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全国海岸带地质环境综合数据集

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摘要：全国海岸带地质环境综合数据集为海岸带综合地质调查工程的数据成果，按照陆海统筹的总体思路设计，重点实现海陆调查专业学科全覆盖，技术方法手段全覆盖。数据内容主要包括野外综合调查、野外综合施工、野外动态监测、样品测试 4 大类，共计数据表 130 个，数据 177 592 条。其中野外综合调查类包含 9 个数据表，9 006 条数据；野外综合施工类包含 68 个数据表，89 551 条数据；野外动态监测类包含 28 个数据表，12 305 条数据；样品测试类包含 25 个数据表，66 730 条数据。本数据集为海岸带自然资源统一管理、国土空间规划和用途管制以及生态保护修复等提供高效精准的数据服务。

关键词：海岸带；地质环境；数据集；动态监测；生态保护
数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

海岸带是地球表层大气圈、水圈、岩石圈和生物圈交互作用，并受到人类活动深刻影响的地带，是“资源—环境—生态—人口—经济—社会”等高度集中的复杂系统（黄日鹏等，2018；姜丽君等，2018）。中国位于欧亚大陆东部，濒临太平洋，拥有辽阔的海陆疆域和漫长的海岸线（张秋丰等，2019）。海岸呈“S”形，拱位于中国东南之滨，纵跨温带、亚热带和热带 3 个气候带，地势呈西高东低阶梯状，由陆向海逐渐降低，地貌类型多样，气候水文等条件差异显著（张明书，1998）。

中国海岸带地质环境综合调查主要以沿海县（区）域行政区为基本控制范围、以海岸线向陆地 10 km 以内和向海水深 20 m 以内为重点监测区域（图 1）。由于其环境和生态过程及其机制的特殊性、复杂性等决定了相关研究所面临的巨大挑战和困难（刘洪

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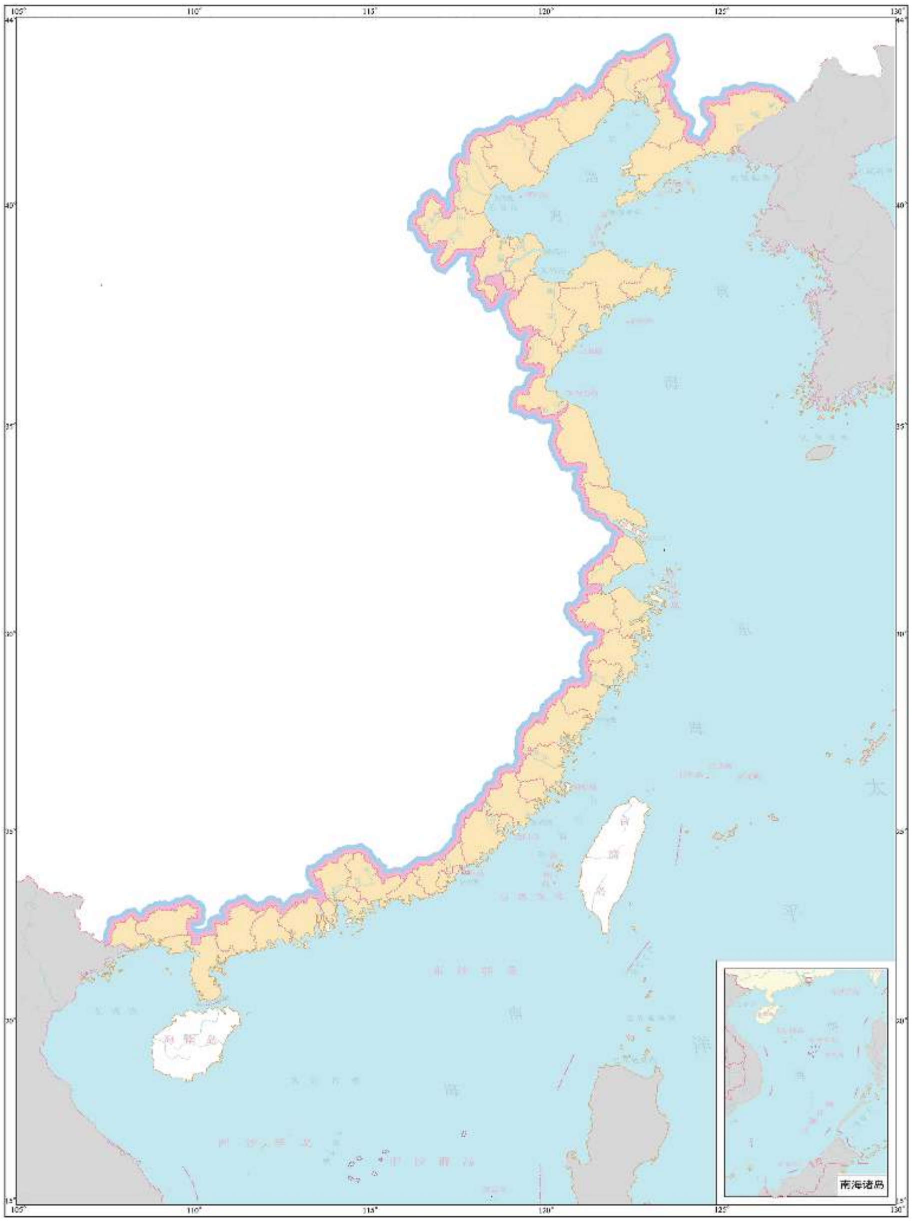

图 1　全国海岸带地质环境调查工作范围

滨，1985）。在研究海岸带的过程中，受地质调查工作手段的限制，海陆连接带调查工作难度大，内容复杂，且存在海陆交互内容空白等问题（涂植凤和杨帆，2019；邢凤存等，2011）。同时，海岸带是中国城镇化程度最高、人口密度最大、经济最发达、工程建设活动最强烈的地区。随着沿海经济建设的深入，关于海岸带地质环境的研究对于经济社会的发展显得尤为重要（印萍等，2017）。

全国海岸带地质环境数据集来源于中国地质调查局海岸带综合地质调查工程，调查区域覆盖全国海岸带地区，目前已重点对津冀沿海、江苏沿岸、长江口、北部湾等区域展开了工作，调查内容涵盖野外综合调查、野外综合施工、野外动态监测、样品测试等（表 1）。本数据集对于评价全国海岸带资源环境承载力、研究海岸带区域地质环境形成、演化过程及趋势等提供了基础数据支撑，同时为国土空间规划和用途管制及生态保护修复等提供了重要依据。

表 1　数据库（集）元数据简表

条目	描述
数据库（集）名称	全国海岸带地质环境综合数据集
数据库（集）作者	李磊，中国地质调查局天津地质调查中心 黄垒，中国地质调查局天津地质调查中心 胡云壮，中国地质调查局天津地质调查中心 刘培，武汉华信联创技术工程有限公司
数据时间范围	2016—2018年
地理区域	全国海岸带
数据格式	SQL Server
数据量	55.81 MB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	津冀沿海资源环境承载能力调查（DD20189506） 国家地质大数据汇聚与管理（华北）（DD20190382）
语种	中文
数据库（集）组成	本数据集主要包括野外综合调查、野外综合施工、野外动态监测、样品测试4大类数据，共计130个数据表，177 592条数据。其中野外综合调查类包含9个数据表，9 006条数据；野外综合施工类包含68个数据表，89 551条数据；野外动态监测类包含28个数据表，12 305条数据；样品测试类包含25个数据表，66 730条数据

2　数据采集和处理方法

全国海岸带地质环境数据采集采用地面调查、钻探、地球物理勘探、野外试验、样品测试、动态监测等多种工作手段完成（表 2）。

表 2　数据类型统计

数据分类	数据个数
地面调查	9 006
钻探	44 552
地球物理勘探	25 546
野外试验	19 453
样品测试	66 730
动态监测	12 305

2.1　遥感解译数据集

利用数字航空摄影、无人机遥感和卫星遥感测量等可以对海岸带土地利用、植被现状及演化、岸线、滩涂、湿地、水体及水质、海域悬浮泥沙运移等进行监测，并为其他工作手段的使用提供参考依据。本次调查使用多种遥感手段作业面积共计 809 300 km^2。

以津冀沿海调查工作为例，遥感数据源选取 2.5 ~ 10 m 分辨率的 SPOT 遥感影像，使用 ENVI 4.3 中的 FLASH 模块进行大气辐射校正，在 1：50 000 比例尺地形图采集控制点进行几何校正，然后根据解译类型对校正后的影像进行不同形式的图像增强处理。解译开始前，携带遥感影像，现场确认各种代表性地物在图像上的图斑形状、颜色色调、影纹结构等识别特征，以建立解译标志。最后利用目视直接判断法对增强后的影像进行解译，解译完成后，对解译分类按比例进行实地抽检式验证。

2.2 水、工、环、生态地质调查

地面调查主要包含水文地质调查、工程地质调查、环境地质调查、生态地质调查等。通过对区域地形地貌、地质构造、地表水、地下水、地质灾害、污染、生态系统等进行系统的调查，能够全面把握区域总体地质状况，为其他更有针对性的调查工作奠定基础。本数据集包含工作范围大小共 3 260 km^2 的各比例尺地质调查数据。

2.3 钻探

钻探是覆盖区地质调查的主要手段。钻探主要用于揭露地层结构与岩性特征，软弱夹层与特殊土层的埋藏分布特征、地质构造破碎带及裂隙发育程度、岩土体工程地质特征、含水层（组）水文地质特征。

2.3.1 水文地质钻探

水文地质钻探主要用于直观了解并掌握地下含水层的主要特征，通过采集钻孔的岩土样品和水样品，及在钻孔内开展现场试验与测试工作，以获取需要的水文地质参数，探明地层剖面和含水层岩性、厚度、埋藏条件、水位（头）、水温和富水性等。

以津冀沿海调查工作为例，采用泥浆护壁钻进方法，探采结合孔为全孔小径（孔径为 127 mm）取芯钻进，达到设计孔深进行物探测井后，再扩孔成井。砂层取芯率≥40%，土层取芯率≥70%，卵砾石层取代表样。探采结合孔扩孔孔径≥550 mm，下入直径 203 mm 或直径 304 mm 的钢管。滤水管为圆孔肋骨缠丝结构，孔隙率≥25%。钻孔孔斜度在 100 m 内≤1.0°。在钻进过程中进行简易水文地质观测工作，观测孔内水位变化、冲洗液明显漏失位置、颜色变化和消耗情况、涌砂坍塌情况等，以及进行地质、水文地质编录。在钻孔中采集水质分析样品，开展水质全分析、污染分析和同位素分析等。

2.3.2 工程地质钻探

工程地质钻探是海岸带地质调查最重要的手段之一，用以查明海陆地区地层、层序、岩性、岩相、厚度、时代、埋藏深度，以及土木性质，同时验证物探资料。

以津冀沿海调查工作为例，采用轻型钻机钻进成孔，泥浆护壁反循环钻进，钻孔直径≥108 mm。每钻进 50 m 及终孔时，都进行孔深校正，终孔孔深误差≤1/1 000。孔深 100 m 的钻孔，孔斜度误差≤2°；小于 50 m 的钻孔，孔斜度误差≤1°；小于 30 m 的钻孔不进行孔斜度测量。钻孔内按岩土工程勘查规范进行标贯测试或波速测试，并取原状样、扰动样。采取原状土样直径≥108 mm，长度≤300 mm。

2.3.3 第四纪地质钻探

第四系钻探主要用于采集第四系沉积物样品，以对其结构和沉积年代、沉积环境等进行研究。

以津冀沿海调查工作为例，钻孔采用轻型钻机钻进成孔，泥浆护壁反循环钻进，钻孔直径≥108 mm，回次进尺≤2 m。每钻进 50 m 及终孔时，都进行孔深校正，终孔孔深误差≤1/1 000。孔深 100 m 的钻孔，孔斜度误差≤2°；＜50 m的钻孔，孔斜度误差≤1°；＜30 m 的钻孔不进行孔斜度测量。现场对岩芯进行分层、描述和拍照，并采取第四系沉积物结构样品，包括粒度分析、地球化学、微体古生物、硅藻、孢粉、黏土矿物和氧碳同位素等样品。粘性土层岩芯采取率＞90%，砂性土层岩芯采取率＞70%。

2.3.4 海洋地质钻探

海洋地质钻探是研究海底地层与岩性的重要手段。

以津冀沿海调查工作为例，钻孔采用轻型钻机钻进成孔，在船体和钻孔之间使用套管，钻孔直径≥108 mm，回次进尺为 2 ~ 3 m。每钻进 50 m 及终孔时，都进行孔深校正，终孔孔深误差≤1/1 000。孔深 100 m 的钻孔，孔斜度误差≤2°；小于 50 m 的钻孔，孔斜度误差≤1°；小于 30 m 的钻孔不进行孔斜度测量。现场对岩芯进行分层、描述和拍照。样品采集兼顾第四系综合研究样品与土体物理力学性质测试样品。粘性土层岩芯采取率＞90%，砂性土层岩芯采取率＞70%。

2.4 地球物理勘探

2.4.1 陆域

结合地面调查成果布置物探工作，主要采用了磁、电、震等多种方法，用于查明岩土体结构特征、基岩面形态、断层位置、产状、岩溶塌陷范围、含水层分布、厚度等。本次调查中地震测量作业长度 87 km，电磁测量作业长度 30 km，高密度电法测量共布设 2020 个点位。

以江苏沿岸地区调查工作为例，其浅层地震的观测参数为：道间距 3 m，炮间距 12 m，72 道接收，覆盖次数 9 次；采集参数为：采样间隔 0.25 ms，采样长度 1 000 ~ 2 000 ms。张量 CSAMT 的观测参数为：发射偶极矩 AB 为 1 000 ~ 1 500 m，收发距 r≥5 000 m；接收偶极矩 MN 为 50 m，测点距 100 m，频率观测范围 0.125 ~ 8 192 Hz。接收装置采用 5 个电磁场分量 *EX*、*EY*、*HX*、*HY* 和 *HZ*。电极采用“+”字形布设。同一测点采集 2 次数据，共采集 10 个分量。采集参数为：布设 2 组不重合或平行的场源交替发射，采用不锈钢电极或铺设铝箔，并尽量选择在土壤潮湿处埋设电极，保证接地良好，接地电阻≤70 Ω。接收电极 M、N 采用固体不极化电极，接地电阻≤5 000 Ω；水平磁棒的方位采用森林罗盘或罗盘定位，误差小于 1°。观测过程中，随时观察观测数据，并视干扰情况，适时改变仪器增益或增加叠加次数，以保证采集数据的质量。

2.4.2 海域

开展海岸带调查采用的物探方法主要有单波束测深、多波束测深、单道地震、多道地震、浅地层剖面测量、侧扫声呐测量等。其中单波束测深和多波束测深主要是利用向海底发射并接收声波来求取水深和海底地形，其在本次调查中的作业长度分别为 11 975 km 和 31 800 km。单道地震、多道地震、浅地层剖面测量和侧扫声呐测量则主要用于反映海底沉积结构和构造特征，其在本次调查中的作业长度分别为 11 653 km、1 300 km、15 256 km、3 686 km。

以长江口地区多波束海底地形测量为例，获得 100% 海底全覆盖，同时符合 IHO 深度测量误差标准，即水深≤30 m 时，误差＜0.3 m。回声测深仪系统测量时，海底地形测量的精确度以主测线与联络测线相交点水深测量值的差值来衡量，其均方根差小于实际水深的 1%。测量船在预定的测线方向上保持匀速直线航行，偏离测线不超过测幅宽度的 1/10。每条测线结束后，维持原航向、航速 1 min 后再转向。每个发射脉冲接收到的波束大于总波束的 80%。

2.5 野外试验

野外试验主要是指工程地质原位测试和水文地质试验。

2.5.1 工程地质原位测试

原位测试是指在岩土层原来所处的位置、基本保持天然结构、天然含水量以及天然

应力状态下，测定岩土的工程力学性质指标的方法，常用的有静力触探试验、标准贯入试验、十字板剪切试验等，它们能够测定难于取得不扰动土样的有关工程力学性质，也可避免取样过程中应力释放的影响。

以长江口地区标准贯入试验为例，试验锤重为 63.5 kg，以 0.76 m 的自由落距进行锤击。试验时先预打 15 cm 后，再打入 30 cm 并记录每打入 10 cm 的锤击数，累计打入 30 cm 的锤击数为标准贯入实测击数 $N_{63.5}$。对在深度 0 ~ 20 m 范围内分布的砂土、粉土，为判定其地震液化可能性和液化等级，试验间距为 1.5 m，取样做颗粒分析试验；20 m 以下试验间隔一般为 2 ~ 3 m，对标贯器内土样进行地质编录，取样做颗粒分析试验。为保证试验结果的精度，成孔时采用泥浆护壁。当钻至试验深度以上 15 cm 处时，先清除孔底残土再进行试验。

2.5.2　水文地质试验

水文地质试验是为取得岩（土）水文地质参数，查明水文地质条件和对地下水进行定量研究而进行的测试工作，包括抽水试验、渗水试验等，这些试验是在现场对探测目的层位进行直接测试，其成果能比较真实地反映客观情况。

以抽水试验为例，采用单孔稳定流法反向抽水，按 3 个落程进行，稳定时间分别为 24 h、16 h、8 h。当水量很小或水位下降不明显时，做一次降深，稳定时间不小于 24 h。当抽水孔水位不能稳定时，进行一次最大降深的非稳定流试验，抽水延续时间视 $s-lgt$ 曲线确定，一般不小于 24 h。稳定流抽水试验在稳定时间内应达到涌水量和水位稳定，或在一定范围内波动，不得有持续下降或上升的趋势。水位波动范围的误差一般不能超过平均降深值的 1%，涌水量波动值不能超过平均流量的 3%。

2.6　样品测试

在野外调查中，按规范要求采集样品进行各种室内测试。海岸带地质环境调查中涉及陆域、海域和潮间带的各类样品，具体包括表层土壤、表层沉积物、柱状沉积物、地下水样、海水样等。对其进行测试分析的技术方法主要有岩矿测试和土工试验 2 类。

2.6.1　岩矿测试

主要包括粒度分析、微体古生物分析、孢粉分析、重砂矿物分析、光释光测年、磁化率测试、地球化学测试等。

2.6.2　土工试验

主要包括含水量 w、重度 γ、比重 G、粘性土的 W_P 和 W_L、粉性土和砂土的颗粒分析等物理性试验项目和固结试验、固结快剪等力学性试验项目。

2.7　动态监测

2.7.1　地面沉降监测

建设工程增荷、地下水开采、地热开采等均可能引起地面沉降，利用基岩标、分层标、水准测量、GPS 监测和 InSAR 空间观测等方法对其进行监测研究，方便我们客观认识地面沉降地质灾害的形成、发展、演化规律，为综合治理地质灾害环境提供高效可行的决策，对评估地质灾害后果，减轻地质灾害的影响起到积极作用。

此次调查在渤海湾地区建成了地面沉降深分层标组 8 组，监测深度大于 800 m 的 3 组，其中塘沽 G2 分层标组最大控制深度 1 218 m，是亚洲截止目前最深的机械分层标。它包括地面标 1 个，分层标 8 个，结合分层标建设水位观测孔 6 个，孔隙水压力

孔 5 个，从 2010 年 7 月起已取得了长序列监测数据。二等水准监测路线 300 km，其主要精度指标为：水准测量偶然中误差不超过±1 mm/km，水准测量全中误差不超过±2.0 mm/km。GPS 监测 25 站位。

2.7.2 水土环境监测

监测自然因素和人类工程活动因素对地下水环境（水位、水质、水温等）、地表水环境、土地环境以及对生态环境的影响，监测内容为地下水分层水位、水质及水温、土地质量（海域底质）等要素，监测手段主要有遥感、地面电法物探、地下水监测井等。

以天津滨海新区为例，东西向布设 3 条地下水监测剖面，控制沿海地区 20 ~ 30 km 宽度的滨海地区，分析结果可以相互印证，避免单一剖面造成的认识偏差。每条剖面布置 10 眼监测井，共计 30 个监测井，井深 15 m 与 30 m 相间，井间距在 2 ~ 4 km。考虑到垂向地层结构，监测 15 m 井，主要监测第一海相层孔隙水变化；30 m 井主要监测第二陆相层孔隙水变化，30 m 井设计双层观测，监测两层水位，上部 15 m 止水成井，与 15 m 井监测层位一致，15 ~ 30 m 部上下止水成井，观测 15 ~ 30 m 的水位动态变化。

2.7.3 海岸与滩涂侵蚀淤积动态监测

由于海岸带地区地貌和区域水动力条件发生变化，导致海岸和滩涂侵蚀和淤积发生剧烈变化，监测内容包括海岸线变化、岸滩和近岸海域地形地貌变化、岸滩和水下沉积物变化，监测手段主要有无人机、RTK-GPS 测量、单波束测深、浅剖等。

岸滩剖面测量采用 RTK-GPS 测量技术，利用连续地形模式对剖面进行测量，测量剖面平面和高程数据，获得完整连续的剖面地形形态。剖面起点一般为防护林的边界线，方向为垂直岸线方向，终点为低潮线附近，数据平均采样间隔 0.5 m，以后每次测量均根据第一次测量时确定的剖面起点、测线方位和终点进行定线保证每次测量数据的重合度。通过多次重复测量对比，掌握岸滩剖面变化的动态。

2.7.4 海洋水动力监测

主要监测内容包括潮汐、波浪、潮流、悬浮泥沙、大气风场、温度、盐度等影响海洋水动力条件的要素。通过各类监测站获取相对完整连续、存在耦合关系的各类海洋水动力影响要素，及各类海洋水动力特性指标，为海岸带冲淤影响等分析预测评价提供基础数据。

以渤海湾为例，在山东、河北、天津海岸带地区进行了综合方法的监测，包括风速风向、大气压、潮汐、波浪、水流、泥沙、冲淤等多要素监测。其中潮汐和气压监测站 8 个，风速风向监测站 3 个，海洋流速流向监测站 2 个，综合水动力监测平台 1 个，14 条水动力监测剖面，15 个水动力测量定点站位，基本覆盖了渤海湾海岸带全域。

2.7.5 地质灾害或潜在不稳定地质体监测

监测活动断裂、地应力、海底滑坡、浅层气、不稳定地质因素、重大工程区水下不稳定边坡、崩滑流等地质灾害或潜在不稳定地质体，为区域地质灾害风险评价提供依据，从而避免不必要的经济损失，排除安全隐患。

以海底滑坡为例，具体调查监测技术方法为：通过大范围的较大比例尺水深地形资料划定海底滑坡易发区，重点关注强潮冲刷、侵蚀发育的区域，特别是重大工程附近海域。对重点关注区开展精细的多波束调查，提高水深地形资料的精度，基本圈定海底滑坡的位置。开展有针对性的浅地层剖面或极浅剖面测量，揭示海底滑坡体的地层特征及滑坡面位置等。针对滑坡体布署地质钻探、工程地质钻探或海域静力触探等手段，获取

滑坡体地层细部结构、粒度、黏土矿物、地球化学、工程力学性质等重要参数。综合获得的地质、地球物理、工程地质、地球化学、水动力特征等数据开展数值模拟工作，对滑坡的触发机制进行研究。重点区布署多波束重复测量工作，形成动态监测数据。结合滑坡体周边重大工程开展海底滑坡风险评估。

3　典型数据样本描述

全国海岸带地质环境的数据样本选取典型的 8 个表进行简要概述，分别为钻孔基本情况表、钻孔地层描述表、高密度电阻率观测数据记录表、单波束测线信息记录表、浅地层剖面测量工作信息记录表、单道地震记录班报表、潮位潮汐观测记录表、分层标监测数据表。

钻孔基本情况表包含如下内容：统一编号、野外编号、地理位置、经度、纬度、孔口高程、钻机类型、钻孔类型、开孔日期、终孔日期、井斜、开孔直径、终孔直径、终孔深度、成井深度、含水层初见水位、静止水位、质量等级、钻孔级别、含水层特征、取样情况、平面位置示意图、施工单位、机长、地质编录人、调查日期、填表日期、项目名称等，如表 3 所示。

钻孔地层描述表包含的内容如下：统一编号、序号、地质时代、层底标高、层底深度、层底接触关系、单层厚度、层理构造、岩土名称、岩土颜色、地层岩性描述等，如表 4 所示。

高密度电阻率法观测数据记录表包含的内容如下：测点统一编号、工区统一编号、测线统一编号、测点野外编号、实测电阻率值、一次场电压、一次多场电流等，如表 5 所示。

单波束测线信息记录表包含的内容如下：测线统一编号、工区统一编号、测线野外编号、测线起点经度、测线起点纬度、测线终点经度、测线终点纬度、测线长度、工作时间等，如表 6 所示。

单道地震记录班报表包含的内容如下：测点统一编号、工区统一编号、测线统一编号、测点野外编号、记录纸卷号、时间、航向、激发间隔、扫描宽度、滤波、文件名、备注等，如表 7 所示。

悬沙观测标包含的内容如下：测点统一编号、测点野外编号、经度、纬度、海潮、海况、调查船、监测时间、表层含沙量、中间层含沙量、底层含沙量、水深、备注等，如表 8 所示。

分层标监测数据表包含的内容如下：统一编号、测量日期、测量类型、变形量等，如表 9 所示。

海水入侵观测井基本情况表包含的内容如下：统一编号、野外编号、地理位置、经度、纬度、地面高程、井口高程、井口直径、水位埋深、井深、井类型、井与地表水距离、水温、气温、嗅、pH、色、透明度、井壁结构、井淘洗情况、建井年限、开采方式等，如表 10 所示。

4　数据质量控制和评估

工作区内开展的所有工作手段均依照《国家行业规范海岸带地质环境建设指南》（DD 2012−04）执行，所产生的数据表均依照规范附表执行，精度满足海岸带地质环境综合数据集的要求。

表 3　钻孔基本情况

序号	字段名称	量纲	数据类型	实例
1	统一编号	–	字符型	11759029394355901
2	野外编号	–	字符型	Z025
3	地理位置	–	字符型	河北省唐山市丰润区丰登坞镇
4	经度	–	字符型	117590290
5	纬度	–	字符型	39435590
6	孔口高程	m	浮点型	5.436
7	钻机类型	–	字符型	XY-100
8	钻孔类型	–	字符型	工程地质钻孔
9	开孔日期	–	字符型	2012-02-23
10	终孔日期	–	字符型	2012-02-23
11	井斜	°	浮点型	0
12	开孔直径	mm	浮点型	110
13	终孔直径	mm	浮点型	110
14	终孔深度	m	浮点型	20
15	成井深度	m	浮点型	20
16	含水层初见水位	m	浮点型	7.0
17	静止水位	m	浮点型	6.2
18	质量等级	–	字符型	合格
19	钻孔级别	–	字符型	中等区域
20	含水层特征	–	字符型	钻孔位于冲洪积倾斜平原水文地质区，分布第四系松散岩类孔隙水、蓟县—青白口系岩溶裂隙水
21	取样情况	–	字符型	共取5个原状样，4个扰动样，15次标贯
22	平面位置示意图	–	长二进制数据	（图片）
23	施工单位	–	字符型	河北省地矿局第五地质大队
24	机长	–	字符型	杨贵周
25	地质编录人	–	字符型	马洪志
26	调查日期	–	字符型	2012-02-23
27	填表日期	–	字符型	2012-02-23
28	项目名称	–	字符型	唐山城市重点规划区工程地质调查评价报告（新华道以北地区及空港城和丰南城区）

数据集配套系统内置数据检查引擎，数据入库人员可对数据进行质量检查，包括数据表完整性、数据类型准确性、数据是否重复等，同时提示定位错误内容，便于修改。

同时，工作区内的调查数据表 100% 开展项目数据自检与互检，数据表整理完成后已经完成了 15% 抽检，抽查结果显示的质量可信度满足海岸带地质环境调查工作的规范要求。

5　总结

全国海岸带地质环境综合数据集包括野外综合调查、野外综合施工、野外动态监测、样品测试 4 大类数据，共计数据表 130 个。其中野外综合调查类数据 9 006 条，野

表 4　钻孔地层描述

序号	字段名称	量纲	数据类型	实例
1	统一编号	–	字符型	11800348391952901
2	序号	–	字符型	2
3	地质时代	–	字符型	全新世
4	层底标高	m	浮点型	−1.4
5	层底深度	m	浮点型	1.25
6	层底接触关系	–	字符型	整合接触
7	单层厚度	m	浮点型	0.95
8	层理构造	–	字符型	水平层理
9	岩土名称	–	字符型	粉质黏土
10	岩土颜色	–	字符型	灰褐色
11	地层岩性描述	–	字符型	硬塑，有较多锈染斑及还原斑发育，可见铁染质团粒，下部有极少量砂质纹层发育，局部可见少量的钙质团粒

表 5　高密度电阻率法观测数据记录

序号	字段名称	量纲	数据类型	实例
1	测点统一编号	–	字符型	11336305223504301
2	工区统一编号	–	字符型	11336305223504301
3	测线统一编号	–	字符型	11336305223504301
4	测点野外编号	–	字符型	L13G97
5	实测电阻率值	Ω·m	浮点型	76.83
6	一次场电压	mV	浮点型	94.783
7	一次场电流	mA	浮点型	209.369

表 6　单波束测线信息记录

序号	字段名称	量纲	数据类型	实例
1	测线统一编号	–	字符型	12147549302301201
2	工区统一编号	–	字符型	12147549302301201
3	测线野外编号	–	字符型	ZS-L1
4	测线起点经度	–	字符型	12147549
5	测线起点纬度	–	字符型	3023012
6	测线终点经度	–	字符型	12204379
7	测线终点纬度	–	字符型	3023012
8	测线长度	km	浮点型	50
9	工作时间	–	字符型	2016-06-20

外综合施工类数据 89 551 条，野外动态监测类数据 12 305 条，样品测试类数据 66 730 条，共计 177 592 条。

全国海岸带区域在此之前开展了大量的地质调查工作，获得了原国土资源部中国地质调查局、国家海洋局、地方政府部门、地方企事业单位、国家自然科学基金委员会等资助项目的数据支持。扩展了遥感、航放、航电、电法、浅层地震、地面放射性等物化

表 7　单道地震记录班报表

序号	字段名称	量纲	数据类型	实例
1	测点统一编号	–	字符型	11933376243220901
2	工区统一编号	–	字符型	11933376243220901
3	测线统一编号		字符型	11933376243220901
4	测点野外编号	–	字符型	L1G1
5	记录纸卷号	–	字符型	无
6	时间	–	字符型	2017-07-16
7	航向	°	浮点型	116.9
8	激发间隔	ms	浮点型	1 300
9	扫描宽度	ms	浮点型	500
10	滤波	Hz	浮点型	150
11	文件名	–	字符型	1-L1
12	备注	–	字符型	无

表 8　悬沙观测表

序号	数据项名称	量纲	数据类型	实例
1	测点统一编号	–	字符型	12202258302206301
3	测点野外编号	–	字符型	SW01
4	经度	–	字符型	12202258
5	纬度	–	字符型	3022063
6	海潮	–	字符型	半日潮
7	海况	–	字符型	3级
8	调查船	–	字符型	浙海科1
9	监测时间	–	字符型	2016-06-01
10	表层含沙量	mg/L	浮点型	319.909
11	中间层含沙量	mg/L	浮点型	399.886
12	底层含沙量	mg/L	浮点型	639.818
13	水深	m	浮点型	20
14	备注	–	字符型	无

表 9　分层标监测数据表

序号	字段名称	量纲	数据类型	实例
1	统一编号	–	字符型	11830407385954101
2	测量日期	–	字符型	2010-05-18
3	测量类型	–	字符型	人工检测
4	变形量	mm	浮点型	4.365 08

遥各类技术方法，扩展了海洋调查物探方法，增加了解译类中间性成果、海岸带调查方法、海岸带监测方法、地灾监测等内容，扩展了岩土样品测试结果表等。完善了调查点基本表与调查点属性表之间的直接对应关系，增加了线与面属性表数据的空间信息，为后期空间数据库与可视化平台的建立奠定了良好的基础。

表 10 海水入侵观测井基本情况

序号	字段名称	量纲	数据类型	实例
1	统一编号	–	字符型	11836021391011601
2	野外编号	–	字符型	CFZK3
3	地理位置	–	字符型	河北省唐山市曹妃甸区
4	经度	–	字符型	11836021
5	纬度	–	字符型	3910116
6	地面高程	m	浮点型	0.1
7	井口高程	m	浮点型	2.1
8	井口直径	m	浮点型	2.1
9	水位埋深	m	浮点型	1.39
10	井深	m	浮点型	6
11	井类型	–	字符型	机井
12	井与地表水距离	m	浮点型	160
13	水温	℃	浮点型	14
14	气温	℃	浮点型	30
15	嗅	–	字符型	无
16	pH	–	浮点型	8.05
17	色	–	字符型	无色
18	透明度	–	字符型	透明
19	井壁结构	–	字符型	水泥管
20	井淘洗情况	–	字符型	不详
21	建井年限	–	字符型	10
22	开采方式	–	字符型	间歇开采

致谢：数据集的录入、整理及分析得到了数据库专家的指导；数据论文修改阶段得到了审稿专家及编辑部的宝贵意见，在此表示最诚挚的感谢。

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Comprehensive Dataset of the Geological Environment in China's Coastal Zone

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Abstract: The comprehensive dataset of the geological environment in the coastal zone of China obtained as a result of geological survey, is designed according to the overall concept of land-sea coordination to achieve full coverage of relevant disciplines, techniques and methods. The data fall into four categories, namely, comprehensive field surveys, comprehensive field construction, field dynamic monitoring and sample testing. There are total 130 data tables and 177 592 pieces of data, including 9 types of data table and 9 006 pieces of data in the comprehensive field survey category, 68 types of data table and 89 551 pieces of data in the comprehensive field construction category, 28 data table types and 12 305 pieces of data in the field dynamic monitoring category, and 25 data table types and 66 730 pieces of data in the sample testing category. This dataset provides efficient and accurate data services for the unified management of coastal natural resources, spatial planning of territory, use control, ecological protection and restoration.

Key words: coastal zone; geological environment; dataset; dynamic monitoring; ecological protection

Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

The coastal zone, which features the interaction between the earth's surface atmosphere, hydrosphere, lithosphere and biosphere, is now deeply affected by human activities. It is a highly complex system of concentrated factors in terms of resources, environment, ecology,

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population, economy and society (Huang RP et al., 2018; Jiang LJ et al., 2018). China is located in the eastern part of Eurasia, bordering the Pacific Ocean. It has a vast land and sea territory and a long coastline (Zhang QF, et al., 2019). Its coast is 'S'-shaped, with a protruding southeast coast and spans three climatic zones, i.e., temperate, subtropical and tropical. Higher in the west and lower in the east, China's terrains show decreasing elevations from land to sea. With diverse landforms, China has significantly different climatic and hydrological conditions (Zhang MS, 1998).

With the administrative region of coastal counties (districts) as the basic control area, the comprehensive geological environment survey of China's coastal zone adopts the coastline (within 10 km from seashore on land and an alongshore sea area with water depth of less than 20 m) as the key monitoring area (Fig.1). The particularity and complexity of its environment, ecological processes and mechanisms present great challenges and difficulties for relevant studies (Liu HB, 1985). Due to the limitation of geological survey methods, the investigation of the coastal belt is complicated and challenging, with knowledge gaps in land–sea interaction (Tu ZF and Yang F, 2019; Xing FC et al., 2011). At the same time, the coastal zone is the area with the highest degree of urbanization, the highest population density, the most developed economy and the busiest construction activities in China. With the continued growth of the coastal economy, research on the geological environment of the coastal zone holds great significance for economic and social development (Yin P et al., 2017).

The Dataset of the Geological Environment in China's Coastal Zone is derived from the China Geological Survey's integrated coastal zone geological survey. The survey area covers all coastal zones in China. Currently, work has been focused on areas along the Tianjin–Hebei coast, Jiangsu coast, Yangtze River estuary, Beibu Gulf and other areas. The survey content covers all kinds of data, such as comprehensive field survey, comprehensive field construction, field dynamic monitoring, and sample testing, etc (Table 1). This dataset provides support for the evaluation of national coastal zone resources and environmental carrying capacity, as well as the study of the formation, evolution and trends of regional geological environment. It also provides important basis for land spatial planning, use control, ecological protection and restoration, etc.

2 Methods for Data Collection and Processing

Multiple methods have been applied in the survey of the geological environment of the coastal zone in China, such as ground investigation, drilling, geophysical exploration, field test, sample testing and dynamic monitoring (Table 2).

2.1 Remote Sensing Interpretation Dataset

Digital aerial photography, UAV remote sensing and satellite remote sensing measurements have been applied to monitor the use of coastal land, the evolution and current situation of vegetation, coastal line, tidal flat, wetland, water body, water quality and suspended sediment transport in sea areas, etc. These data also provide reference for the use of other methods. In this survey, the total area of operation using various remote sensing methods

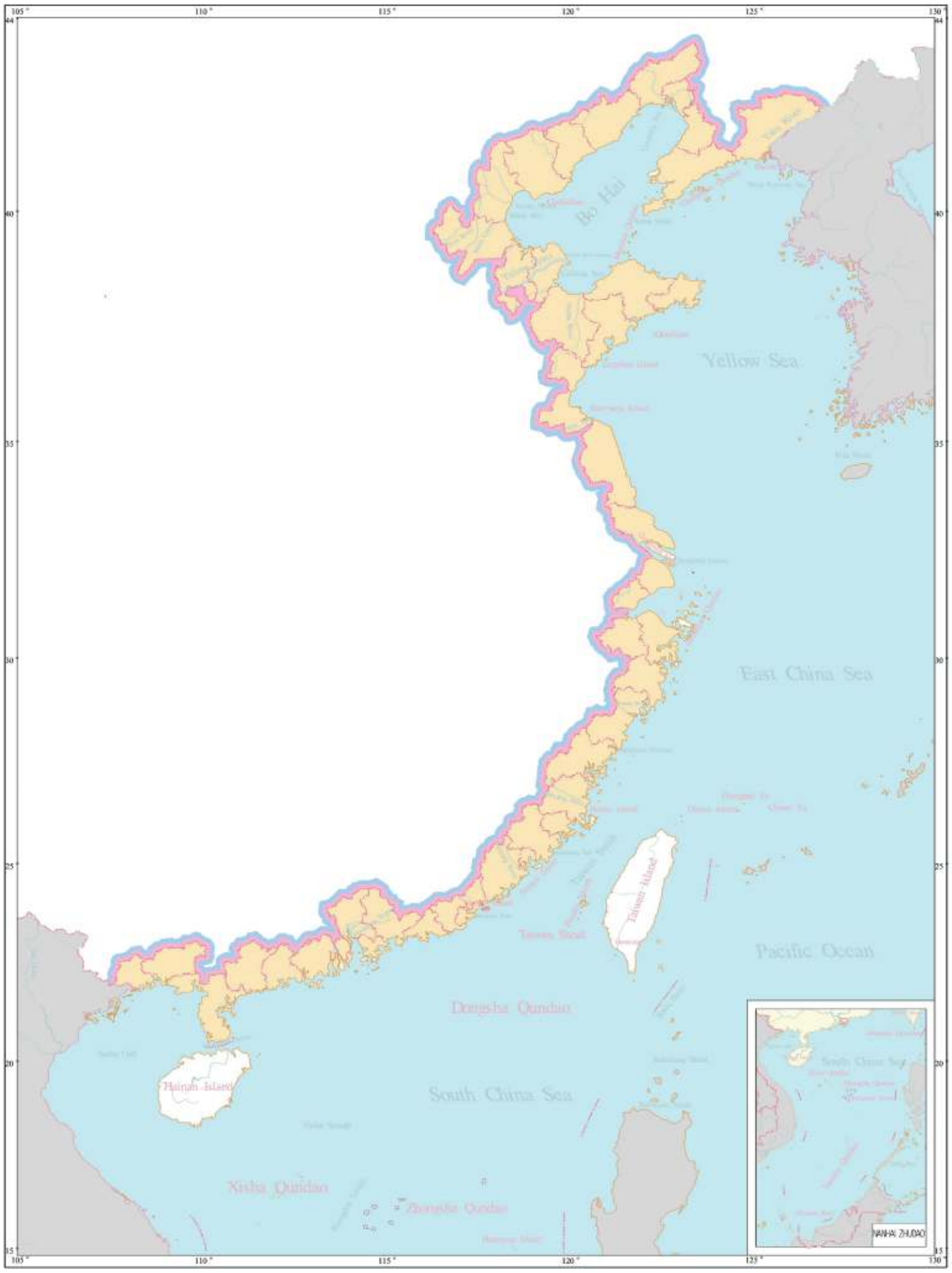

Fig. 1 Scope of Geological Environment Survey in Coastal Zone of China

is 809 300 km^2.

Taking the coastal investigation in Tianjin and Hebei as an example, the remote sensing data source selects SPOT (Small Programmable Object Technology) remote sensing images with a resolution of 2.5~10 m. The FLASH module in ENVI 4.3 is used to carry out atmospheric radiation correction, conducting geometric correction at acquisition control points of 1∶50 000 topographic map, and then enhancing different forms of corrected images according to the types of interpretation. Before interpretation, remote sensing images are brought to the spot to confirm such identification features as shape, color, tone, and shadow texture of various representative ground objects in the images, so as to establish interpretation marks. Finally, the enhanced image is interpreted by the visual judgment method. After the

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	Comprehensive Dataset of the Geological Environment in China's Coastal Zone
Database (dataset) authors	Li Lei, Tianjin Center, China Geological Survey Huang Lei, Tianjin Center, China Geological Survey Hu Yunzhuang, Tianjin Center, China Geological Survey Liu Pei, Wuhan Huaxin Lianchuang Technology Engineering Co., Ltd
Data acquisition time	2016—2018
Geographic area	National Coastal Zone
Data format	SQL Server
Data size	55.81 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	"Investigation on Carrying Capacity of Tianjin–Hebei Coastal Resources and Environment" (DD20189506) and "Big Data Gathering and Management of National Geology (North China)" (DD20190382))
Language	Chinese
Database (dataset) composition	The database (dataset) consists of 4 categories of data for comprehensive field investigation, field construction, field dynamic monitoring and sample testing, with a total of 130 data tables and 177 592 pieces of data, of which the field comprehensive investigation category includes 9 data table types and 9006 pieces of data, the comprehensive field construction category includes 68 types of data table and 89 551 pieces of data, the field dynamic monitoring category includes 28 data table types and 12 305 pieces of data, and the sample testing category includes 25 types of data table and 66 730 pieces of data.

Table 2 Data Types

Data type	Number of data items
Ground investigation	9 006
Drilling	44 552
Geophysical exploration	25 546
Field test	19 453
Sample test	66 730
Dynamic monitoring	12 305

interpretation is completed, an interpretation classification is verified on the spot in proportion.

2.2 Hydrological-Engineering-Environmental-Ecological Geological Surveys

The ground survey mainly includes hydrological geological surveys, engineering geological surveys, environmental geological surveys, and ecological geological surveys. Through systematic investigation of the regional topography, geological structure, surface water, groundwater, geological disasters, pollution, and ecological system, the overall geological condition of the region can be fully understood, laying the foundation for other more targeted investigations. This dataset includes geological survey data of various scales with a total scope of 3 260 km^2.

2.3 Drilling

Drilling is the main means of geological survey in the coverage area. It is primarily used to present the stratum structure and lithological characteristics, the distribution pattern of soft rock strata and special soil layers, the crushed zone in geological structure and the development degree of fissure, geological characteristics for geotechnical engineering, and hydrogeological characteristics of aquifers (groups).

2.3.1 Hydrogeological Drilling

Hydrogeological drilling is mainly used to observe and understand the major features of underground aquifers directly. Through collecting rock and soil samples and water samples from boreholes, and carrying out on-site tests in boreholes, the required hydrogeological parameters can be obtained, and the stratum section and aquifer lithology, thickness, burial conditions, water level (head), water temperature and water yield property verified.

For example, during the investigation along the coast of Tianjin and Hebei, the slurry hole-boring method was adopted, and both exploration and mining boreholes were used to core drilling with a full hole diameter (127 mm). Boreholes are widened after reaching the designed hole depth and performing geophysical logging. The coring rate of a sand layer is not less than 40% and a soil layer not less than 70%. The gravel layer is sampled as well. Boreholes for both exploration and mining have an expansion diameter of not less than 550 mm. A steel pipe with a diameter of 203 mm or 304 mm is put into the hole. The applied filter tube is made of a rib coiled with wire and with a round hole in it. The porosity is no less than 25% and the hole deflection is not more than 1.0° within 100 m. Simple hydrogeological observations can be made during the process of drilling, such as observing the change of water level in the hole, the change of color and consumption of the flushing fluid, the exact position where the flushing fluid leaks noticeably, and the degree of sand gushing and collapsing. Additionally, geological and hydrogeological cataloguing should be conducted. Samples for water quality analysis are collected in boreholes for analyzing water quality, pollution and isotopes.

2.3.2 Engineering Geological Drilling

Engineering geological drilling is one of the most important means of geological investigation in coastal zones, which is used to identify the stratigraphic sequence, lithological properties, lithofacies, thickness, age, burial depth, and the properties of civil engineering in marine and continental areas, as well as to verify geophysical prospecting data at the same time.

For example, in the investigation along the coast of Tianjin and Hebei, a light drilling machine was used to drill holes, adopting the slurry hole-boring method for reverse circulation drilling. The diameter of the hole is greater than or equal to 108 mm. When every 50 m is drilled or the drill-hole is finished, the hole depth is corrected, and the error of the final hole depth should not be greater than 1/1000. For a hole with a depth of 100 m, the hole deflection should be no more than 2°; a hole with a depth of less than 50 m should not be more than 1°. It is not necessary to measure hole deflection for boreholes less than 30 m. A standard penetration test or wave velocity test should be conducted in the borehole according to geotechnical engineering exploration specifications, and undisturbed as well as disturbed samples taken. The undisturbed soil samples should have a diameter of not less than 108 mm and a length of not more than 300 mm.

2.3.3 Quaternary Geological Drilling

Drilling is mainly used to collect Quaternary sediment samples for study of structure, time and environment of Quaternary sediments.

For example, in the investigation along the coast of Tianjin and Hebei, a light drilling machine was used to drill the hole, with the slurry hole-boring method for reverse circulation drilling. The diameter of the hole is greater than or equal to 108 mm. The round trip meterage is not longer than 2 m. When every 50 m is drilled or the drill-hole is finished, the hole depth is corrected, and the error of the final hole depth should not be greater than 1/1000. Hole deflection should be no more than 2° for a hole with a depth of 100 m, and no more than 1° for a hole with a depth of less than 50 m. It is not necessary to measure hole deflection for boreholes less than 30 m. The rock cores are described and photographed in layers on site. Samples of Quaternary sediment structure are taken, including samples for granularity analysis, geochemistry, micro-fossil, diatom, sporopollen, clay minerals, oxygen and carbon isotopes. The core monitor rate of cohesive soil is more than 90%, and that of sandy soil is more than 70%.

2.3.4 Marine Geological Drilling

Marine geological drilling is an important means to study seabed strata and lithology.

For example, in the investigation along the coast of Tianjin and Hebei, a light drilling machine was used to drill holes, and bushing placed between the hull and borehole. The diameter of the hole is greater than or equal to 108 mm. Roundtrip meterage is from 2 m to 3 m. When every 50 m is drilled or the drill-hole is finished, the hole depth is corrected, and the error of the final hole depth should not be greater than 1/1 000. For a hole with a depth of 100 m, the hole deflection should be no more than 2°; a hole with a depth of less than 50 m should not be more than 1°. As to a borehole less than 30 m, there is no need to measure hole deflection. The cores were described and photographed in layers on site. Samples were collected to consider the Quaternary with comprehensive research samples and samples of soil for testing physical and mechanical properties. The core monitor rate of cohesive soil is more than 90%, and that of sandy soil is more than 70%.

2.4 Geophysical Exploration

2.4.1 Land

Geophysical exploration work is arranged in combination with the results of ground survey. Magnetic, electric, seismic and other exploration methods are used to understand the structural characteristics of rock and soil mass, morphology of bedrock surface, fault location, occurrence, collapse range of Karst, aquifer distribution, thickness, etc. The operation lengths of the seismic and electromagnetic surveys in the exploration are 87 km and 30 km, respectively. 2 020 points are deployed for high-density resistivity method.

For example, in the investigation of Jiangsu coastal areas, the observation parameters of shallow earthquakes are as follows: group interval of 3 m, shot interval of 12 m, 72 tracks for reception and 9 times of coverage. Collection parameters are: 0.25 ms for sampling interval, 1 000–2 000 ms for sampling length. Observation parameters of tensor CSAMT are: 1 000–1 500 m for emission dipole moment AB, transceiver distance greater or equal to 5 000 m. The receiving dipole moment MN is 50 m. The distance between measuring points is 100 m, and the frequency observation range is 0.125–8 192 Hz. The receiving device adopts five electromagnetic field components EX, EY, HX, HY and HZ, of which the electrodes are arranged in a "+" shape. Data is collected twice at the same measuring point with a total of 10 components. The collection parameters are as follows: two groups of field sources, which are not coincident or parallel, are arranged to emit alternately, with stainless steel electrodes or aluminum foil. Electrodes are buried in moist soil to ensure sound grounding. The grounding resistance is less than or equal to 70 Ω. The receiving electrodes M and N adopt solid nonpolarized electrodes and the grounding resistance is not more than 5 000 Ω. The position of the horizontal magnetic rod is located by forest compass or compass with an error less than 1°. Data is observed at any time during the process. Instrument amplification can be gained and the superposition times increased according to the degree of interference, to ensure the quality of the collected data.

2.4.2 Sea Areas

Geophysical exploration methods used in coastal zone surveys mainly include single-beam bathymetry, multi-beam bathymetry, single-channel seismic survey, multi-channel seismic survey, shallow stratum section survey, and side scan sonar survey. Among these, single-beam and multi-beam bathymetry primarily use sound waves that are emitted to and received from the seabed to obtain water depth and seabed topography. The operation lengths in this survey are 11 975 km and 31 800 km, respectively. Single-channel and multi-channel seismic survey, shallow stratum section survey and side scan sonar survey are used to reflect the submarine sedimentary structure and structural characteristics, and their operation lengths in this survey are 11 653 km, 1 300 km, 15 256 km and 3 686 km, respectively.

Taking the multi-beam seabed topographic survey in the Yangtze River estuary area as an example, 100% seabed full coverage was obtained, and the IHO depth measurement error standard was met at the same time, i.e., when the water depth is less than or equal to 30 m, the error is less than 0.3 m. Based on the echo-sounder, the accuracy of the seabed topographic survey is measured by the difference of water depths measured at the intersection point of the main line and the cross line, with the root mean square error less than 1% of actual water depth. The surveying ship kept sailing in a straight line at a constant speed in the direction of a predetermined survey line. Each line deviates from the survey line by no more than 1/10 of the measuring width. Having finished the survey for each line, the surveying ship maintained the original heading speed for 1 min and then turned. Each transmitting pulse thus receives a beam greater than 80% of the total beam.

2.5 Field Test

Field tests mainly refer to in-situ engineering geological and hydrogeological tests.

2.5.1 In-situ Engineering Geological Test

In-situ testing refers to the method of determining the engineering mechanical property indexes of rock and soil under the condition that the original position of rock and soil layers basically maintains the natural water content of natural structure and natural stress state. Commonly used are static sounding test, standard penetration test, vane shear test, etc. They can measure the relevant engineering mechanical properties of undisturbed soil samples that are difficult to obtain, and can also avoid the influence of stress release during sampling.

Taking the standard penetration test in the Yangtze River estuary area as an example, the weight of the test hammer was 63.5 kg, hammering with a free fall distance of 0.76 m; 15 cm is pre-hammered when testing. Then 30 cm is driven, and the hammering number of each 10 cm is recorded. The cumulative hammering number of 30 cm is the standard penetration blow count $N_{63.5}$. To judge the liquefaction possibility and grade of sandy soil and silt distributed in the depth range of 0–20 m, samples were taken for particle size analysis with a test interval of 1.5 m. The test interval for depths below 20 m is generally 2–3 m. Geological logging should be carried out on soil samples in the SPT and samples taken for particle size analysis. In order to ensure the accuracy of the test results, slurry wall protection should be used when drilling holes. When drilling to a depth of 15 cm above the test depth, the operator should remove the residual soil at the bottom of the borehole before conducting the test.

2.5.2 Hydrogeological Test

Hydrogeological tests are conducted to obtain rock (soil) hydrogeological parameters, to understand hydrogeological conditions and to carry out quantitative research on groundwater, including pumping and infiltration tests. These methods directly test the target horizon on site, and the results can truly reflect the objective situation.

Taking the pumping test as an example, the single-hole steady flow method is adopted for reverse pumping, which is carried out in three stages. The steady time is 24 h, 16 h, 8 h, respectively. In case of a small water amount or insignificant water level drops, a drawdown is carried out, with the steady time not less than 24 h. When the water level of the pumping hole cannot be stabilized, an unsteady flow test of maximum drawdown is made. The pumping duration is determined according to the s–l gt curve, which is generally not less than 24 h. The pumping test for steady flow should reach the amount of inflow and stability of water level in a fixed time period, or fluctuate within a certain range, without the trend of continuous decline or rise. The error of the fluctuation range of water level should not exceed 1% of the average drawdown number, and the fluctuation of water inflow should not exceed 3% of the average flow rate.

2.6 Sample Testing

In field investigation, samples are collected according to the requirements for diverse indoor tests. In the geological environment survey of the coastal zone, various types of samples of land area, sea area and intertidal zone are involved. To be specific, this includes surface soil, surface sediment, columnar sediment, underground water sample, seawater sample. The technical methods for testing and analysis are mainly as follows.

2.6.1 Rock and Mineral Analysis

The analysis includes particle size analysis, microfossil analysis, sporopollen analysis, placer mineral analysis, optically stimulated luminescence dating, magnetic susceptibility testing, and geochemical testing.

2.6.2 Geotechnical Test

The test includes physical test items such as water content w, volumetric weight γ, specific gravity G, W_P and W_L of cohesive soil, particle analysis of silty soil and sandy soil, and mechanical test items such as consolidation test and consolidated quick shear test.

2.7 Dynamic Monitoring

2.7.1 Monitoring of Land Subsidence

Land subsidence may be caused by increasing load of construction projects, groundwater exploitation, geothermal exploitation. Such methods as bedrock mark, layerwise mark, leveling surveying, GPS monitoring and InSAR space observation are applied to monitor and study the ground subsidence, which facilitates understanding of the formation, development and evolution of geological disasters caused by land subsidence. Monitoring also plays a role in providing efficient and feasible decisions for comprehensive management of geological disasters, evaluating the consequences and mitigating the impact of geological disasters.

In this investigation, 8 layerwise marker groups for land subsidence were established in the Bohai Bay area, 3 groups with monitoring depths greater than 800 m, of which the Tanggu G2 group has a maximum control depth of 1 218 m and is by far the deepest mechanical layerwise marker in Asia. This includes 1 surface marker, 8 layerwise markers. 6 boreholes for water level observation and 5 for pore water pressure drilled in combination with layerwise markers. Since July 2010, a long sequence of monitoring data has been obtained. The route of second-class leveling surveying is 300 km. Its main accuracy indexes are: the accidental root mean square error of leveling per km does not exceed±1 mm, and the total root mean square error of leveling per km does not exceed±2.0 mm. 25 stations were monitored by GPS.

2.7.2 Monitoring of Soil and Water Environment

The monitoring focuses on the influence of natural factors and human engineering activities upon groundwater environment (water level, water quality, water temperature, etc.), surface water environment, land environment, and ecological environment. The monitoring content includes such elements as stratified groundwater level, water quality, water temperature, land quality (sea bottom material), etc. Means of monitoring mainly consist of remote sensing, ground electrical and geophysical prospecting, and monitoring wells for groundwater.

Taking the Tianjin Binhai New District as an example, three groundwater monitoring sections were set up in an east-west direction to control the coastal area with a width of 20–30 km. The analysis results can be mutually verified to avoid cognitive deviation caused by a single section. Ten monitoring wells were set up in each section, with a total number of 30, of which depths of 15 m alternate with 30 m. The space of each well is of 2–4 km. Considering the vertical stratum structure, 15-m wells mainly served to monitor the change of pore water in the first marine strata. The 30-m well mainly monitors the change of pore water in the second continental strata. The 30-m well is designed with double-layer observation to monitor the water level of the two layers. The upper 15 m is sealed to form a well, which is level with the monitoring horizon of the 15-m well. 15 m above and 30 m below are sealed to form wells to observe the dynamic change of water level between 15−30 m.

2.7.3 Dynamic Monitoring of Coastal and Tidal Flat Erosion and Deposition

Due to the changes of landform and regional hydrodynamic conditions in the coastal zone, the erosion and deposition of the coast and tidal flat have undergone drastic changes. The monitoring contents include the change of coastline, the change of topography and landform in the coastal areas, and the change of beach and underwater sediment. The monitoring means mainly include unmanned aerial vehicle, RTK-GPS, single-beam sounding, shallow section, etc.

RTK-GPS technology and continuous terrain mode are adopted in the measurement of the beach section. The obtained section and elevation data help gain a complete and continuous section topography. Generally, the starting point of the section is the boundary line of the shelter forest; the direction is vertical to the shoreline; the end point is near the low tide line. The average sampling interval of the data is 0.5 m. After each survey, the alignment should be carried out according to the orientation and end point of the section starting line determined during the first survey to ensure the coincidence degree of each survey data. Through repeated measurement and comparison, the dynamic change of the beach section can be mastered.

2.7.4 Monitoring of Marine Hydrodynamics

The main monitoring contents include the factors affecting marine hydrodynamic conditions such as tide, wave, tidal current, suspended sediment, atmospheric wind field, temperature, salinity, etc. Various kinds of factors affecting ocean hydrodynamics are obtained by monitoring stations. These factors, which together with multiple kinds of marine hydrodynamic characteristic indexes, provide basic data for the analysis, prediction and evaluation of coastal zone erosion and deposition effects, are relatively complete and continuous with a coupling relationship.

Taking Bohai Bay as an example, comprehensive monitoring methods have been adopted in the coastal zone of Tianjin, Hebei and Shandong provinces, including observations of wind speed, wind direction, atmospheric pressure, tide, wave, current, sediment, erosion and deposition, etc. Among them, there are 8 tidal and atmospheric pressure monitoring stations, 3 wind speed and wind direction monitoring stations, 2 marine flow velocity and direction monitoring stations, 1 comprehensive hydrodynamic monitoring platform, 14 hydrodynamic monitoring sections and 15 fixed-point stations of hydrodynamic measuring, which almost cover the whole area of the Bohai Bay coastal zone.

2.7.5 Monitoring of Geological Disasters or Potentially Unstable Geological Bodies

This monitoring focuses on geological disasters or potential unstable geological bodies, such as underwater unstable slope, collapse, landsliding and humid-rock flow in major engineering areas, coupled with active faults, crustal stress, submarine landslides, shallow gas and other unstable geological factors, which provides a basis for risk assessment of regional geological disasters, thus avoiding unnecessary economic losses and eliminating potential safety hazards.

Taking submarine landslide as an example, the specific technical methods for investigation and monitoring are as follows: the areas prone to submarine landslide are delineated according to large-scale bathymetric and topographic sources within a broad range. Attention is drawn to the areas where strong tides wash up and erosion occurs, especially the sea areas near major engineering projects. Meticulous multi-beam investigation is carried out on the key areas, so that the accuracy of bathymetric and topographic data is improved, and the location of submarine landslide is basically fixed. Targeted shallow stratum section or extremely shallow section survey is made to reveal the stratigraphic characteristics of submarine landslide and the position of landslide slope. Such methods as geological drilling, engineering geological drilling and static sounding in sea areas for landslide are deployed to obtain the important parameters of details, granularity, clay minerals, geochemical properties, and engineering mechanical properties of the landslide stratum. The comprehensive property data of geology, geophysics, engineering and geology, geochemistry and hydrodynamics are used to carry out numerical simulation and study the triggering mechanism of landslides. Multi-beam repeated measurement is deployed in key areas to form dynamic monitoring data. Submarine landslide risk assessment is conducted in combination with major engineering projects in the vicinity of the landslide.

3 Description of Typical Data Samples

The data samples of the geological environment of China's coastal zone are briefly summarized in 8 typical tables, namely, the basic information of drilling, the drilling stratum description table, the record of high-density resistivity observation data, the record of single-beam survey line information, the record of information of shallow stratum section measurement, the tour report of single seismic trace, the record of tidal level observation, the monitoring data table of stratified markers.

The basic information of drilling includes the following items: unified serial number, field serial number, location, longitude, latitude, borehole elevation, type of drill, type of borehole, starting date of drilling, finishing date of drilling, angle of inclination, diameter of opening hole, diameter of finished hole, depth of finished hole, depth of drilled well, initial water level of aquifer, still water level, quality level, grade of drilling, properties of aquifer, sampling situation, diagram of plane location, construction unit, Head of drill team, personnel for geological logging, date of survey, date of form filling, and project name (Table 3).

Drilling stratum description includes the following items: unified serial number, sequence number, geological age, elevation of stratum bottom, depth of stratum bottom, contact relationship of stratum bottom, thickness of single layer, bedding structure, name of rock and soil, color of rock and soil, and description of stratum lithology (Table 4).

The record of high-density resistivity observation data includes the following items:

Table 3 Basic Information of Drilling

Sequence number	Field name	Dimension	Data type	Example
1	Unified serial number	–	Character	11759029394355901
2	Field serial number	–	Character	Z025
3	Location	–	Character	Fengdengwu Town, Fengrun District, Tangshan, Hebei Province
4	Longitude	–	Character	117590290
5	Latitude	–	Character	39435590
6	Borehole elevation	m	Floating	5.436
7	Type of drill	–	Character	XY-100
8	Type of borehole	–	Character	Engineering Geological Drilling
9	Starting date of drilling	–	Character	February 23, 2012
10	Finishing date of drilling	–	Character	February 23, 2012
11	Angle of inclination	°	Floating	0
12	Diameter of opening hole	mm	Floating	110
13	Diameter of finished hole	mm	Floating	110
14	Depth of finished hole	m	Floating	20
15	Depth of drilled well	m	Floating	20
16	Initial water level of aquifer	m	Floating	7.0
17	Still water level	m	Floating	6.2
18	Quality level	–	Character	Qualified
19	grade of drilling	–	Character	Medium
20	Properties of aquifer	–	Character	Boreholes are located in the hydrogeological area of the alluvial-proluvial inclined plain, where Quaternary pore phreatic water in loose rock mass, and Jixian-Qingbaikou karst fissure water are distributed.
21	Sampling situation	–	Character	A total of 5 undisturbed samples, 4 disturbed samples and 15 standard penetrations were taken.
22	Diagram of plane location	–	Long	(picture)
23	Construction unit	–	Character	The Fifth Geological Brigade of Hebei Bureau of Geology and Mineral Resources Exploration
24	Head of drill team	–	Character	Yang Guizhou
25	Personnel for geological logging	–	Character	Ma Hongzhi
26	Date of survey	–	Character	February 23, 2012
27	Date of form filling	–	Character	February 23, 2012
28	Project name	–	Character	Report on Engineering Geological Survey and Evaluation of Key Planning Areas of Tangshan City (North of Xinhua Road, Airport City (aerotropolis) and Fengnan Urban Area)

Table 4 Description of the Drilling Stratum

Number	Field name	Dimension	Data type	Example
1	Unified serial number	–	Character	11800348391952901
2	Sequence number	–	Character	2
3	Geological age	–	Character	Holocene
4	Elevation of stratum bottom	m	Floating	–1.4
5	Depth of stratum bottom	m	Floating	1.25
6	Contact relationship of stratum bottom	–	Character	Comfortable contact
7	Thickness of single layer	m	Floating	0.95
8	Bedding structure	–	Character	Horizontal bedding
9	Name of rock and soil	–	Character	Silty clay
10	Color of rock and soil	–	Character	Taupe
11	Description of stratum lithology	–	Character	Hard plastic, with much rust stain, development of reduced stain, visible iron stain aggregates, a very small amount of sandy laminae development in the lower part, and a small amount of calcareous aggregates locally

unified serial number of observation points, unified serial number of work area, unified serial number of survey line, field number of observation points, measured resistivity, primary field voltage, and primary multiple-field current (Table 5).

The record of single-beam survey line information contains the following items: unified serial number of survey line, unified serial number of work area, field number of survey line, starting point of survey lines, starting longitude of survey lines, starting latitude of survey lines, end longitude of survey lines, end latitude of survey lines, length of survey lines, and working time (Table 6).

Single-channel seismic survey records include the following items: unified serial number of observation points, unified serial number of work area, unified serial number of survey line, field number of observation points, number of record sheet, time, course, excitation interval, width of scanning, filtering, name of file and notes (Table 7).

Table 5 Record of High-density Resistivity Observation Data

Number	Field name	Dimension	Data type	Example
1	Unified serial number of observation points	–	Character	11336305223504301
2	Unified serial number of work area	–	Character	11336305223504301
3	Unified serial number of survey line	–	Character	11336305223504301
4	Field serial number of observation points	–	Character	L13G97
5	Measured resistivity	Ω·m	Floating	76.83
6	Primary field voltage	mV	Floating	94.783
7	Primary field current	mA	Floating	209.369

Table 6 Record of Single-beam Survey Line Information

Number	Field name	Dimension	Data type	Example
1	Unified serial number of survey line	–	Character	12147549302301201
2	Unified serial number of work area	–	Character	12147549302301201
3	Field serial number of survey sine	–	Character	ZS-L1
4	Starting longitude of survey lines	–	Character	12147549
5	Starting latitude of survey lines	–	Character	3023012
6	End longitude of survey lines	–	Character	12204379
7	End latitude of survey lines	–	Character	3023012
8	Length of survey lines	km	Floating	50
9	Working time	–	Character	20-06-2016

Table 7 Single-Channel Seismic Survey Records

Number	Field name	Dimension	Data type	Example
1	Unified serial number of observation points	–	Character	11933376243220901
2	Unified serial number of work area	–	Character	11933376243220901
3	Unified serial number of survey line		Character	11933376243220901
4	Field serial number of observation points	–	Character	L1G1
5	Number of record sheet	–	Character	/
6	Time	–	Character	16-07-2017
7	Course	°	Floating	116.9
8	Excitation interval	ms	Floating	1300
9	Width of scanning	ms	Floating	500
10	Filtering	Hz	Floating	150
11	Name of file	–	Character	1-L1
12	Notes	–	Character	/

Suspended sediment observation markers contain the following items: unified serial number of observation points, field number of observation points, longitude and latitude, sea tide and sea state, oceanographic research vessel, time of observation, surface sediment concentration, middle layer sediment concentration, bottom sediment concentration, water depth and notes (Table 8).

The monitoring data of stratified markers include the following items: unified serial number, date of observation, type of observation, and deformation (Table 9).

Information of observation wells for seawater invasion includes the following items: unified serial number, field serial number, location, longitude, latitude, ground elevation, well elevation, well diameter, buried depth of groundwater level, measured depth of well, type of well, distance between well and surface water, water temperature, air temperature, smell, PH, color, transparency, well wall structure, well elutriation, construction period, and mining method (Table 10).

Table 8 Observation of Suspended Sediment

Number	Data item	Dimension	Data type	Example
1	Unified serial number of observation points	–	Character	12202258302206301
3	Field serial number of observation points	–	Character	SW01
4	Longitude	–	Character	12202258
5	Latitude	–	Character	3022063
6	Sea tide	–	Character	Semi-diurnal Tide
7	Sea state	–	Character	Level 3
8	Oceanographic research vessel	–	Character	No.1 Research Vessel of Zhejiang
9	Time of observation	–	Character	June 1, 2016
10	Surface sediment concentration	mg/L	Floating	319.909
11	Middle layer sediment concentration	mg/L	Floating	399.886
12	Bottom sediment concentration	mg/L	Floating	639.818
13	Water depth	m	Floating	20
14	Notes	–	Character	/

Table 9 Monitoring Data of Stratified Markers

Sequence number	Sequence number	Sequence number	Data type	Example
1	Unified serial number	–	Character	11830407385954101
2	Date of observation	–	Character	May 18, 2010
3	Type of observation	–	Character	Manual Test
4	Deformation	mm	Floating	4.36508

4 Control and Evaluation of Data Quality

All operations conducted in the work area comply with *the National guidelines of Geological Environment Construction in the Coastal Zone* (DD2012–04). All data tables are implemented according to the annex of the guidelines, with accuracy meeting the requirements of the geological environment comprehensive dataset in coastal zone.

The supporting system of this dataset has a built-in data examination engine. Therefore, personnel in charge of data warehousing can perform quality examination on data, including data table integrity, accuracy of data type, and data repeatability. At the same time, the engine provides location of the wrong content so that correction can easily be made.

Additionally, 100% of the survey data sheets in the work area carry out self-inspection and mutual inspection of project data, and 15% of the selective examination has been completed after finishing the data sheets. Random inspection results show that the data quality meets the requirements of geological environment survey in coastal zone.

5 Conclusion

The Comprehensive Dataset of the Geological Environment in China's Coastal Zone includes four categories of data, namely, field comprehensive investigation, comprehensive field construction, field dynamic monitoring and sample testing. In total this comprises 130 data tables and 177 592 pieces of data, including 9 006 pieces of data in the comprehensive

Table 10 Basic Information of Observation Wells for Seawater Invasion

Number	Field name	Dimension	Data type	Example
1	Unified serial number	–	Character	11836021391011601
2	Field serial number	–	Character	CFZK3
3	Location	–	Character	Caofeidian District, Tangshan, Hebei Province
4	Longitude	–	Character	11836021
5	Latitude	–	Character	3910116
6	Ground elevation	m	Floating	0.1
7	Well elevation	m	Floating	2.1
8	Well diameter	m	Floating	2.1
9	Buried depth of groundwater level	m	Floating	1.39
10	Measured depth of well	m	Floating	6
11	Type of well	–	Character	Pumping Well
12	Distance between well and surface water	m	Floating	160
13	Water temperature	℃	Floating	14
14	Air temperature	℃	Floating	30
15	Smell	–	Character	/
16	PH	–	Floating	8.05
17	Color	–	Character	Colorless
18	Transparency	–	Character	Transparent
19	Well wall structure	–	Character	Cement Pipe
20	Well elutriation	–	Character	Unknown
21	Construction period	–	Character	10
22	Mining method	–	Character	Discontinuous mining technology

field survey category, 89 551 in comprehensive field construction, 12 305 in field dynamic monitoring, and 66 730 in sample testing.

Prior to this survey, many geological surveys had been conducted in the national coastal zone, and data have been obtained from projects of the China Geological Survey of the former Ministry of Land and Resources, the State Oceanic Administration, local government departments, local enterprises and institutions, and the National Natural Science Foundation of China. This survey has contributed to the development of various geophysical-geochemical-remote sensing methods, such as remote sensing, airborne radiation, airborne electromagnetic survey, electrical method, shallow seismic survey, and ground radioactivity, while introducing new approaches to marine geophysical exploration. It has increased intermediate results of coding and interpretation, coastal zone survey methods, coastal zone monitoring methods, and disaster monitoring, and expanded the result table of rock and soil sample tests. In addition, the survey has also improved the direct correspondence between the basic and attribute tables of survey points, and enriched the spatial information of line and surface attributes, laying a solid foundation for the establishment of a spatial database and visualization platform at a later period.

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