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# 塔中地区晚奥陶世镶边台地沉积演化①

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**摘　要**　通过大量岩芯、薄片、测井、地震等资料的对比分析,建立了塔中地区上奥陶统良里塔格组层序地层格架,并研究了沉积相演化、分布规律。晚奥陶世塔中地区为开阔台地、台地边缘组成的沉积型镶边台地。良里塔格组层序可划分出海侵体系域、高位体系域,共 10 个准层序组。前者包括准层序组 1~4,为退积、加积准层序组,岩性以泥晶灰岩类为主、夹颗粒灰岩,局部发育生物灰岩。后者包括准层序组 5~10,为加积、进积准层序组,岩性为颗粒灰岩、生物礁灰岩夹泥晶灰岩。海侵体系域时期,沉积范围逐步覆盖研究区,开阔台地与台地边缘的沉积范围相对稳定,开阔台地以滩间海、台内洼地等低能沉积亚相为主,台地边缘丘、滩沉积范围逐步扩大,出现镶边沉积特征。高位体系域时期,台地边缘沉积范围基本具有继承性,发育 2~7 期礁(丘)—滩的沉积旋回,形成礁滩复合体镶边特征;开阔台地大范围内为较低能滩间海沉积,局部发育 2~4 期丘(礁)—滩沉积旋回。该时期,台地边缘与开阔台地沉积地貌出现明显的高低分异,镶边台地成熟、定型。

**关键词**　沉积演化　镶边台地　礁滩相　良里塔格组　晚奥陶世　塔中地区

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## 0　引言

碳酸盐岩台地类型有陆表海台地、缓坡、镶边台地、孤立台地四种,其中镶边台地的特点是台地边缘有一个从台地(或潟湖)进入斜坡(几度~60°以上)的坡折,可分为沉积型、过路陡坡型、过路斜坡型和侵蚀型四种[1,2]。它们共同的沉积特征是台地边缘都为生物礁、颗粒滩的沉积,向内为浅水台地沉积,向外为深水的斜坡(或陡崖)、盆地沉积。镶边台地的台缘及台内礁、滩相沉积物堆积速率相对较快[3],容易受到同生岩溶作用形成大量原生孔隙,后期的近地表岩溶、白云石化、埋藏期溶蚀等作用的叠加改造,使得礁滩相成为有利的储集相带[4~14]。塔中地区上奥陶统良里塔格组镶边台地沉积体系中形成了大型礁型油气藏[15~18],研究镶边台地的沉积演化过程,对有利储集相带的预测及勘探有重要指导作用。

## 1　地质背景

塔中低凸起位于塔里木盆地中央隆起中段,南北分别与塘古孜巴斯凹陷和满加尔凹陷以断裂带形式相接,呈北西向条带状展布[18]。塔中低凸起包括塔中 1 号断裂坡折带、北斜坡、中央断垒带、南斜坡、东部潜山带等五个次级构造单元[18]。受不同欺次构造作用影响,塔中地区奥陶系现今保留的地层自下而上为蓬莱坝组、鹰山组、良里塔格组、桑塔木组[19,20],良里塔格组与上覆桑塔木组及下伏鹰山组均为不整合接触关系[21]。中晚奥陶世,塔里木板块处于南纬 20°~30°,古水温为 24.22℃~31.53℃[16,22],塔中地区气候温暖湿润,缺少陆源碎屑,海水清澈、较浅,水体

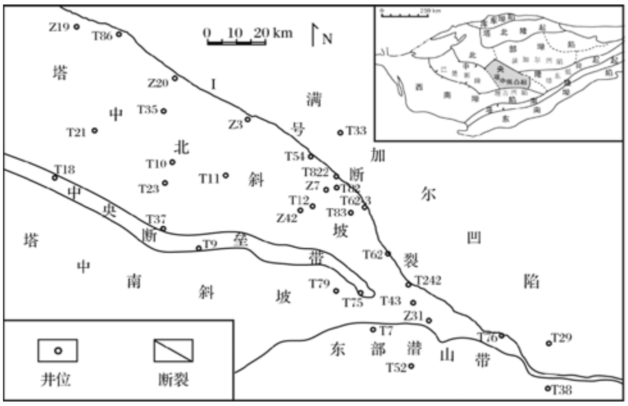


图 1　塔中地区构造位置图

Fig.1　The tectonic location map of Tazhong area

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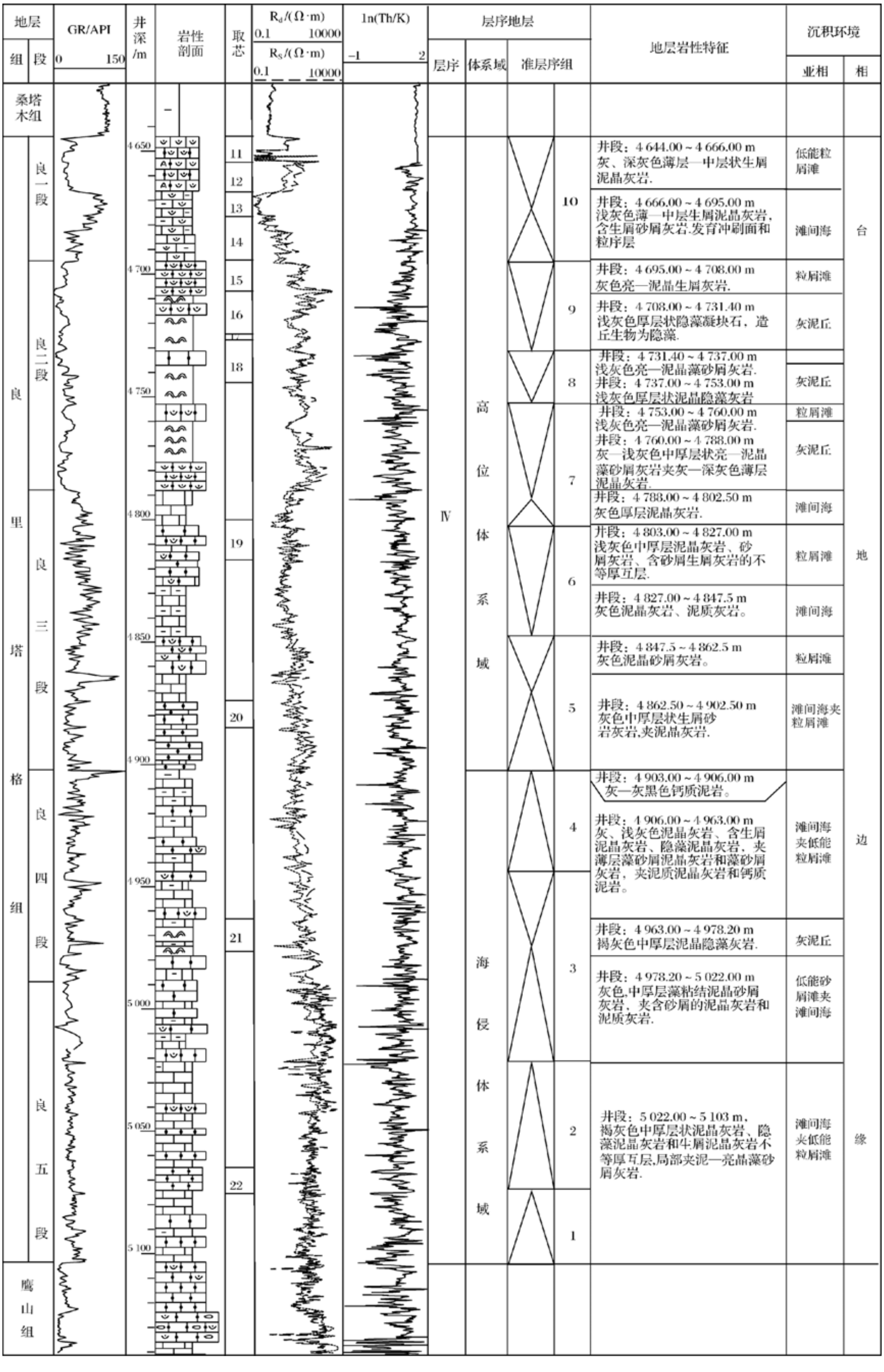


图2 塔中地区良里塔格组层序地层格架

Fig.2 The sequence stratigraphic framework of the Lianglitage Formation in Tazhong area

能量较高,形成了碳酸盐岩开阔台地—台地边缘的沉积体系[15,23,24]。良里塔格组沉积时期,该体系主要发育生物礁(分为礁丘、灰泥丘两类)、颗粒滩(包括台缘粒屑滩及台内滩)及低能的滩间海、台内洼地沉积亚相,各亚相可进一步分为若干沉积微相[25,26]。

## 2　层序地层特征

### 2.1　良里塔格组层序地层划分

据赵宗举等的研究,塔里木盆地奥陶系可划分出 8 个三级层序,良里塔格组属于层序 6[27]。结合岩芯、测井等资料,笔者进一步划分出海侵体系域、高位体系域,共 10 个准层序组,各准层序组的岩性、电性具有不同特征,纵向具有叠置组合特征(图 2)。

### 2.2　准层序组叠置特征

(1) 海侵体系域

包括准层序组 1~4,以退积准层序组、加积准层序组为主。准层序组 1~2 为退积准层序组,岩性主要为深灰色—灰色中厚层泥晶灰岩、泥质条带(条纹)灰岩夹灰色薄层砂屑灰岩。准层序组 3~4 为加积、退积准层序组,岩性以灰色、深灰色薄—中层泥质泥晶灰岩(图 3a)、薄层砂屑灰岩不等厚互层为主,准层序组 3 出现隐藻泥晶灰岩等生物灰岩。

(2) 高位体系域

包括准层序组 5~10,以加积准层序组、进积准层序组为主。准层序组 5~7 分别为加积、进积、加积准层序组,岩性主要为灰色中厚层砂屑灰岩、生屑砂砾屑灰岩、生物礁灰岩及灰色厚层泥晶灰岩、含泥质条纹灰岩(图 3b,c)。准层序组 8~9 均为进积准层序组,岩性为灰色块状生物礁灰岩如格架岩、障积岩、隐藻泥晶灰岩、隐藻凝块石灰岩与浅灰色中厚层砂屑灰岩、生屑砂砾屑灰岩(图 3d,e)。准层序组 10 为加积准层序组,岩性有灰色中厚层泥晶灰岩、灰色泥—亮晶砂屑灰岩、含砾生屑砂屑灰岩灰岩及灰色厚层生物礁灰岩(图 3f)。

## 3　层序格架内的沉积特征

从图 4 可以看出,海侵体系域内地震反射总体为弱振幅不连续状的特征,开阔台地(Z42—Z7 井区)连续性较台地边缘(Z7—T822 井区)略好。高位体系域内,开阔台地(Z42—Z7 井区)为中强振幅连续反射特征,而台地边缘(Z7—T822 井区)表现为中强振幅杂乱反射特征,具有建隆形成的镶边特征。

依据准层序组的岩性、叠置及对比特征,将 10 个准层序组分为五个组合进行沉积特征的对比分析(图 5)。准层序组 1~2:海侵开始,塔中地区大范围开始灰岩沉积。台地边缘、开阔台地均以较低能滩间海沉积为主,夹有滩相(台缘粒屑滩或台内滩)沉积。准层序组 3~4:进一步的海侵,塔中地区良里塔格组沉积范围增大。台地边缘以滩间海、粒屑滩沉积为主,后者沉积范围、厚度扩大,如 Z7 井出现巨厚的粒屑滩沉积。开阔台地仍以低能的滩间海沉积为主,但局部如 T12 井开始出现灰泥丘等台内点礁(丘)沉积。准层序组 5~7:该时期的礁滩相碳酸盐岩沉积速率略大于或与可容纳空间增长速率基本保持一致,表

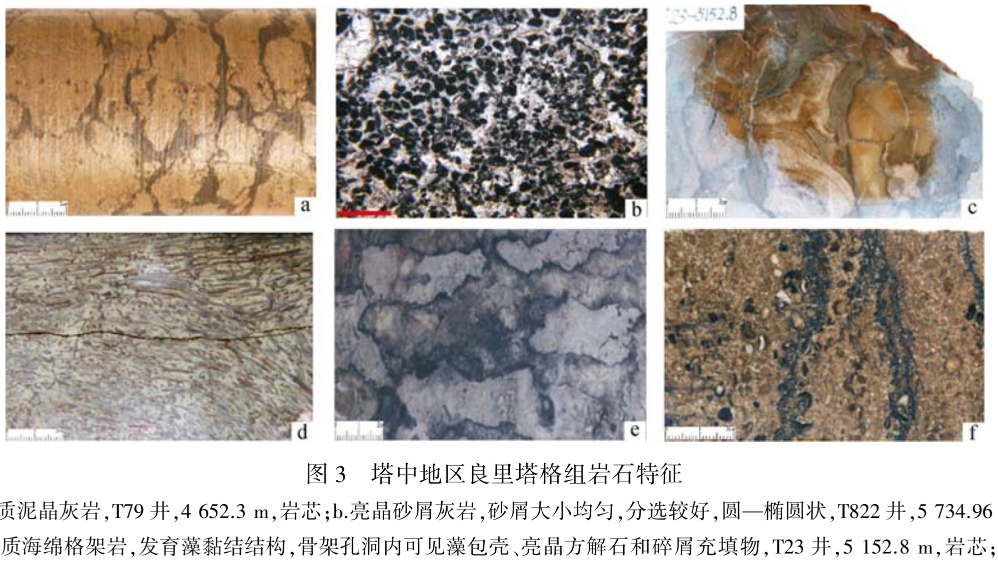


图 3　塔中地区良里塔格组岩石特征

a.灰—深灰色泥质泥晶灰岩,T79 井,4 652.3 m,岩芯;b.亮晶砂屑灰岩,砂屑大小均匀,分选较好,圆—椭圆状,T822 井,5 734.96 m,单偏光;c.浅灰色层孔虫—钙质海绵格架岩,发育藻黏结结构,骨架孔洞内可见藻包壳、亮晶方解石和碎屑充填物,T23 井,5 152.8 m,岩芯;d.珊瑚格架岩,珊瑚个体呈直立丛状生长,格架之间障积灰泥,T30 井,5 045.72 m,岩芯;e.隐藻凝块石灰岩,呈柱状生长形态,柱间充填灰泥、生屑,T12 井,4 710.50 m,岩芯。f.亮晶含砾屑生屑砂屑灰岩,生屑主要为棘屑、介形类,见藻包壳,发育缝合线,沥青充填,T54 井,5 752.57 m,岩芯。

Fig.3　The lithological features of the Lianglitage Formation in Tazhong area

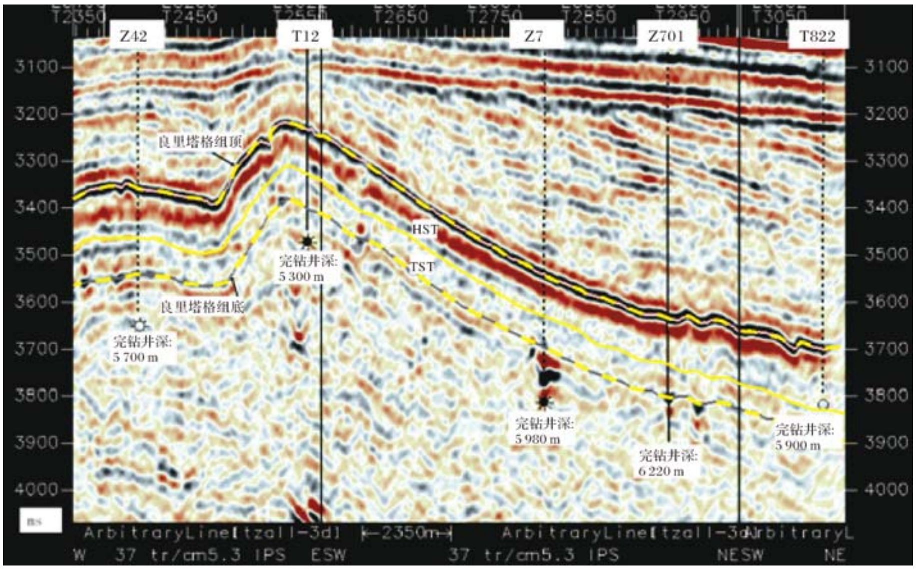


图4 塔中地区三维地震剖面反射特征

Fig.4 The reflectance features in 3D seismic section in Tazhong area

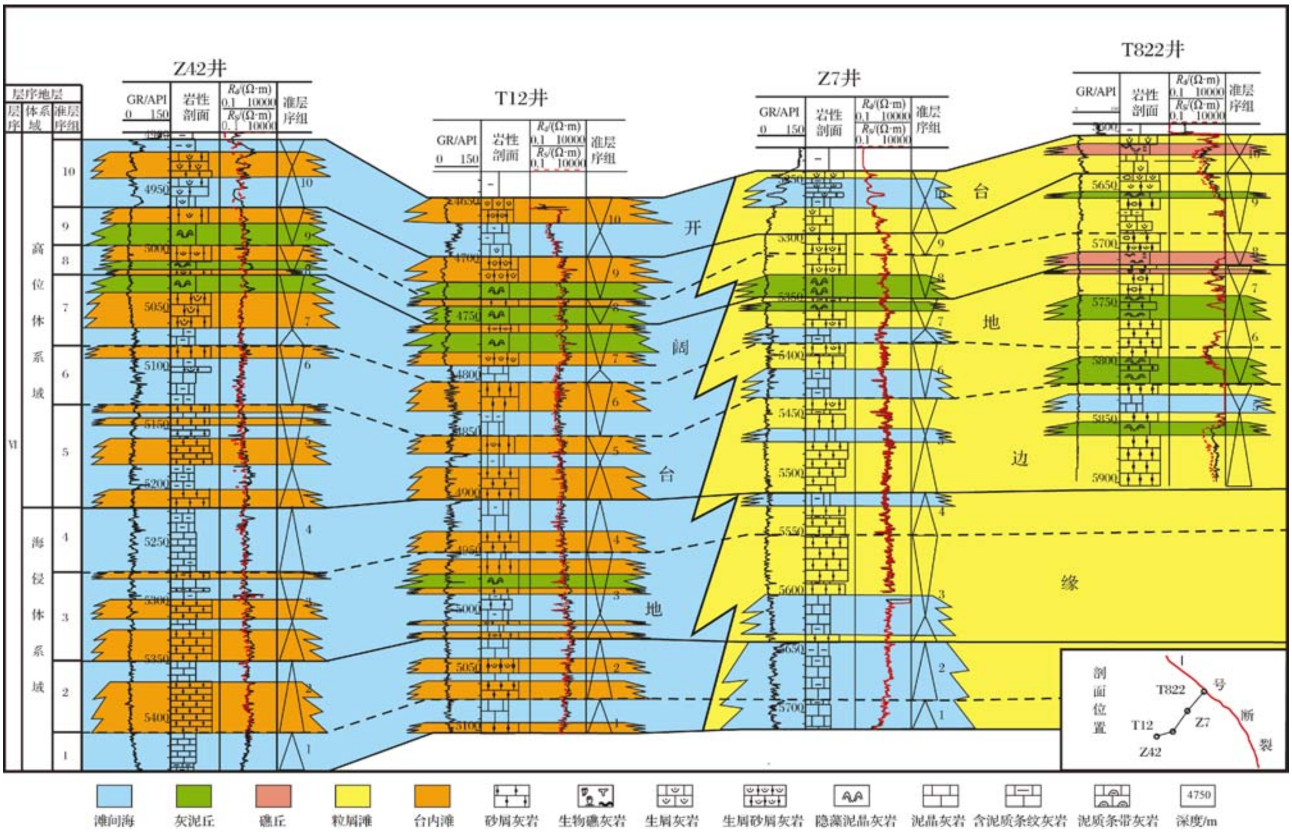


图5 塔中地区良里塔格组层序格架内沉积相对比图

Fig.5 The profile correlation map of sedimentary features in the stratigraphic framework of the Lianglitage Formation in Tazhong area

现出加积—进积—加积准层序组叠置特征。台地边缘以粒屑滩、生物礁沉积为主,局部为低能的滩(礁)间海沉积。如Z7井沉积了巨厚的粒屑滩,T822井位于台地边缘外带,沉积了3期灰泥丘及1期礁丘,与粒屑滩纵向叠置沉积,形成巨厚的礁滩复合体沉积。开阔台地台内滩沉积厚度增大,在准层序组7出现台内滩—灰泥丘复合体沉积。准层序组8~9:该时期,开阔台地—台地边缘沉积地貌呈现明显的分异。台

地边缘以生物礁、粒屑滩沉积为主,未见滩间海沉积。如 T822 井出现 2 期生物礁建造,形成巨厚的建隆。开阔台地的台内礁滩体沉积达到鼎盛时期,如 Z42 井、T12 井沉积了 2 期灰泥丘—台内滩复合体。准层序组 10:台地边缘以粒屑滩—滩间海交互沉积为主,生物礁建造基本消失,仅在东部的局部高地貌如 T822 井仍可见少量礁丘建造。开阔台地主要为巨厚的滩间海与台内滩的交互组合沉积。

## 4　镶边台地的沉积演化

### 4.1　海侵体系域

(1) 准层序组 1~2

该时期为海侵早期阶段,但 T86—Z18—T21 井一线的北西部地区为鹰山组风化壳岩溶古地貌的高部位[26],未沉积良五段(图 6a)。除地层超覆区及剥蚀区外,该时期塔中地区形成镶边台地—斜坡—盆地的沉积体系。Z20—Z11—Z4—T162—T78 井一线、塔中Ⅰ号断裂分别为开阔台地/台地边缘、台地边缘/斜坡的相带边界。开阔台地主要为滩间海沉积,北斜坡上的 T10—T11 井一带及南斜坡的 T79—T43 井一带是低能的台内洼地沉积,藻坪、台内滩则主要沿着台内洼地周缘分布,沉积范围较小,台内点礁不发育。台地边缘宽度约 1~10 km,长约 160 km,范围略大于塔中Ⅰ号断裂坡折带。台地边缘以滩间海沉积为主,粒屑滩呈片状发育,局部出现灰泥丘沉积,零星分布。

(2) 准层序组 3~4

区域上进一步海侵,古陆区范围缩小至 Z19—Z17—T45 井一线以西部分(图 6b)。Z18—Z20—Z4—T162—T262 井一线、塔中Ⅰ号断裂分别为开阔台地/台地边缘、台地边缘/斜坡的相带边界。该时期整个镶边台地水体循环通畅,形成加积—退积准层序组叠置型式,开阔台地、台地边缘均沉积了巨厚的颗粒灰岩、泥晶灰岩。台地边缘宽度略有增大,约 2~10 km,长约 160 km。台地边缘的灰泥丘—粒屑滩组合沉积范围逐步扩大,初步表现出镶边沉积特征。

### 4.2　高位体系域

(1) 准层序组 5~7

区域构造挤压应力使得沉积地貌由之前的“西高东低”变为“西低东高”的特征[16]。Z162—Z4—T162—T78 井一线、塔中Ⅰ号断裂分别为开阔台地/台地边缘、台地边缘/斜坡的相带边界,台地边缘相带宽度约 3~14 km,长度约 210 km,范围增大。该时期台地水体变浅、波浪作用较强,能量较高,沉积速率较大。同时,可容纳空间增长速率略小于与沉积速率基本保持一致,表现出加积—进积—加积准层序组叠置特征。开阔台地的台内洼地范围缩小、台内滩沉积范围增大、点礁在局部较高沉积地貌及先期台内滩基础上开始发育,如 T23、Z31 井。台地边缘开始大量发育灰泥丘,并在 T83 井—T78 井一带发育由格架岩、障积岩等形成的礁丘。粒屑滩大范围沉积,且厚度大,与生物礁纵向叠置,巨厚的礁滩复合体形成了台缘镶边体系(图 6c)。

(2) 准层序组 8~9

该时期的沉积地貌分异已经比较明显,礁滩复合体正性隆起与滩间海略低地貌相间分布。开阔台地内继承性的台内礁、滩沉积地貌之间形成台内洼地,如 T21—T10 井一带。台内点礁、台内滩的沉积范围达到最大,纵向上有 1~2 期沉积旋回,厚度约 50~100 m。台地边缘相带位于 Z162—Z4—T162—T78 井一线与塔中Ⅰ号断裂之间,宽度约 4~14 km、长度约 210 km。该相带内生物礁继续大量沉积,南东部的 T54 井—T78 井一带表现出礁丘大量发育,北西部的 T54—Z19 井一带则发育大量灰泥丘。粒屑滩广泛沉积,与生物礁形成 1~2 期沉积旋回,总厚度达 100~200 m。自良里塔格组沉积以来,台地边缘的宽度虽然略有变化,但是沉积范围基本具有继承性。因此,纵向上多期次的礁、滩连续叠置沉积,形成了较开阔台地更高的沉积地貌,镶边台地基本成熟、定型(图 6d)。

(3) 准层序组 10

该时期的沉积速率基本等于可容空间增大速率,开阔台地以滩间海、台内滩沉积为主,但台内滩沉积范围明显缩小,台内点礁仅在 T77 井、T35 井等局部发育。台地边缘范围缩小至 Z162—Z4—T62 井一线与塔中Ⅰ号断裂之间,宽度约 1~12 km,长度约 100 km。台地边缘以中低能粒屑滩及滩间海沉积为主,生物礁仅在北西、南东部零星发育(图 6e)。

## 5　结论

(1) 良里塔格组层序可划分出海侵体系域、高位体系域,共 10 个准层序组。前者包括准层序组 1~4,为退积、加积准层序组。岩性以泥晶灰岩类为主、夹颗粒灰岩,局部发育生物灰岩。后者包括准层序组 5~10,为加积、进积准层序组。岩性以颗粒灰岩、生物礁灰岩夹泥晶灰岩。

(2) 海侵体系域时期,除西北区块不同程度缺失

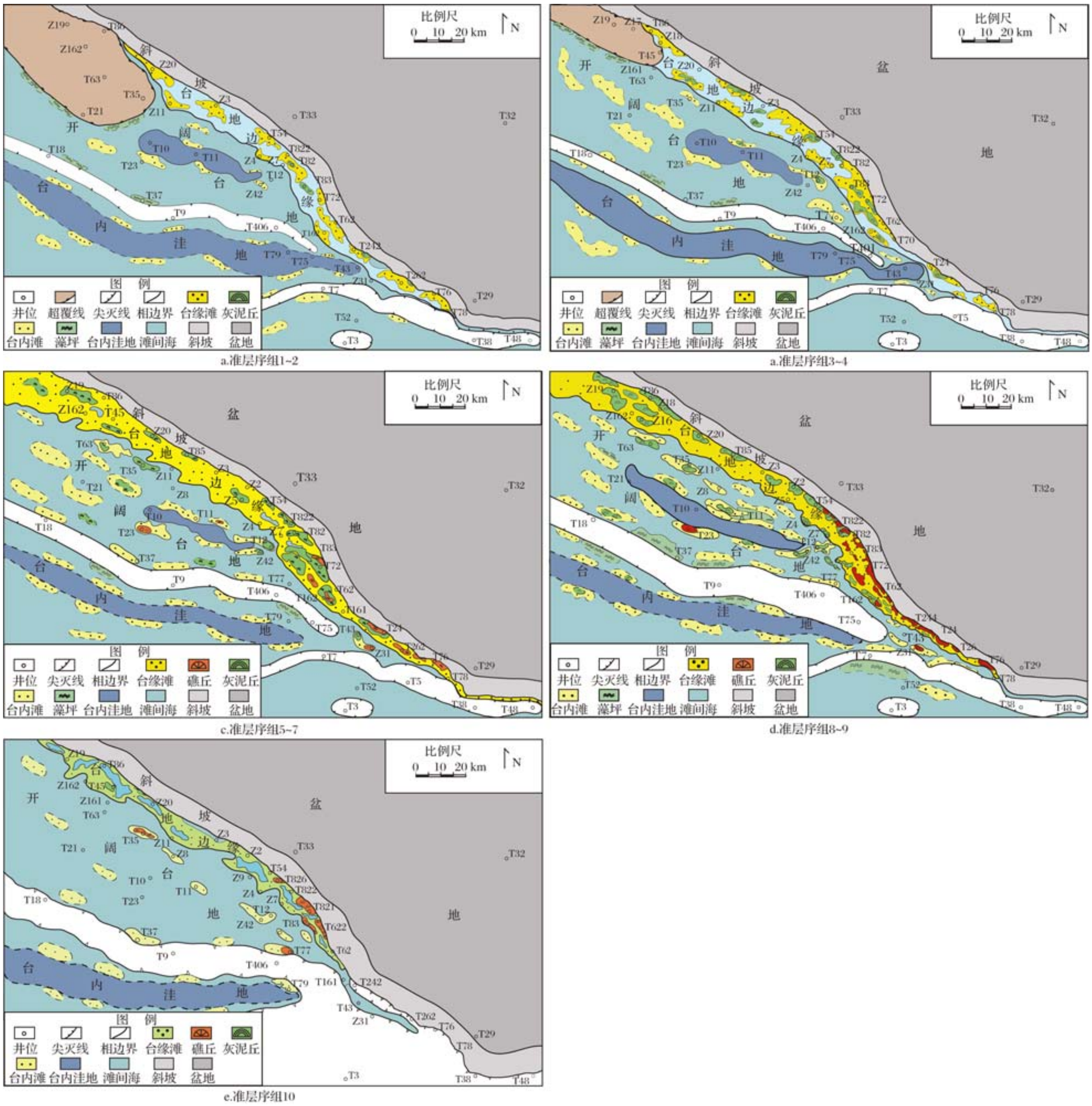


图6 晚奥陶世良里塔格组沉积时期塔中地区镶边台地沉积演化图

Fig.6 The sedimentary evolution maps in the period of Lianglitage Formation of Late Ordovician in Tazhong area

该期沉积外,台地边缘以滩间海、粒屑滩沉积亚相为主;开阔台地大范围内以滩间海、台内洼地等低能沉积亚相为主。高位体系域时期,台地边缘发育2~7期巨厚礁(丘)—滩的沉积旋回,低能的滩(礁)间海仅表现为较薄的夹层沉积特征,开阔台地发育3期丘(礁)—滩沉积旋回,与低能的滩(丘)间海交互沉积。

(3)海侵体系域时期,除沉积范围逐渐覆盖的西北区块外,开阔台地/台地边缘的沉积范围相对稳定,台地边缘丘、滩沉积范围扩大,表现出镶边沉积特征。高位体系域时期,台地边缘沉积范围整体具有继承性,以高能的礁(丘)—滩沉积为主,形成巨厚的礁滩体镶边特征;开阔台地大范围内为较低能滩间海沉积,局部为较高能的礁(丘)—滩沉积。该时期,台地边缘与开阔台地沉积地貌出现明显的高低分异,镶边台地成熟、定型。

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# Characteristics and Evdution of Sedimentary Facies in the Rimmed Platform, Upper Ordovician, Tazhong area, Tarim Basin

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**Abstract**: Tazhong area is located in middle Central uplift in Tarim Basin. The at the north is Manjiaer depression, and the south is Tanggubazi depression. Its strike direction is NW-SE. Based on the datas of seismic, well logging and core, the authors establish the sequence stratigraphic framework and the evolution of the sedimentary facies of Lianglitage Formation in the Tazhong area.

The depositional rimmed platform include open platform facies and platform margin facies in Lianglitage Formation depositional stage in the Tazhong area. The open platform facies can be divided into patch reef, grain bank, tide flat, interbank sea, intra-platform bottomland. The platform margin facies can be divided into reef mound, carbonate mud mound, granule shoal, interbank sea. The Lianglitage formation's sedimentary sequence can be dividied into transgressive systems track and highstand systems track, and they contain ten parasequence sets. The transgressive systems track contains parasequence sets from 1 to 4, which are retrogradational stacking or aggradational stacking. Their lithology are mainly mudstone and grainstone with interbed biolithite. The highstand systems track includes parasequence sets from 5 to 10, which are aggradational stacking or progradational stacking. Their lithology are grainstone and biohermal limestone with interbed lime mudstone.

In the transgressive systems track, the sedimentary trap gradually cover the whole research area. In the parasequence sets 1 to 2, the Z20—Z11—Z4—T162—T78 wells and the Tazhong NO.1 fault are the boundaries of platform margin/open platform and platform margin/slope. The northwest of T86—Z18—T21 wells is blockmass. In this period, the open platform mainly deposit interbank sea, and the intra-platform bottomland distribute in the T10—T11 wells and T79—T43 wells. The width of platform margin is about 1~10 km, and its length is about 160 km. It also mainly deposit the interbank sea, and the granule shoal develop longitudinal zonality. In the parasequence sets 3 to 4, the blockmass boundary shrink to the western part of Z19—Z17—T45 wells. The Z18—Z20—Z4—T162—T262 wells and the Tazhong NO.1 fault are the boundaries of platform margin, open platform, slope. In this period, the water circulates unobstructedly, so that form the aggradational stacking and retrogradation stacking parasequence sets, which form the thick grainstone and micrite in both platform margin and open platform. The width of platform margin is about

2 ~ 10 km, and its length is still about 160 km. Because the deposition range of granule shoal and mud mound gradually expand, the rimmed sedimentary character become obvious.

In the highstand systems track, the accretion rate of accommodation is equal to (or smaller than) the rate of sedimentation, so that form the aggradational stacking and progradational stacking. In the parasequence sets 5 to 7, the range of platform margin expand, its width is about 3 km to 14 km, and its length is about 210 km. A lot of carbonate mud mound deposit, and the reef mound deposit in the range of T83 well to T78 well. The granule shoals have the largest sedimentary trap and thickness, longitudinally stacked with the reef mound, so that form the rimmed system of platform margin. The range of intra-platform bottomland diminish, while the range of grain bank expand. The patch reefs deposit in the higher sedimentary topography or previous grain bank. In the parasequence sets 8 to 9, the differentiation of sedimentary topography is obvious, and the uplift of reef-bank complex alternatively distribute with the lower interbank sea. The intra-platform bottomland distribute among the inherited deposit range of patch reef and grain bank in the open platform, and their sedimentary range become maximum in this period. The sedimentary cycle of patch reef and grain bank are 1 to 2, and the thickness is about 50 m to 100 m. The width of platform margin is 4 km to 14 km, and the length is 210 km. The range of T54 well to T78 well deposit lots of reef mound, and the range of T54 well to Z19 well deposit the carbonate mud mound. The granule shoal deposit widely, and it stacked with reef longitudinally form 1 to 2 sedimentary cycle, which the thickness is about 100 m to 200 m. The rimmed platform become a pattern essentially. In the parasequence sets 10, the accretion rate of accommodation is equal to the rate of sedimentation. The open platform mainly deposit the grain bank and interbank sea, and the range of interbank sea diminish apparently. The patch reef only deposit in local area like T77 well、T35 well. The range of platform margin diminish between the Z162—Z4—T62 well to the Tazhong NO.1 fault. Its width is 1 km to 12 km, and the length is about 100 km. It mainly deposit the granule shoal and interbank sea, the reef only deposit in local area. In this period, the depositional topography between platform margin and open platform appear apparently high low differentiation, so the rimmed platform is mature and formalized.

**Key words**: sedimentary evolution; rimmed carbonate platform; reef-bank facies; Lianglitage Formation; Upper Ordovician; Tazhong area