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南黄海辐射沙脊群西洋潮流通道的浅部沉积层序及其形成演化再认识

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摘要:晚第四纪以来, 黄河、长江都曾经江苏中部海岸注入南黄海, 河海交互作用形成一系列沉积, 全新世海侵后发育岸外辐射沙脊群。沙脊群西北部、由岸滩与沙脊所夹持的西洋潮流通道, 位于北侧废黄河三角洲和南侧长江三角洲两大地貌单元间的过渡区, 成为揭示不同大河交互作用下的海岸、陆架晚第四纪沉积层序模式的重要窗口。最近通过更多晚第四纪钻孔对比和浅层地震剖面集成研究发现: ① 由于混乱的测年结果和陆相硬黏土层对比不当, 造成之前基于 07SR01 孔和 Y1 孔构建的辐射沙脊群西洋潮流通道浅部沉积 (标高-60 m 以内) 的年代框架有误, 其主体应是晚更新世沉积且发育两个沉积旋回, 末次冰盛期硬黏土层多被潮流侵蚀而缺失, 表层全新世沉积厚度在水下沙脊处基本不足 10 m, 其余普遍不足 5 m, 甚至缺失; ② 仅在西洋西北段稳定分布的浅层地震单元 U3 指示了 MIS 3 古黄河三角洲的南缘, 自晚更新世以来西洋所在的江苏中部海岸可能深受古黄河物源的影响, 这尚需在西洋西北段的关键位置钻取新孔, 并结合已有浅层地震剖面和东南段钻孔来进一步研究证实。提出下一步工作将基于层序地层学方法, 通过对已有控制性浅层地震剖面进行地震层序格架的三维可视化、提取地震单元和反射界面的空间分布特征, 结合已有及新增控制性钻孔的沉积学和年代学研究, 构建可靠年代框架、判识大河物源, 并参考邻区钻孔资料, 来探明西洋潮流通道的浅部沉积层序, 反演其形成演化。

关键词:南黄海; 江苏中部海岸; 辐射沙脊群; 潮流通道; 沉积层序; 晚第四纪

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Rethinking on shallow sedimentary sequence and its evolution of the Xiyang tidal channel in the Radial Sand Ridge Field, South Yellow Sea

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Abstract: Since the Late Quaternary, both the Yellow River and Changjiang River entered into the South Yellow Sea flowing through the middle Jiangsu coast. As a result, a series of sediments have been deposited in this area controlled by the river-sea interactions. The Radial Sand Ridge Field (RSRF) off the middle Jiangsu coast has been formed after the Holocene transgression. The Xiyang tidal channel in the northwestern RSRF is constrained by the tidal flat coast and tidal ridges. It is located in the transition zone between the northern Abandoned Yellow River delta and southern modern Changjiang River delta. Therefore, it becomes the important window area to reveal the sedimentary sequence formed in the coast and continental shelf under the active interactions between different large rivers during the Late Quaternary. As to the upper strata with the depth less than 60 m below the current mean sea-level in the Xiyang tidal channel, there are still different viewpoints on its sedimentary sequence, chronology framework and evolution, while the concerned studies are still pretty limited. Recently, the results of further Late Quaternary stratigraphic correlations and synthesis study on shallow seismic profiles showed that, (1) Due to disordered dating results and improper correlation of terrigenous stiff mud layers, the chronology framework of Xiyang upper strata built previously based on core 07SR01 and Y1 is incorrect, the main part of the upper strata including two sedimentary cycles are the Late Pleistocene deposits and the stiff mud layer of the Last Glacial Maximum is often missing due to the tidal scouring, the thickness of surficial Holocene sediments are generally

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less than 10 m in the submerged sand ridges, and extensively less than 5 m in other places, or even zero in some places; (2) The shallow seismic unit 3 (U3) only steadily located in the northwestern part of the Xiyang tidal channel indicates the southern margin of the old Yellow River delta developed during MIS 3, and the middle Jiangsu coast in which the Xiyang tidal channel is located was probably influenced deeply by the old Yellow River sediments since the Late Pleistocene, however it is still necessary to recover a new sedimentary core in the key position of northwestern part, plus further study and verification based on the new core and other acquired shallow seismic profiles and cores in the southeastern part should be done. Thus, this paper proposed the further study plan as follows, based on the 3D visualization of the seismic sequence framework, the spatial characteristics of the seismic units and main reflection interfaces would be extracted. Furthermore, combined with the sedimentology and chronology studies of the existing and designed cores, the reliable chronology framework would be set up expectedly, and the provenance from large rivers would be identified. Applying the sequence stratigraphy method, referencing the adjacent published core data, it is targeted to ascertain the shallow sedimentary sequence in the Xiyang tidal channel, and to reveal its evolution.

Key words: South Yellow Sea; middle Jiangsu coast; Radial Sand Ridge Field; tidal channel; sedimentary sequence; Late Quaternary

作为海岸海洋主体部分的海岸和陆架,既是极易受全球变化和人类活动影响的敏感地区、过去和现今全球变化的信息库,也是全球变化的重要贡献者,成为一个能量和物质输入状态复杂、各种因素处于高度动态状况、系统行为的时空变异特征非常显著的复杂系统^[1-2]。在第四纪时间尺度的全球变化背景下,海岸和陆架环境演化经历过相应的系统状态转换和沉积环境响应,而基于对沉积记录的分析则是研究上述问题的重要手段和方法之一;在沉积地质学中开展这项研究,对于“应对气候变化”具有促进作用,并可为第四纪期间不同时期形成的沉积体系的对比提供基础数据,以分析系统演化转换的机理,评价全球变化对海岸和陆架沉积体系的影响^[1,3]。

晚第四纪以来,中国海岸海洋地貌与沉积环境的演化主要受控于全球性海面升降旋回背景下的复杂海陆交互作用^[4]。其中,河流与海岸、陆架的交互作用普遍且强烈,尤其对于黄河、长江等大河则更为突出和复杂,大河与海岸、陆架交互作用的产物、过程和机制应是上述海陆交互作用研究的重要组成部分。大河与海岸、陆架不同时间尺度交互作用形成的沉积体系包含着丰富的全球变化信息,是提取海面变化、大河下游迁徙与河口海岸演化以及入海沉积物输运和归宿等信息的重要载体。对于晚第四纪时间尺度,尤其是末次冰盛期以来黄河^[5-15]、长江^[16-25]等单一大河与海岸、陆架交互作用形成的沉积体系,在近二十年的研究中获得了极多的深入认识。但是,对于不同大河交互作用下的海岸、陆架晚第四纪沉积体系的研究较少,进展较慢且精度有待提高,最近有东海浙闽沿岸和扬子浅滩东南部的全新世沉积物源示踪^[26-27]、黄河与不同小河交互作用下的渤海湾全新世沉积层序模式^[28]等相关研究报道,然而这类研究对于探索堆积型陆架发育、丰富海陆交互作用与沉积演化模式意义显

著,亟需加强。晚第四纪以来,黄河、长江都曾经江苏中部海岸注入南黄海,并且南黄海西侧内陆架的辐射沙脊群(图1)就是在持续构造沉降和海面变化背景下,由黄河、长江等大河供沙、经河海动力作用而形成的重要海陆交互作用产物^[29-32]。它是南北长约200 km、东西宽约140 km,由70多条沙脊和潮流通道组成、以琼港为顶点向海呈辐射状延伸的现代潮流沉积体系。因此,江苏中部海岸和辐射沙脊群北部是构建不同大河交互作用下的海岸、陆架晚第四纪沉积层序模式的理想区域。

1 地貌和沉积背景

本文选择的研究区是辐射沙脊群西北部最大的潮流通道——西洋,它呈NNW向开口的喇叭形,是全新世海侵以来形成的冲刷型潮流通道(图1)。西洋与辐射沙脊群地区的多数潮流通道不同,其西侧是江苏中部粉砂淤泥质海岸,东侧和南侧分别是亮月沙、东沙、高泥和条子泥等沙脊。作为岸滩与沙脊所夹持的冲刷型潮流通道,西洋成为江苏中部海陆过渡带沉积层序及其演化的典型研究区。同时,西洋地处北侧废黄河三角洲(AD 1128—1855年)和南侧全新世长江三角洲两大地貌单元的中间过渡区,也是探索历史与地质时期古黄河、古长江及其三角洲体系所影响范围的敏感地区。因此,西洋潮流通道是揭示不同大河交互作用下的海岸、陆架晚第四纪沉积层序模式的重要窗口。此外,大丰港是江苏省委、省政府重点建设的江苏沿海三大深水海港(分别是滨海港、大丰港和洋口港)之一,是江苏沿海开发的重要节点和面向世界的特色产业港,而它就是利用西洋潮流通道来建造码头和开辟深水航道。因此,探明西洋的浅部沉积层序及其形成演化,将为大丰港扩建和持续高质量发展提供重要科学基础。

射状潮流场改造古海岸沉积而成^[30]。另一种亦认为辐射沙脊群主要是河海交互作用的产物,但现代沙脊群历史只有约1 ka,且物源是多源的,低海面时期的陆相沉积(河湖、风沙),冰消期以来的黄河、淮河和长江的入海沉积,都可能参与沙脊建造,但主要物源由历史时期的黄河提供,尤其是AD 1855年后苏北废黄河三角洲侵蚀南移泥沙参与了老沙脊的调整改造,形成现代沙脊;由黄河物源为主建造的北部和东北部沙脊的面积是南部沙脊面积的10倍;南部则以古长江和冰期陆相沉积为主提供沙脊物源;中部为黄河、长江混合源^[31]。此外,还有学者认为辐射沙脊群的形成与AD 1128年以来苏北废黄河入海带来的沙源输入相关,且下伏巨厚潮滩沉积主要由晚更新世古长江泥沙形成^[53]。

2.2 西洋潮流通道晚第四纪沉积与环境演化研究进展

从目前研究进展来看,关于西洋潮流通道的研

究集中于现代沉积动力过程,而晚第四纪沉积研究相比较少^[29-30,32,41,49-53,55,58]。受限于各种主客观原因,对西洋浅部沉积的层序、年代框架和形成演化尚存在不同认识,大致可分为三类(图2):第一类是西洋上部约35 m沉积层形成于全新世海侵之后,之下为晚更新世沉积,两者间为略具脊形的侵蚀面^[29-30,49];第二类是西洋上部约20 m沉积层形成于全新世海侵之后的潮汐环境,之下为晚更新世滨岸沼泽、陆相硬黏土层和潮汐河口沉积等,浅层地震剖面揭示两者间存在区域性强反射界面^[32,50-52,55,58];第三类是西洋浅部沉积的中下段都是晚更新世潮滩沉积,全新世沉积相对较薄,且西侧潮滩钻孔大剖面较少揭露末次冰盛期发育的硬黏土层^[41,53]。虽然上述研究成果从不同方面和程度上,揭示了西洋浅部沉积层序及其形成演化的信息,但是高质量研究的钻孔匮乏,将可控制西洋的浅层地震剖面与关键钻孔有效结合的研究还很欠缺,对西洋全区的认识远不够完整和详细,甚至忽略了一些重要信息(比如,与北侧

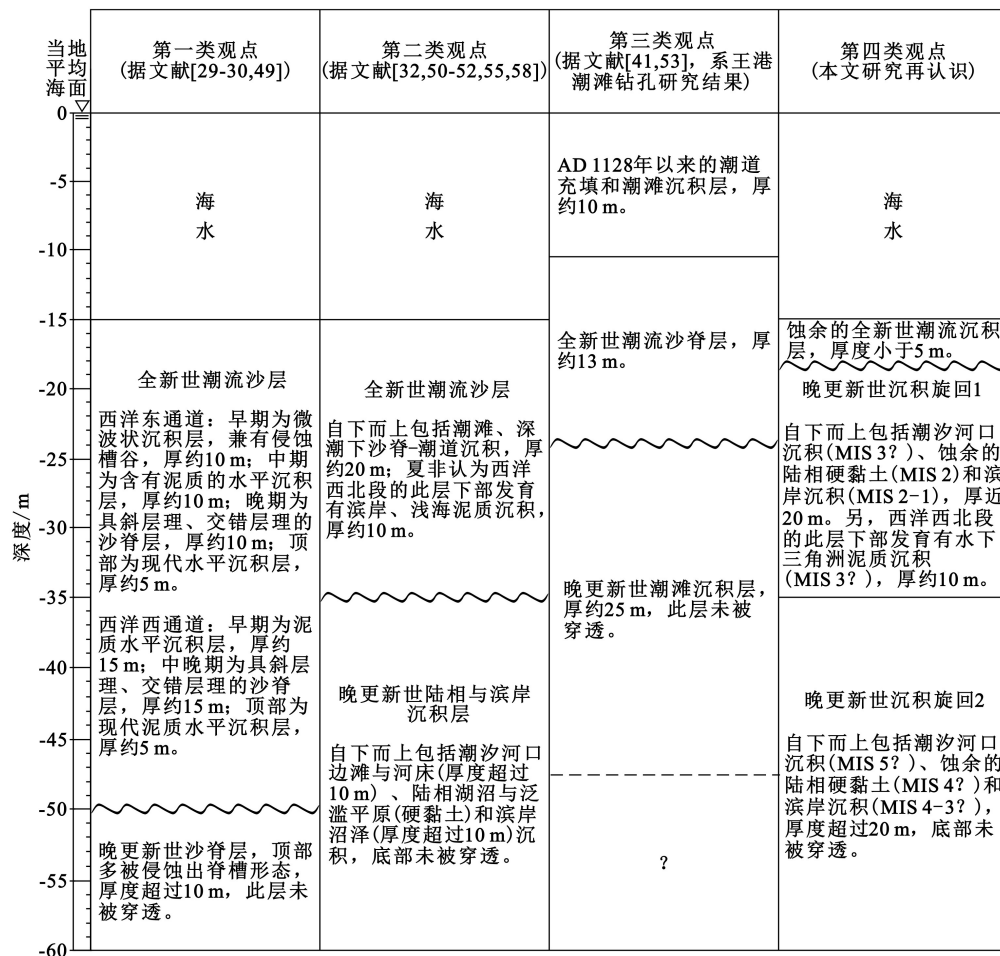


图2 前人对西洋潮流通道浅部沉积层序和年代框架的三类观点及本文研究再认识的第四类观点

Fig.2 Previous three viewpoints on the sedimentary sequence and chronology framework of the Xiyang tidal channel in the Radial Sand Ridge Field and the fourth viewpoint derived from the restudy of this paper

废黄河水下三角洲区域浅部沉积的关联等),更没有将其置于南黄海西侧陆架的区域沉积演化框架中去探索。

2.3 本文作者对西洋潮流通道的前期研究概述

相比于辐射沙脊群的其他潮流通道,笔者攻读硕士和博士学位所在的南京大学海岸与海岛开发教育部重点实验室经过二十多年的不断积累,已在西洋获得长度超过 440 km、可控制全区的高分辨率浅层地震剖面 and 2 个钻孔(07SR01 孔和 Y1 孔)等第

一手数据资料(图 3)。因此,我们较好的基础条件并采用层序地层学方法,来研究西洋潮流通道的浅部沉积层序及其形成演化。基于此,笔者在发表阶段性成果^[50-51]之后,进一步利用上述实验室获取的第一手和其他搜集整理的的数据资料,来完成博士学位论文研究工作,即采用层序地层学方法分别进行地震地层和钻孔地层的详细分析与对比,进而初步建立深海氧同位素 3 阶段(MIS 3)以来西洋的层序地层格架,并宏观演绎了该区的沉积环境演化历史^[52]。

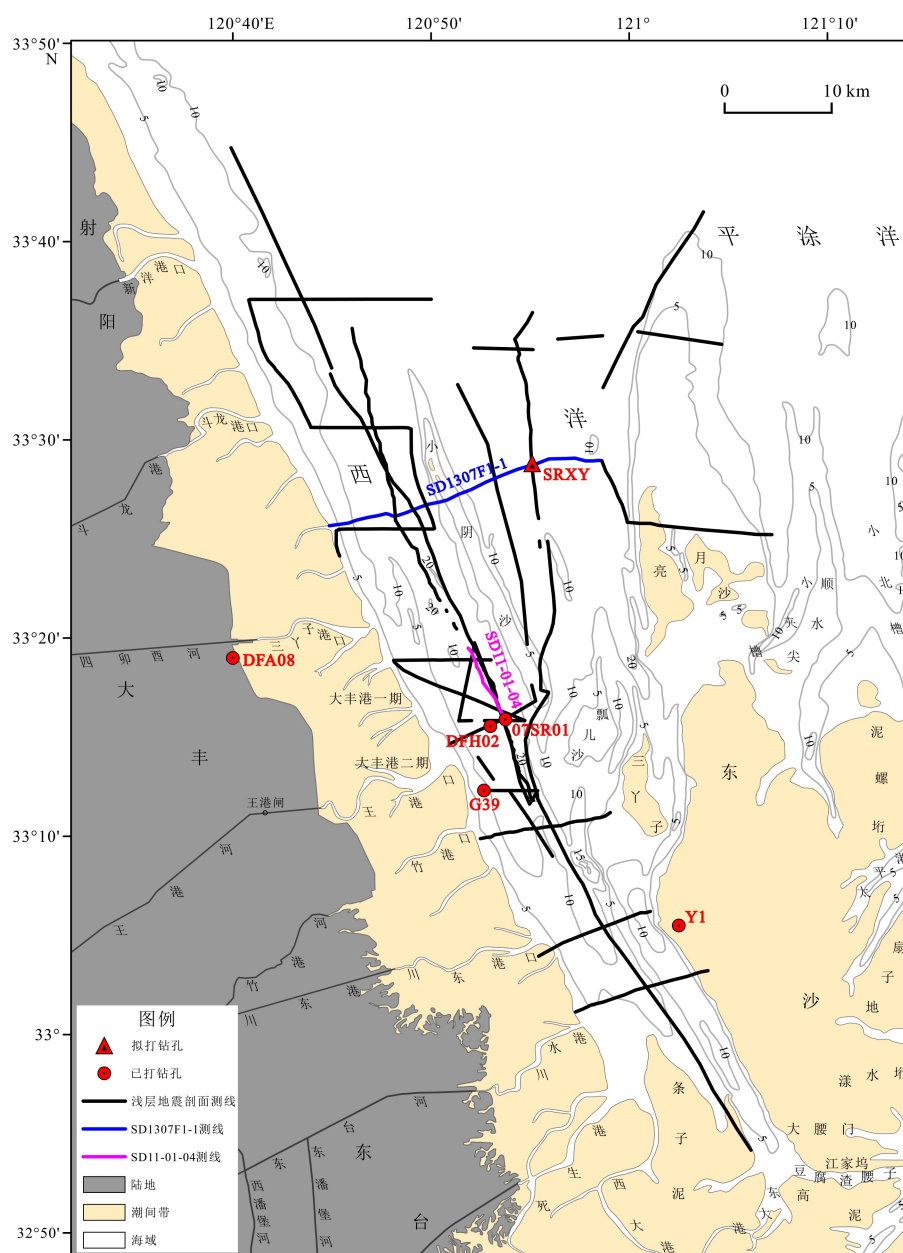


图 3 辐射沙脊群西洋潮流通道的浅层地震剖面测线和钻孔位置

注:因西洋及周边区域缺乏最新完整的水深实测资料,故图 3 的底图水深取自 1979 年海图,加之辐射沙脊群局部区域动力地貌调整明显,因而此图上西洋周边潮滩和沙脊形态与近期遥感影像存在一定差异。

Fig.3 Location of shallow seismic profiles and sedimentary cores in the Xiyang tidal channel, Radial Sand Ridge Filed

该研究结果显示, 西洋自海底向下 50 m 沉积层中可识别出 5 个浅层地震单元和反射界面(分别为 U1—U5 和 T1—T5, 图 4), 并且大致以 33°19'N(大丰港一期码头附近)为界, 西洋西北段和东南段的地震层序存在一致性差异, 主要表现为浅层地震单元 U3 仅在西北段稳定分布, 向南厚度减薄、直至 33°19'N 附近尖灭(图 5)。U3 单元的几何外形基本呈席状, 内部以连续性好、振幅较弱和频率高的平行、亚平行反射结构为特征, 具泥质沉积的典型反射表现。由于 07SR01 孔和 Y1 孔都位于西洋东南段, 故 U3 单元泥质沉积层缺乏钻孔揭示, 因而尝试借助西洋北侧、苏北废黄河口近岸的已有认识, 来外推 U3 单元的确切沉积环境和形成年代, 故推测其

可能是形成于 9~5 kaBP 的滨岸、浅海泥质沉积^[52]。

此外, 在对 07SR01 孔和 Y1 孔研究中发现, 这两个孔的 AMS ¹⁴C 测年数据(分别为 17 个和 14 个, 图 6)普遍出现倒置混乱: 07SR01 孔以 20~40 kaBP 和大于 43 kaBP 的数据为主, 仅钻孔顶部和中部的 2 个数据在 10 kaBP 以内; 而 Y1 孔跟 07SR01 孔的情况稍有不同, 表现在钻孔上部被解释为 MIS 1 潮汐环境形成的沉积层中出现小于 1 kaBP、小于 10 kaBP 和大于 43 kaBP 的数据共存, 底部被解释为 MIS 3 潮汐河口环境形成的沉积层中出现大于 43 kaBP 和小于 10 kaBP 的数据并存^[52]。所以, 鉴于海侵层位下伏基底泥炭是稳定的标志性层位^[59-60], 笔者判断 07SR01 孔(主要研究钻孔)的大多数测年

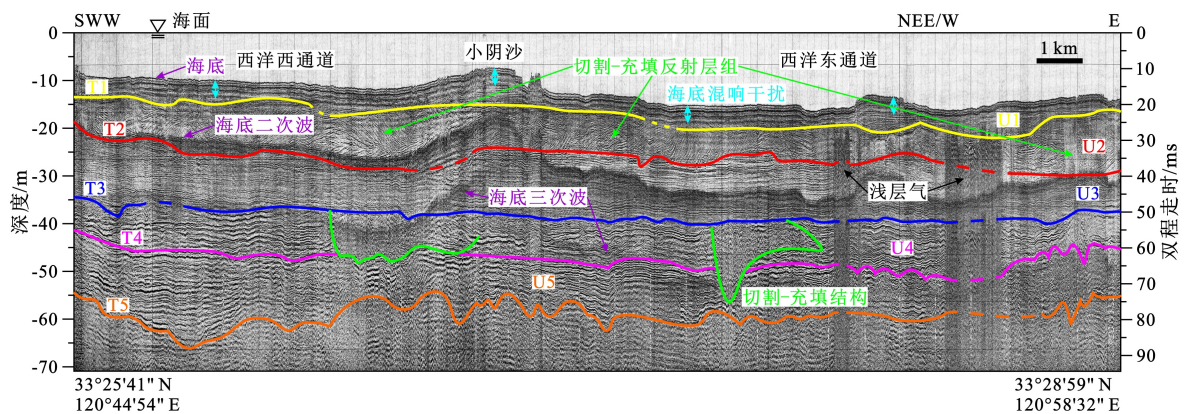


图 4 西洋潮流通道 SD1307F1-1 测线浅层地震剖面及其解释

图中 U 为地震单元, T 为反射界面。

Fig.4 Shallow seismic profile SD1307F1-1 in the Xiyang tidal channel and its interpretation

U: seismic unit, T: seismic bounding surface.

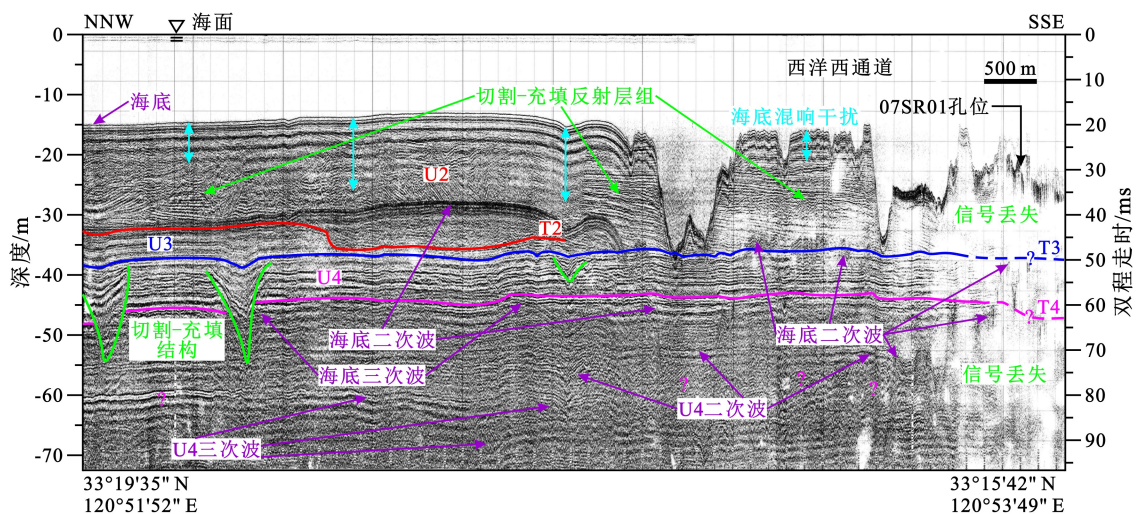


图 5 西洋潮流通道 SD11-01-04 测线浅层地震剖面及其解释

图中 U 为地震单元, T 为反射界面。

Fig.5 Shallow seismic profile SD11-01-04 in the Xiyang tidal channel and its interpretation

U: seismic unit, T: seismic bounding surface.

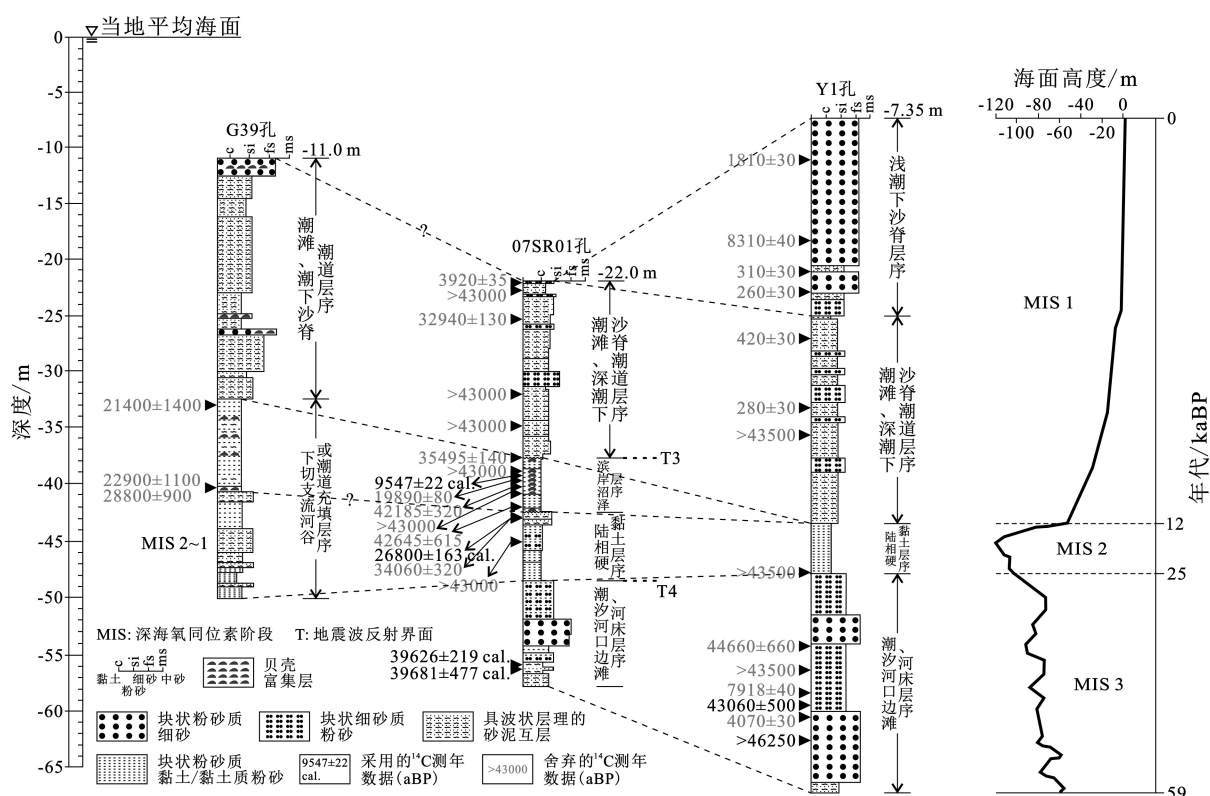


图 6 西洋潮流通道东南段 07SR01 孔与 G39 孔、Y1 孔沉积层序对比

07SR01 孔据文献 [50-51] 改绘, G39 孔据文献 [61] 改绘, Y1 孔据文献 [53,62] 改绘, 海面变化曲线据文献 [11] 改绘。

Fig.6 Stratigraphic correlation among core 07SR01, G39 and Y1 in the southeastern part of Xiyang tidal channel

Core 07SR01 was modified after reference [50-51], Core G39 was modified after reference [61], Core Y1 was modified after reference [53,62], Curve of sea-level changes was modified after reference [11].

数据皆可能因再搬运或受污染而出现混乱,故仅采用 4 个测年数据并参考海面变化曲线来建立 07SR01 孔的地层年代框架,且与 Y1 孔和 G39 孔进行对比分析(图 6, G39 孔位见图 3)。该地层年代框架显示,自上而下识别出的第一个陆相硬黏土层(洪泛平原和淡水湖沼沉积)形成于 MIS 2,且该硬黏土层上覆的滨岸沼泽沉积相当于海侵边界层,其顶面(标高-37.6 m)可与浅层地震反射界面 T3 相对比,顶部的泥炭为全新世海侵层的基底泥炭[52]。

3 研究再认识

3.1 西洋潮流通道及其西侧邻近陆域的补充钻孔对比

由于笔者在博士论文研究工作中,仅挑选了少量做过较为详细沉积学研究的陆域滨海平原钻孔进行对比分析,且非集中在西洋潮流通道周围,因而海陆钻孔的对比研究明显不足,这限制了对西洋浅部沉积层序和年代框架更准确的把握。为了弥

补这一研究缺陷,笔者在博士毕业后,进一步搜集整理了大丰港区及周边的大丰和东台滨海平原的大量工程地质、水文地质和第四纪地质钻孔,总数超过 200 个。通过对比分析大量岩心描述、照片和少量测年、微体古生物数据,以充分获取西洋本身及其西侧滨海平原的浅部沉积层序和年代信息。

该后续研究发现,对于西洋西侧的大丰港区及周边的大丰和东台滨海平原,在地表以下 60 m 沉积层内经常出现两个陆相沉积特征显著的层位,主要由黏土和粉砂组成,可与苏北和长江三角洲平原常见的第一和第二硬黏土层相对比[63-64],其中第一陆相沉积层顶板标高约-16~-18 m,第二陆相沉积层顶板标高约-36~-38 m,局部会上下浮动[61,65-72]。部分钻孔(例如 DFA08 孔,孔位见图 3)揭示出典型的陆相沉积层上部为暗绿色、灰绿色、黄绿色,显示出经历过潜育化作用和湖沼环境的特征,偶有铁锰质浸染;向下逐渐变为黄褐色、黄棕色、棕褐色,呈致密块状或发育极细的水平或微波状纹层,含较多均匀分布的铁锰质浸染产生的斑点、斑纹和斑块,呈花斑状,可见大小不同的铁锰质结核、钙质结

核、植物根系和黏粒,显示出经历过潜育化作用和洪泛平原环境的特征(图7)。对于上述层序,第一陆相沉积层普遍不如第二陆相沉积层完整和稳定,经常只揭露出下部明显的铁锰质浸染沉积或缺失,直接上覆潮汐沉积层,有时夹杂贝壳碎屑层。更有趣的是,位于07SR01孔西侧、西洋西通道内的DFH02孔(孔位见图3),顶部埋深约1 m处即揭露出可与陆域相对比的第一陆相沉积层,厚约3 m(孔口标高-14.72 m)^[72]。

另外,综合考虑第一陆相沉积层底部和上覆潮汐沉积的¹⁴C测年数据(表1)、第一和第二陆相沉积

层之间潮汐沉积的大量20~40 kaBP和大于43 kaBP的¹⁴C测年数据^[41,52]以及盐城龙冈LG孔的同类问题再认识^[73]等,可以推断西洋潮流通道及其西侧邻近陆域的第一陆相沉积层应形成于MIS 2,而第二陆相沉积层可能形成于MIS 4或更早。

3.2 西洋潮流通道的浅部沉积层序及其形成演化再认识

基于上述第一和第二陆相沉积层的分布标高及测年和浅层地震剖面数据,可以判断:①之前构建的西洋07SR01孔年代框架存在问题,误将该孔

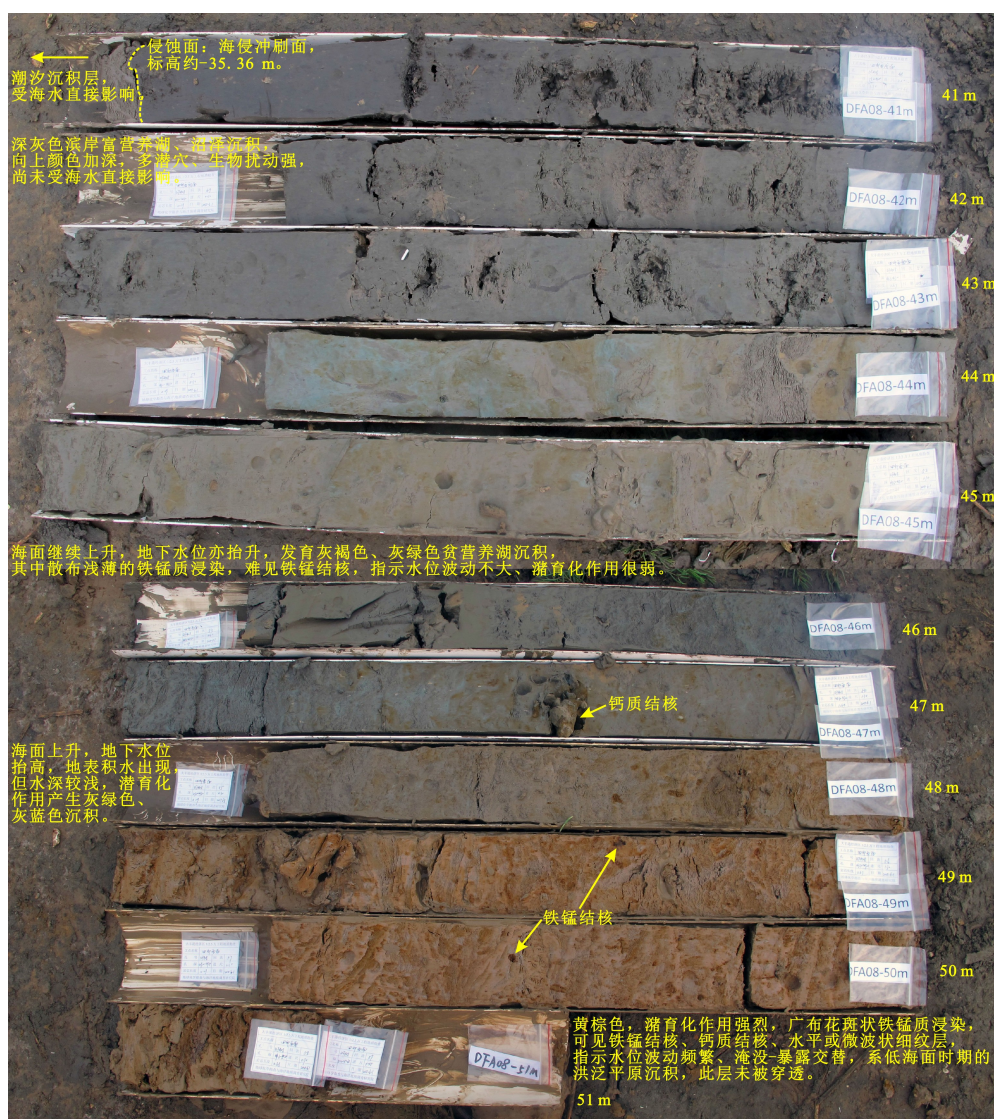


图7 大丰港西北侧 DFA08 孔揭露的典型第二陆相沉积层及其沉积环境解释
岩芯照片由江苏省有色金属华东地质勘查局提供, 图上右侧数值为岩芯段埋深值。

Fig.7 A typical second continental sedimentary layer revealed by core DFA08 in the northwest of Dafeng Port and its interpretation of sedimentary environments

The core photo was provided by East China Geological Exploration Bureau of Nonferrous Metals, Jiangsu Province. The value on the right of the figure is the buried depth of the core section.

表 1 西洋潮流通道周围第一陆相层底部和上覆沉积的 ¹⁴ C 测年数据					
Table 1 ¹⁴ C dating ages of the bottom and overlying deposits of the first continental layer around the Xiyang tidal channel					
钻孔编号	地理位置	埋深/m	测年材料	¹⁴ C 年龄/aBP	数据来源
PY19	东台新曹	33	泥炭	36470±2000	文献[65]
DF02	大丰港区陆域	20.5	软体动物壳	7040±30	文献[69]
SC	东台三仓	8	软体动物壳	670±30	文献[74]
		21.5	软体动物壳	5890±180	文献[75]
JC-1204	东台三仓	10.86	软体动物壳	1090±30	文献[71]
		14.09	软体动物壳	4040±30	
YZ08	东台弼港	7.38	软体动物壳	640±30	文献[70]
		8.28	软体动物壳	690±30	
		10.68	软体动物壳	770±30	
		14.18	软体动物壳	830±30	
		19.22	软体动物壳	1140±30	
		19.73	软体动物壳	1070±30	
		20.22	软体动物壳	1000±30	
		22.64	炭屑	3870±30	
		25.41	软体动物壳	5300±30	
		29.42	软体动物壳	8360±30	
Y5	高泥（西洋南侧）	3.08	软体动物壳	520±30	文献[53]
		5.85	植物碎屑	560±30	
		10.12	软体动物壳	690±30	
		15.24	软体动物壳	790±30	
		17.26	软体动物壳	880±30	
		19.48	软体动物壳	6180±30	

第二陆相沉积层当成第一陆相沉积层来构建年代框架,该孔中下部识别出的滨岸沼泽、洪泛平原和淡水湖沼沉积更适合与第二陆相沉积层相对比,其并未保存有第一陆相沉积层;② 西洋标高-60 m 以内的浅部沉积主体应是晚更新世形成的且发育两个沉积旋回,末次冰盛期硬黏土层多被潮流侵蚀而缺失,表层全新世沉积(大致对应于浅层地震单元 U1)厚度在水下沙脊处基本不足 10 m,其余普遍不足 5 m,甚至缺失(图 2)。

此外, Liu 等研究发现江苏北部岸外、南黄海西部发育有 MIS 3 古黄河三角洲沉积体系,其中与西洋交接的近岸部分顶板标高约-25 m^[11],这与西洋西北段的浅层地震单元 U3 的泥质沉积顶板标高一致(图 4),应该指示着 MIS 3 古黄河三角洲至少南伸至盐城大丰港岸外。还有,上覆于 U3 或 U4 单元、分布于整个西洋、以复杂的切割-充填反射结构

为特征的 U2 单元,其形成环境目前并不确切,尚有陆相沉积、砂席(古河道充填沙体后经潮流改造而成)和埋藏古潮流沙脊等多种解释^[52,76-78], 07SR01 孔的碎屑矿物分析结果显示该层受黄河物源影响^[52]。那么,最上部的 U1 单元是否基本由苏北废黄河供源? 下部的 U4 单元是否由古黄河主控下的洪泛平原、湖沼等沉积构成?

因此,为了进一步探明西洋潮流通道的浅部沉积层序及其形成演化,弄清西洋西北段和东南段沉积层序差异的成因,亟需在其西北段的关键位置钻取新孔,联合使用 AMS ¹⁴C 和 OSL 测年方法,重新研究钻孔沉积序列和年代框架,采用判识黄河、长江物源的有效方法(黏土矿物、元素地球化学等)^[11,74-75] 进行目标物源识别,并与已有数据资料进行全面对比分析,以深入研究西洋浅部沉积层序、年代框架和物源演化。该研究成果对于丰富认识

大河与海岸、陆架交互作用的产物,揭示堆积型陆架的冲刷型潮流通道的物质基础与形成演化,提升对辐射沙脊群形成演化的认识具有重要意义;对利用潮流通道的进行港口建设和人工岛围填,亦有重要的理论指导意义。

4 结语

4.1 结论

(1)由于混乱的测年结果和陆相硬黏土层对比不当,造成之前基于 07SR01 孔和 Y1 孔构建的辐射沙脊群西洋潮流通道的浅部沉积(标高-60 m 以内)的年代框架有误,其主体应是晚更新世沉积且发育两个沉积旋回,末次冰盛期硬黏土层多被潮流侵蚀而缺失,表层全新世沉积厚度在水下沙脊处基本不足 10 m,其余普遍不足 5 m,甚至缺失。

(2)仅在西洋西北段稳定分布的浅层地震单元 U3 指示了 MIS 3 古黄河三角洲的南缘,自晚更新世以来西洋所在的江苏中部海岸可能深受古黄河物源的影响,这尚需在西洋西北段的关键位置钻取新孔,并结合已有浅层地震剖面 and 东南段钻孔来进一步研究证实。

4.2 下一步工作计划

鉴于以上对西洋潮流通道的浅部沉积层序及其形成演化的再认识,下一步工作将基于层序地层学方法,通过对已有控制性浅层地震剖面进行地震

层序格架的三维可视化、提取地震单元和反射界面的空间分布特征,结合已有及新增控制性钻孔的沉积学和年代学研究,构建可靠年代框架、判识大河物源,并参考邻区钻孔资料,来探明西洋潮流通道的浅部沉积层序、反演其形成演化。进一步研究的技术路线如图 8 所示,具体阐述如下:

(1)系统整理西洋潮流通道已有的控制性浅层地震剖面、东南段 07SR01 孔和 Y1 孔,以及西侧陆域滨海平原和邻近海域的各类钻孔等数据资料,形成有待集成分析的数据集。

(2)在对长度超过 440 km、可控制西洋的高分辨率浅层地震剖面解译分析基础上,依据可识别出的 5 个主要浅层地震单元和反射界面,对西洋目前获得的所有剖面进行详细解译,尽可能提取出上述浅层地震单元和反射界面,进而完成三维栅状剖面图的绘制,实现西洋浅部地震层序格架的三维可视化。以上整个过程采用现代地震地层学的解译处理方法。

(3)针对可能由古黄河供源、浅层地震单元 U1 至 U4 相应的沉积层,在 ArcGIS 平台上采用地统计学方法,来提取、分析西洋所有剖面中上述浅层地震单元和相应反射界面的空间分布特征,例如采用浅层地震单元顶底板(海底和相应反射界面)标高、单元层厚、特殊反射结构(如沟槽状切割-充填)等要素的空间分布型式来表征。整合以上(2)和(3)研究工作,以实现定性与定量相结合来揭示西洋浅部地震层序格架。

(4)拟在盐城大丰斗龙港口外、西洋西北段的

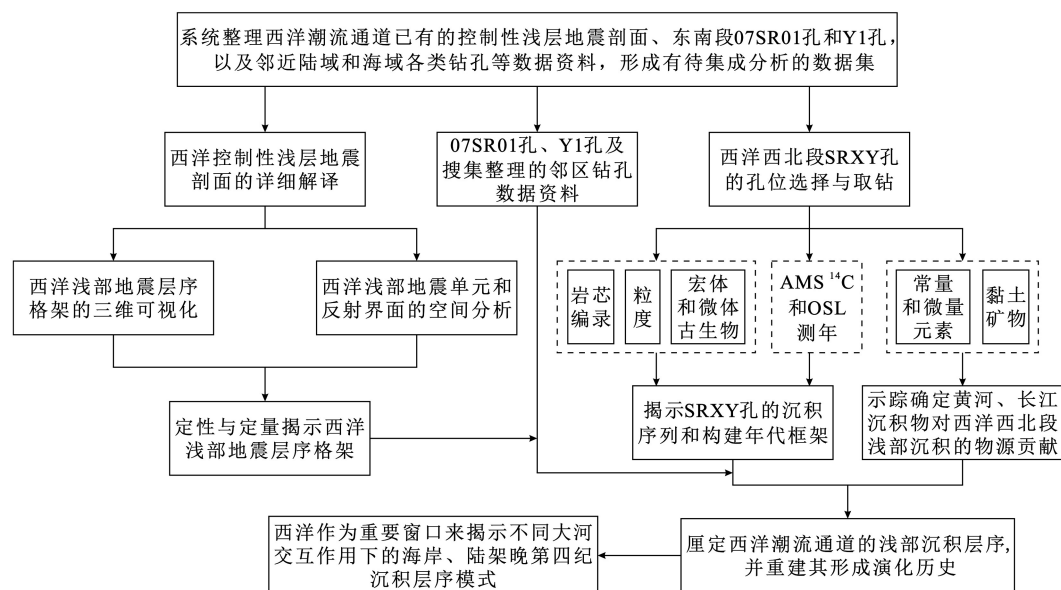


图 8 进一步研究西洋潮流通道浅部沉积层序及其形成演化的技术路线

Fig.8 Technical route of further study on the shallow sedimentary sequence and its evolution of the Xiyang tidal channel

东通道中钻取 SRXY 孔(设计孔位见图 3, 该区处于基本冲淤平衡状态, 水深比较稳定, 未见冲刷槽、穴), 孔口标高约-15 m, 设计孔深 40 m(可完整揭露浅层地震单元 U1 至 U4 相应沉积层)。将钻孔岩心运回实验室后, 完成岩心的室内编录(主要是岩心拍照和沉积特征的描述、分析等, 包括描述分析沉积物颜色、组分质地、沉积结构与构造、接触关系和层次等), 然后根据研究设计需要按照一定间隔或对特殊层位, 采集粒度、AMS ^{14}C 和 OSL 测年、宏体(腹足类和双壳类)和微体(有孔虫和介形虫)古生物、常量和微量元素、黏土矿物等样品, 并完成相应的实验室测试分析。基于以上 SRXY 孔的沉积学和年代学数据综合研究, 可揭示该孔的沉积序列和构建年代框架, 并进一步整理挖掘已做的西洋东南段 07SR01 孔的相关数据资料, 完成这两个控制性钻孔的对比分析。

(5) 研究上述获得的 SRXY 孔中与浅层地震单元 U1 至 U4 相应沉积层的黏土矿物、常量和微量元素的组成变化特征, 并与现代黄河、长江沉积物的黏土矿物、常量和微量元素的组成特征进行对比, 来示踪确定黄河、长江沉积物对西洋西北段浅层地震单元 U1 至 U4 相应沉积层的物源贡献, 再与东南段 07SR01 孔相应的物源示踪结果对比分析。

(6) 在完成并整合以上(2)—(5)研究工作后, 可掌握西洋全区标高-60 m 以内浅部沉积的地震层序格架, 控制性钻孔的沉积序列、年代框架及物源演化历史, 进而在地震地层、钻孔地层和物源演化的结果基础上, 再结合以上(1)搜集整理的邻区钻孔资料, 完成厘定西洋浅部沉积层序, 并重建其形成演化历史。

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