 个阶段。

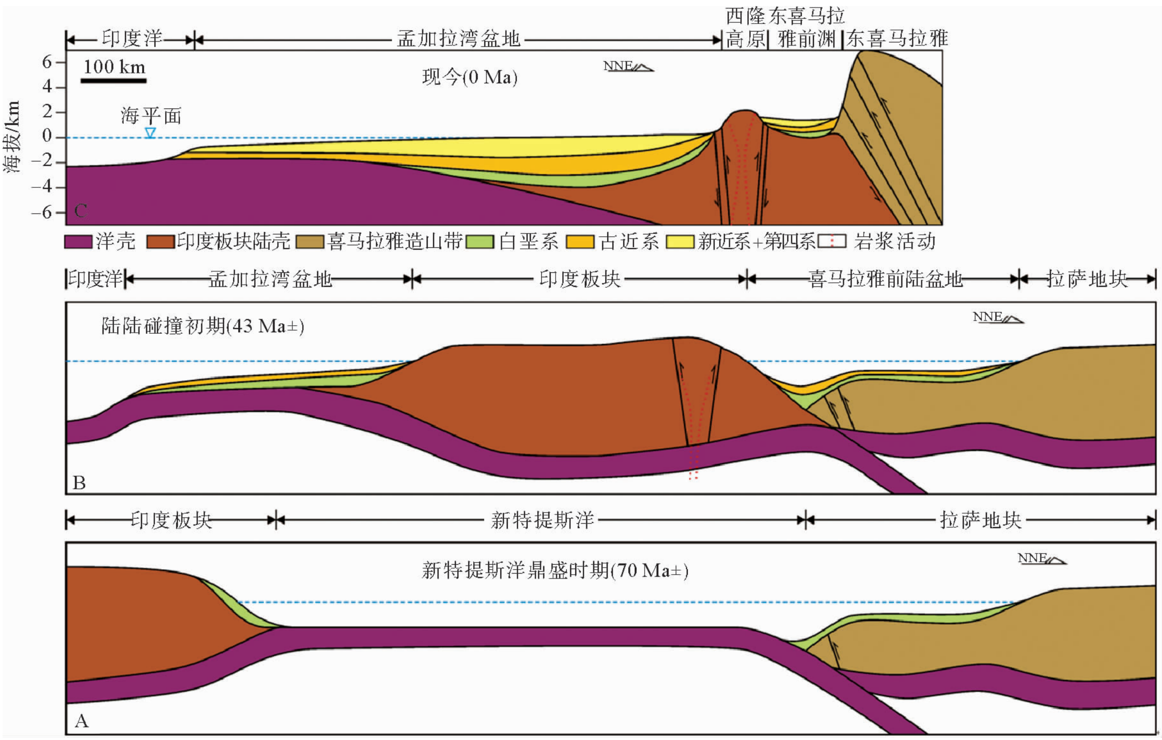
(1)晚白垩世—早始新世

印度板块向欧亚大陆漂移，印度洋扩张，新特提斯洋萎缩，欧亚大陆的拉萨地块南缘主要发育弧前及弧后盆地，印度地块周缘发育被动陆缘盆地(图 6A)。喜马拉雅造山带的藏斯卡和藏南地区发育的上白垩统和古近系向上变浅

的沉积序列是印度板块逐渐与欧亚大陆拼贴的沉积记录。孟加拉湾盆地发育上白垩统和古近系下部沉积序列是印度地块从冈瓦纳分离：印度地块周缘发育被动大陆边缘盆地与新生洋盆的沉积记录。

(2)中始新世—早中新世

印度地块与拉萨地块陆陆碰撞，印度洋壳开始向缅甸地块俯冲。喜马拉雅前陆盆地开始发育(图 6B)，印度查谟地区出露的新生界沉积序列记录了喜马拉雅前陆盆地的发育过程；孟加拉湾盆地洋壳停止生长，开始演化为残留洋盆(图 6B)，孟加拉湾盆地始新统—中新统的沉积序列及西北薄、东南厚的沉积特征，反映残留洋盆逐渐萎缩、陆源碎屑供应增强的过程。



A-晚白垩世，位置见图 5B；B-中始新世，位置见图 5C；C-现今，位置见图 1

图 6　喜马拉雅前渊至孟加拉湾盆地演化剖面

Fig. 6　Geological evolution of the Himalayan foredeep and the Bengal Bay Basin

(3)中新世(21 Ma)—现今

印度地块与拉萨地块强烈碰撞，印度洋壳向缅甸地块俯冲加剧。喜马拉雅前陆盆地隆升，顶部及周缘遭受剥蚀，形成现今的喜马拉雅前渊盆地(图 6C)。孟加拉湾盆地受喜马拉雅和印缅山脉急剧隆升、陆源碎屑供应逐渐增强的影响，在残留洋盆中形成巨厚的、广泛分布的陆源碎屑沉积(图 6C)，孟加拉湾盆地新生代巨厚的沉积序列正是残留洋盆陆源碎屑供应充分的记录。

4　结论

(1)喜马拉雅前渊和孟加拉湾盆地的形成演化既有同步性，又有差异性，与印度地块—印度洋、新特提斯洋壳向欧亚大陆俯冲密切相关。

(2)喜马拉雅前渊是在晚白垩世—早始新世弧前及弧后盆地基础上发育起来的前陆盆地，中始新世—早中新世是前陆盆地发育的鼎盛时期，经过中新世(21 Ma)—现今的强烈隆升剥蚀，形成残留前陆盆地。

(3)孟加拉湾盆地是在晚白垩世—早始新世被动陆缘盆地—大洋盆地基础上发育起来的残留洋盆，中始新世以来，喜马拉雅和印缅山脉隆升逐渐加剧，残留洋盆的陆源碎屑供应逐渐增强。

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参考文献:

[1] Khan A, Chouhan R. The crustal dynamics and the tectonic trends in the Bengal basin[J]. Geodynamics, 1996, 22 (314) : 267-286.

[2] Uddin A, Lundberg N. A paleo-Brahmaputra Subsurface lithofacies analysis of Miocene deltaic sediments in the Himalayan-Bengal system, Bangladesh[J]. Sedimentary Geology, 1999, 123:239-254.

[3] Uddin A, Lundberg N. Miocene sedimentation and subsidence during continent-continent collision, Bengal basin, Bangladesh[J]. Sedimentary Geology, 2004, 164:131-146.

[4] Alam M, Alam M, Curray J, et al. An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history[J]. Sedimentary Geology, 2003, 155:179-208.

[5] Yin A. Cenozoic tectonic evolution of the Himalayan orogen as constrained by along-strike variation of structural geometry, exhumation history, and foreland sedimentation[J]. Earth-Science Reviews, 2006, 76 : 1-131

[6] Acharyya S K. Evolution of the Himalayan Paleogene foreland basin, influence of its litho-packet on the formation of thrust-related domes and windows in the Eastern Himalayas-A review[J]. Journal of Asian Earth Sciences, 2007, 31(1):1-17.

[7] Clark M, Bilham R. Miocene rise of the Shillong Plateau and the beginning of the end for the Eastern Himalaya[J]. Earth and Planetary Science Letters, 2008, 269:337-351.

[8] Hossain H, Roser B, Kimura J. Petrography and whole-rock geochemistry of the Tertiary Sylhet succession, northeastern Bengal Basin, Bangladesh: Provenance and source area weathering[J]. Sedimentary Geology, 2010, 228: 171-183.

[9] DeCelles P, Kapp P, Quade J, et al. Oligocene-Miocene Kailas basin, southwestern Tibet: Record of postcollisional upper-plate extension in the Indus-Yarlung suture zone[J]. GSA Bulletin, 2011, 123(7/8): 1337-1362.

[10] Islam M, Shinjo R, Kayal J. The tectonic stress field and deformation pattern of northeast India, the Bengal basin and the Indo-Burma Ranges: A numerical approach[J]. Journal of Asian Earth Sciences, 2011, 40: 121-131.

[11] Singh B P. How deep was the early Himalayan foredeep? [J]. Journal of Asian Earth Sciences, 2012, 56: 24-32.

[12] Singh B P. Evolution of the Paleogene succession of the western Himalayan foreland basin[J]. Geoscience Frontiers, 2013, 4:199-212.

[13] Tripathy-Lang A, Hodges K, Van Soest M, et al. Evidence of pre-Oligocene emergence of the Indian passive margin and the timing of collision initiation between India and Eurasia[J]. Lithosphere, 2013, 5(5):501-506.

[14] Curray J R. The Bengal Depositional System: From rift to orogeny[J]. Marine Geology, 2014, 352:59-69.

[15] Khin K, Sakai T, Zaw K. Neogenesyn-tectonic sedimentation in the eastern margin of Arakan-Bengal basins, and its implications on for the Indian-Asian collision in western Myanmar[J]. Gondwana Research, 2014, 26:89-111.

[16] Yang S Y, Kim J W. Pliocene basin-floor fan sedimentation in the Bay of Bengal (offshore northwest Myanmar) [J]. Marine and Petroleum Geology, 2014, 49: 45-58.

[17] 张　朋, 梅廉夫, 马一行, 等. 孟加拉湾盆地构造特征与动力学演化:来自卫星重力与地震资料的新认识[J]. 地球科学——中国地质大学学报, 2014, 39(10): 1407-1421.

[18] Bracciali L, Najman Y, Parrish R, et al. The Brahmaputra tale of tectonics and erosion: Early Miocene river capture in the Eastern Himalaya[J]. Earth and Planetary Science Letters, 2015, 415: 25-37.

[19] Wang E, Kamp P, Xu G, et al. Flexural bending of southern Tibet in a retro foreland setting[J]. Scientific Reports, 2015, 5: 1-9. doi: 10.1038/srep12076.

[20] Diehl T, Singer J, Hetényi G, et al. Seismotectonics of Bhutan: Evidence for segmentation of the Eastern Himalayas and link to foreland deformation[J]. Earth and Planetary Science Letters, 2017, 471:54-64

[21] Rahman M, Worden R. Diagenesis and its impact on the reservoir quality of Miocene sandstones (Surma Group) from the Bengal Basin, Bangladesh[J]. Marine and Petroleum Geology, 2016, 77: 898-915.

[22] Jahan S, Uddin A, Pashin J, et al. Petroleum source-rock evaluation of upper Eocene Kopili Shale, Bengal Basin, Bangladesh[J]. International Journal of Coal Geology, 2017, 172:71-79.

[23] Kotlia B, Goswami P, Joshi L, et al. Sedimentary environment and geomorphic development of the uppermost Siwalik molasse in Kumaun Himalayan foreland basin, north India[J]. Geological Journal, 2018, 53: 159-177.

[24] Neupane B, Ju Y W, Allen C M, et al. Petrography and provenance of Upper Cretaceous-Palaeogene sandstones in the foreland basin system of Central Nepal[J]. International Geology Review, 2018, 60(2): 135-156.

[25] Gaetani M, Garzanti E. Multicyclic history of the northern India continental margin (northern Himalaya)[J]. American Association of Petroleum Geology Bulletin, 1991, 75: 1427-1446.

[26] Beck R A, Burbank D W, SercombeW J, et al. Stratigraphic evidence for an early collision between northwest

India and Asia[J]. Nature, 1995, 373:55-58.

[27] Leech M L, Singh S, Jain A K, et al. The onset of India-Asia continental collision: early, steep subduction required by the timing of UHP metamorphism in the western Himalaya[J]. Earth and Planetary Science Letters, 2005, 234:83-97.

[28] Najman Y, Appel E, Boudagher-Fadel M, et al. Timing of India-Asia collision: geological, biostratigraphic, and palaeomagnetic constraints[J]. Journal of Geophysical Research, 2010, 115(B12416): 1-18, doi: 10. 1029 /2010 JB007673..

[29] Hu X, Wang J, BouDagher-Fadel M, et al. New insights into the timing of the India-Asia collision from the Paleogene Quxia and Jialazi formations of the Xigazeforearc basin, South Tibet[J]. Gondwana Research, 2016, 32 : 76-92.

[30] Garzanti E, Hu X. Latest Cretaceous Himalayan tectonics: Obduction, collision or Deccan-related uplift? [J]. Gondwana Research, 2015, 28:165-178.

[31] Devi K, Duarah B. Geochemistry of Ukhrul limestone of Assam-Arakan subduction basin, Manipur, Northeast India[J]. Journal of the Geological Society of India, 2015, 85(3):367-376.

[32] Girard V, Salpeteur I, Dutta S, et al. An enigmatic piece of amber in the Oligocene of the Assam-Arakan Basin (Eastern India) [J]. Geobios, 2015, 48(1):1-8.

[33] Vadlamani R, Wu F, Ji W. Detrital zircon U-Pb age and Hf isotopic composition from foreland sediments of the Assam Basin, NE India: Constraints on sediment provenance and tectonics of the Eastern Himalaya[J]. Journal of Asian Earth Sciences, 2015, 111: 254-267.

[34] Devi A, Boruah S, Gilfellon G. Geochemical characterization of source rock from the north bank area, upper Assam basin[J]. Journal of the Geological Society of India, 2017, 89 (4):429-434.

[35] Nanda A, Kumar K. Excursion guide on the Himalayan Foreland Basin (Jammu-Kalakot-Udhampur sector) [M]. Dehradun: Wadia Institute of Himalayan Geoglogy, 1999: 1-85.

[36] Khanna Y, Singh Seema, Singh Sarabjeet. Micromorphological studies of the complex early Oligocene Himalayan foreland palaeosols in relation to Asian monsoon climate [J]. Catena, 2018, 164 :1-12.

[37] Metcalfe I. Gondwana dispersion and Asian accretion: Tectonic and palaeogeographic evolution of eastern Tethys [J]. Journal of Asian Earth Sciences, 2013, 66: 1-33.

[38] Subrahmanyam C, Thakur N K, Rao T G, et al. Tectonics of the Bay of Bengal: new insights from satellite-gravity and shipborne geophysical data[J]. Earth and Planetary Science Letters,1999, 171: 237-251.

[39] Radhakrishna M, Rau S G, Nayak S, et al. Early Cretaceous fracture zones in the Bay of Bengal and their tectonic implications: constraints from multi-channel seismic reflection and potential field data [J]. Tectonophysics, 2012, 522-523: 187-197.

[40] Hébert R, Bezard R, Guilmette C, et al. The Indus-YarlungZangbo ophiolites from Nanga Parbat to Namche-Barwa syntaxes, southern Tibet: first synthesis of petrology, geochemistry, and geochronology with incidences on geodynamic reconstructions of Neo-Tethys[J]. Gondwana Research, 2012, 22: 377-397.

[41] Zhu J, Du Y S, Liu Z X, et al. Mesozoic radiolarian chert from the middle sector of the YarlungZangbo suture zone, Tibet and its tectonic implications[J]. Science in China Series D , 2005, 49:348-357.

[42] Aitchison J C, Xia X, Baxter A T, et al. Detrital zircon U-Pb ages along the Yarlung-Tsangpo suture zone, Tibet: implications for oblique convergence and collision between India and Asia[J]. Gondwana Research, 2011, 20: 691-709.

FORMATION AND EVOLUTION OF HIMALAYAN FOREDEEP AND BENGAL BAY BASIN

WANG Qian[1,2], XIN Renchen[3*], DONG Ruijie[3], FAN Xiaotian[3]

(1 School of Earth Science and Resources, China University of Geosciences (Beijing), Beijing 100083, China;
2 China Huadian Green Energy Co., LTD., Beijing 100160, China;
3 School of Ocean Sciences, China University of Geosciences(Beijing), Beijing 100083, China)

Abstract: The formation and evolution of the Himalayan foredeep and Bengal Bay Basin are carefully studied in this paper based on a comprehensive review of regional geology, geophysics, plate reconstruction and their geodynamic background. The Himalayan foredeep and the Bengal Bay Basin are separated by a high named the Shillong plateau. The former is located to the north of the plateau, with its basement dominated by the pre-Cretaceous Lhasa block. From Late Cretaceous to Early Eocene, it was a fore-arc and a back-arc basin resulted from subduction of the Neo-Tethys to the intra-ocean island arc and the Lhasa block. During the period from Middle Eocence to Early Miocene, the neo-Tethys subducted progressively and destructed finally, and the collision between the Indian plate and the Lhasa block was intensified gradually, and as the result, a foreland basin was formed. Since Middle Miocene, as the collision between the Indian plate and the Eurasian plate intensified, the Himalayan foreland basin experienced uplifting and denudation, and left behind a foredeep of the former foreland basin at last. The Bengal Bay Basin is located to the south of the Shillong plateau, the basement of its northwestern part is dominated by the pre-Cambrian of the Indian plate. From Carboniferous to Permian, it was a rift basin, and then denuded during Triassic. Volcanism dominated the Jurassic to Early Cretaceous. From Late Cretaceous to Early Eocene, it became a basin of passive continental margin. Since Middle Eocene, as the Indian plate intensively subducted under the Lhasa block and the Indian Ocean plate subducted under the Burma continent, the Bengal Bay Basin evolved into a residual ocean basin in which terrigenous clastic supply gradually increased. The basement of the southeastern part of the Bengal Bay Basin is dominated by pre-Paleogene oceanic crust, and the thick filling sequences of the residual oceanic basin has been formed since Eocene in the southeastern part of the basin.

Key words: Himalayan foredeep; Bengal Bay Basin; back-arc basin; Foreland basin; residual oceanic basin