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山东省万家镇幅 (J50E021024)、南村镇幅 (J51E021001)、高密市幅 (J50E022024)、蓝村镇幅 (J51E022001)1∶50 000 数字地质图空间数据库

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摘要：山东省万家—蓝村地区位于胶莱盆地，夹于莱阳凹陷和诸城凹陷之间。依托 2016 年中国地质调查局“山东 1∶50 000 万家、南村、高密、蓝村幅区域地质调查”项目，根据《1∶50 000 覆盖区区域地质调查工作指南 (试行)》、《1∶50 000 区域地质调查工作指南 (试行)》的统一标准及要求，在充分利用以往地质资料的基础上，采用数字填图系统进行野外地质填图，并应用室内与室外填编图相结合的方法，完成标准的 1∶50 000 地质图及说明书编制，建立了山东省万家镇幅 (J50E021024)、南村镇幅 (J51E021001)、高密市幅 (J50E022024)、蓝村镇幅 (J51E022001)1∶50 000 数字地质图空间数据库。本数据库针对早白垩世莱阳群杨家庄组、杜村组，青山群八亩地组、王氏群辛格庄组岩性填图，首次在王氏群辛格庄组发现火山机构，并确定辛格庄组内火山岩夹层锆石 U-Pb 年龄为早白垩世。利用前人胶参 1 井、2 井和 3 井钻孔资料，恢复了李党家—马山凸起白垩纪岩相古地理，建立了山东省万家—蓝村地区沉积构造格架。本数据库包含上述 4 个标准 1∶50 000 图幅地质图，数据量约为 22.3 MB，于胶莱盆地火山岩中取得 LA-ICP-MS 锆石 U-Pb 同位素年龄值 3 个，第四系中取得光释光年龄值 3 个，^{14}C 同位素年龄值 4 个。坐标系为 CGCS2000 国家大地坐标系，投影方式为高斯—克吕格投影。本数据库充分反映了 1∶50 000 区域地质调查成果，为区域资源环境研究、能源勘探提供基础地质图件，具有重要的参考意义。

关键词：地质调查工程；1∶50 000；数字地质图；万家镇幅；南村镇幅；高密市幅；蓝

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村镇幅；山东

数据服务系统网址：http://dcc.cgs.gov.cn

1 引言

山东胶莱盆地为晚中生代—新生代叠合断陷盆地 (刘玉强, 2001; 李金良等, 2007; 彭楠等, 2015; 许克民等, 2017), 万家—蓝村地区位于胶莱盆地覆盖区 (图 1), 大地构造位置处于华北板块—胶辽隆起区—胶莱盆地, 跨夏格庄凹陷、平度凹陷、李党家—马山凸起、高密凹陷 4 个 V 级构造单元 (李桂群和范德江, 1994; 宋明春, 2008; 张增奇等, 2014; 孙伟清等, 2019; 徐伟祥, 2019)。区内出露地层以白垩系和第四系为主。地表基岩露头偏少, 绝大部分地区被第四系覆盖 (图 2)。区内白垩系为一套陆相碎屑岩–火山岩沉积建造 (刘明渭等, 2003; 唐风华等, 2003; 佟彦明, 2007; 张岳桥等, 2008; 曹珂, 2010; 杜圣贤等, 2020)。受古地理制约及构造改造, 地层发育不全。构造仅限于中生代以来盖层构造, 构造形迹以 NW 向断裂为主。据区域重磁资料 (陈清华等, 1994; 黄太岭, 2000), 区内存在 NW 向七级 (镇) 断裂、大栏断裂、高密断裂和 NNE 向招远—平度断裂。岩浆岩不发育,

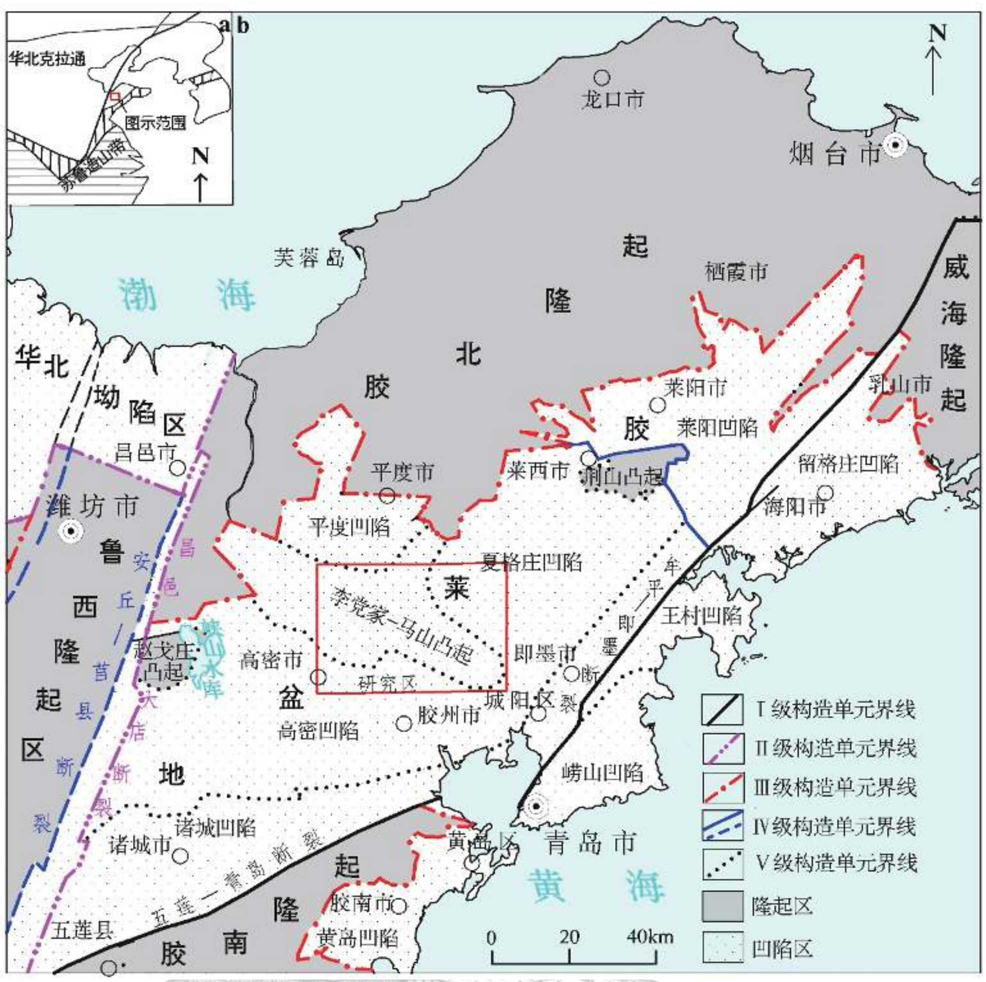

图 1　山东胶莱盆地万家—蓝村地区大地构造位置图 (修改自张增奇等, 2014)

图 a: 山东胶莱盆地万家—蓝村地区区域位置图；图 b: 山东胶莱盆地万家—蓝村地区大地构造位置图

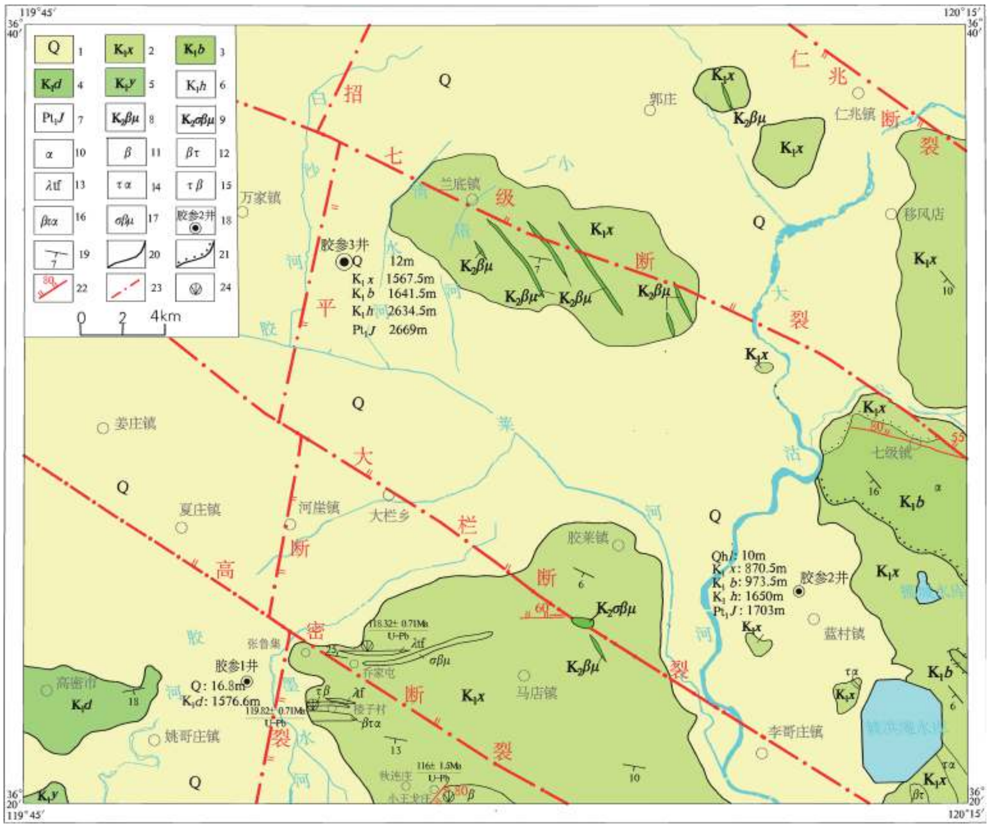

图 2 山东胶莱盆地万家–蓝村地区地质略图 (据徐伟祥, 2019)

1—第四系; 2—早白垩世辛格庄组; 3—早白垩世八亩地组; 4—早白垩世杜村组; 5—早白垩世杨家庄组; 6—早白垩世后夼组; 7—古元古代荆山群; 8—晚白垩世辉绿岩脉; 9—晚白垩世次火山岩 (玄武岩); 10—安山岩; 11—玄武岩; 12—玄武粗面岩; 13—流纹质凝灰岩; 14—粗面安山岩; 15—粗面玄武岩; 16—玄武粗安岩; 17—橄榄玄武岩; 18—钻孔; 19—地层产状; 20—地质界线; 21—角度不整合界线; 22—正断裂; 23—物探推测断裂; 24—锆石 U-Pb 测年

岩浆构造事件表现为中生代火山喷发和 NE 向中基性脉岩侵位 (徐伟祥, 2019)。

山东省万家–蓝村地区区域地质调查工作于 1990—2000 年开展。涉及研究区的 1∶200 000 青岛幅、高密幅、灵山卫幅区域地质调查于 1992 年完成, 1∶250 000 潍坊幅、青岛市幅、灵山卫幅区域地质调查于 2004 年完成, 1∶200 000 区域物探、化探及人工重砂测量主要集中在 20 世纪 80–90 年代。前人对研究区进行了多重地层划分, 建立了岩石地层格架, 对侵入岩进行了岩石谱系单位划分。胶莱盆地的研究重心一直是莱阳凹陷 (李日辉和张光威, 2001; 翟慎德, 2003; 彭文泉等, 2014; 周建波等, 2016; 张嘉良等, 2017) 和诸城凹陷 (张增奇等, 2000; 季燕南, 2010; 旷红伟等, 2014; 安伟等, 2016; 张艳霞等, 2018), 而位于两者之间的胶莱盆地中部覆盖区基础地质研究相对薄弱。山东省万家–蓝村地区万家镇幅 (J50E021024)、南村镇幅 (J51E021001)、高密市幅 (J50E02 2024)、蓝村镇幅 (J51E02 2001)4 幅 1∶50 000 区域地质调查在前人基础上形成, 为中国地质调查局 2016—2018 年地质调查项目成果图件, 力争反映新一轮矿产调查工作中取得的地质调查及科研成果, 为该地区的资源环境研究、能源勘探等提供基础地质图件, 为科研和野外地质调查提供有益的参考资料。山东省万家–蓝村地区 4 幅 1∶50 000 数字地质图空间数据库 (徐伟祥等, 2020) 的元数据简表如（表 1）所示。

表 1 数据库 (集) 元数据简表

条目	描述
数据库(集)名称	山东省万家镇幅(J50E021024)、南村镇幅(J51E021001)、高密市幅(J50E022024)、蓝村镇幅(J51E02 2001)1：50 000数字地质图空间数据库
数据库(集)作者	徐伟祥, 山东省第四地质矿产勘查院 高美霞, 山东省第四地质矿产勘查院 张德明, 山东省第四地质矿产勘查院 胡　冰, 山东省第四地质矿产勘查院 张　恺, 山东省潍坊基础工程公司
数据时间范围	2016.07—2018.12
地理区域	地理坐标: 东经 119°45′ ~ 120°15′, 北纬 36°20′ ~ 36°40′
数据格式	MapGIS 6.7矢量格式(*.wt, *.wl, *.wp), *.msi
数据量	22.3 MB
数据服务系统网址	http: //dcc.cgs.gov.cn
基金项目	中国地质调查局地质调查项目“山东1：50 000万家、南村、高密、蓝村幅区域地质调查”(项目编号: DD20160044-4)资助
语种	中文
数据库(集)组成	本数据库由MapGIS格式的万家镇幅、南村镇幅、高密市幅和蓝村镇幅等4幅区域地质图库组成。每幅地质图库均包括主图、镶图和图饰图例组成。主图主要包括地质体面实体、地质(界)线、产状、火山口、同位素测年、河湖海水库岸线、火山岩相带、标准图框(内图框)、地质代号、产状注记、地质引线、同位素注记等。镶图包括综合地层柱状剖面图、主图地质剖面图、大地构造图、李党家-马山古凸起沉积断面图、重要钻孔柱状图、大地电磁测深断面图、岩相古地理图、第四系等厚度线图及古河道分布图、构造纲要图、地层格架图、火山机构示意图等。图饰图例包括主图图例、各镶图图例、接图表、责任表及中国地质调查局局徽及图幅索引

2　数据采集和处理方法

2.1　基础数据采集

山东省万家-蓝村地区 4 幅 1：50 000 区域地质图以《1：50 000 区域地质调查工作指南 (试行)》和《1：50 000 覆盖区区域地质调查工作指南 (试行)》为基本要求, 以中国地质调查局《关于加强成矿带 1：50 000 区调工作的通知》为指导, 以山东省万家镇幅 (J50E021024)、南村镇幅 (J51E021001)、高密市幅 (J50E02 2024)、蓝村镇幅 (J51E02 2001)1：50 000 区域地质调查地质填图成果而编制。地理底图采用国家测绘地理信息中心 1：50 000 地形图, 更新截止时间为 2013 年, 坐标系为 1980 年西安坐标系, 1985 年国家高程基准。原始数据采集采用 1980 年西安坐标系, 后期按国家相关要求, 对成果图件进行了坐标系转换, 统一使用 CGCS2000 国家大地坐标系。地质填图采用数字地质调查平台 (DGSS) 完成路线调查长度 1 779.25 km, 加强地层、岩石和构造的表达, 编制了 4 幅 1：50 000 区域地质图。按数据格式分为 4 类: 影像文件 (.msi)、区文件 (.wp)、线文件 (.wl) 和点文件 (.wt) (庞健峰等, 2017; 吕琳等, 2018)。

2.2　数据处理

2.2.1　区域地质图

区域地质图形成了独立图层, 点、线、面 3 种数据格式解决不同图件间的拼接问题 (周红智等, 2019)。图上表示的内容主要有: 地层、岩浆岩和构造等地质内容。沉积岩地

层主要为白垩系和第四系，填制了岩石地层组图，进行了组段划分，并注重了非正式填图单位的表达。岩浆岩主要为火山岩和脉岩。火山岩采用岩石地层+火山岩相双重填图方法，划分了火山岩性和岩石组合，并注重了其沉积夹层的表达。脉岩采用“时代+岩性”表示方式。构造采用活动论观点，通过区域重磁异常特征，解译了多条隐伏断裂，并用可控源音频大地电磁测深对招远—平度断裂进行了有效验证。完成了 1∶50 000 区域地质调查面积 1 657 km^2。

2.2.2 镶图

(1) 综合地层柱状剖面图：对主图中岩石地层单元的岩性特征和生物组合特征进行详细表达。通过对图幅内岩石地层岩性组合特征及其生物组合特征的关系进行综合研究，编制综合地层柱状剖面图。

(2) 主图地质剖面图：为有效反映图幅内总体建造和构造特征，图幅内垂直主要建造和构造的总体走向，布置了贯穿全区的图切剖面，控制了白垩纪陆相沉积-火山岩地层和第四系。表达方式主要使用了标准剖面线型+标准代号表达位置，以相应的花纹表达各层岩性，同时在地质剖面上表达产状要素。

(3) 重要钻孔柱状图：利用胜利油田管理局胶参 1 井、2 井、3 井综合录井资料，对研究区基底之上白垩纪地层，研究其岩石组合特征，划分地层层序，进行沉积相研究，分别编制了胶参 1 井、2 井和 3 井钻孔柱状图 (图 3)。

(4) 李党家—马山古凸起沉积断面图：通过对比胶参 2 井和胶参 3 井钻孔录井资料结合区域地质概况，编制了李党家—马山凸起 (高密火山洼地) 沉积断面图 (图 4) 认为：李党家—马山凸起在早白垩世晚期是一个稳定、长期沉降的大型湖泊，沉积了一套巨厚层湖相沉积。据岩石组合特征分析，这套地层归属于青山群后夼组、八亩地组及王氏群辛格庄组。该湖泊辛格庄组沉积时限相当于区域上石前庄组—方戈庄组—林家庄组—辛格庄组—红土崖组早期，揭示了古凸起之上白垩纪沉积特征。

(5) 白垩纪各期岩相古地理图。据胶参 1 井、2 井和 3 井资料，结合地表调查，恢复了研究区早白垩纪世莱阳群杨家庄组、杜村组岩相古地理、青山群后夼组古地理、青山群八亩地组古地理、王氏群辛格庄组古地理和王氏群红土崖组—古近纪岩相古地理图，为整个胶莱盆地原型盆地恢复和岩相古地理环境提供新的思路。

(6) 第四系等厚度线图及古河道分布图：通过以往水工环钻孔资料整理，研究调查区第四系厚度变化情况，编绘了第四系等厚度线图，于夏庄—姜庄一带形成第四系盆地。据《高密市水利志》(1993) 等资料考证，恢复了胶河古河道变迁图。

(7) 可控源音频大地电磁测深卡尼亚电阻率深度断面图：为研究隐伏区招远-平度断裂的位置及空间展布特征，实施了 1 条可控源音频大地电磁测深剖面，基本控制了断裂带延伸方向的深部电性特征，验证有效深度为 1 500 ~ 2 000 m。

(8) 郜家村火山机构：调查区内火山构造属环太平洋中新生代火山活动带 (Ⅰ)、辽鲁中新生代火山带 (Ⅱ)、鲁东中生代火山喷发区 (Ⅲ)、高密火山洼地 (Ⅳ)(宋明春和王沛成, 2003)。火山活动不太发育，首次在王氏群辛格庄组发现 1 个Ⅴ级火山构造，为火山洼地中沿裂隙发育的小型中心式火山。

(9) 白垩纪地层沉积格架图：地层格架的建立能更好的分析盆地的形成机制、沉积模式和构造演化，在掌握野外一手资料的基础上，结合区域构造特征，结合邻幅资料，建立了调查区地层格架。剖面线从高密姚哥庄开始，经胶参 1 井、河崖、胶莱河、胶参 3 井、

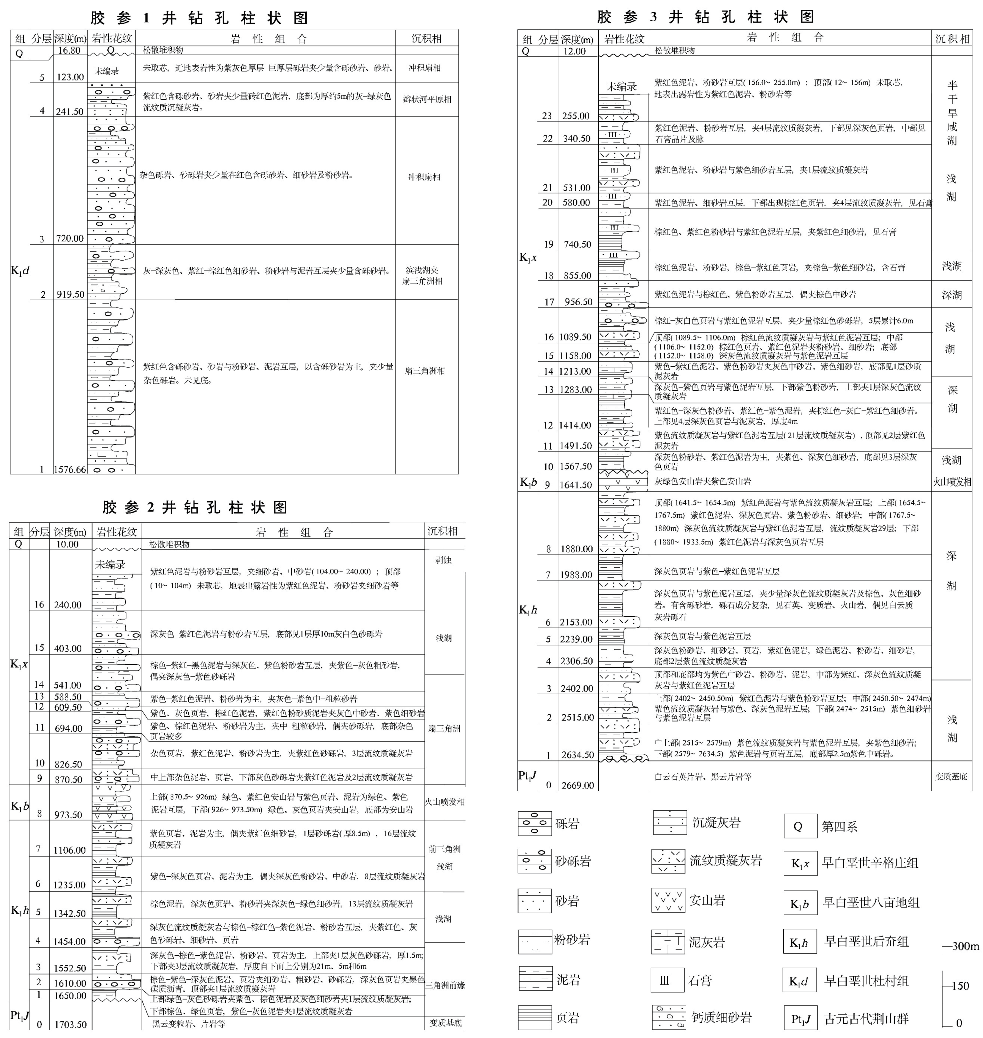

图3 山东胶莱盆地万家—蓝村地区钻孔柱状图(据胜利油田管理局胶参2井、3井综合录井图编制)

万家、兰底,总体呈NNE 12°方向。调查区中生代陆相地层沉积巨厚,可达3 000 m,NW向高密断裂构造控制了青山期、王氏期盆地的沉积。大栏断裂、七级断裂组成阶梯式断裂,对青山期和王氏期盆地控制并起到破坏作用,同时七级断裂为马山凸起和平度凹陷的界线,控制着平度凹陷的沉积。

3 数据样本描述

3.1 数据的命名方式

本数据库主要以*.wp, *.wl, *.wt 3种类型数据命名。镶图中的可控源音频大地电磁测深卡尼亚电阻率深度断面图以msi格式导入。

3.2 图层内容

主图内容包括地质体面实体(_GeoPolygon)、地质(界)线(_GeoLine)、产状(_Attitude)、火山口(_CRATER)、同位素测年(_Isotope)、河湖海水库岸线(_Line_Geography)、火山岩相带(_Volca_Facies)、标准图框(内图框)(_Map_Frame)、地质代号(GEOLABEL.WT)、产状注记(A_ATTITUDE.WT)、地质引线(A_GEOLINE.WL)、

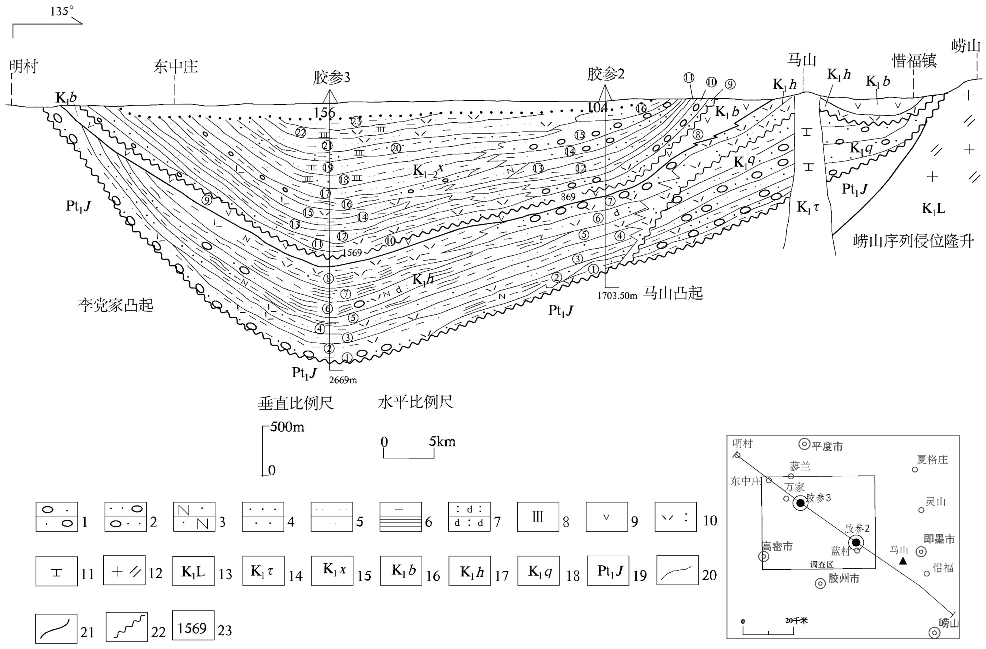

图 4　李党家—马山凸起沉积断面图

1—砂砾岩; 2—含砾砂岩; 3—长石砂岩; 4—砂岩; 5—粉砂岩; 6—泥岩页岩; 7—沉凝灰岩; 8—石膏; 9—安山岩; 10—流纹质凝灰岩; 11—粗面岩; 12—二长花岗岩; 13—早白垩世崂山序列; 14—早白垩世粗面岩; 15—早白垩世王氏群辛格庄组; 16—早白垩世青山群八亩地组; 17—早白垩世青山后夼组; 18—早白垩世莱阳群曲格庄组; 19—古元古代荆山群; 20—岩层界线; 21—组界线; 22—不整合界线; 23—钻遇基底深度 (m)

同位素注记 (A_ISOTOPE.WT) 等。

镶图内容包括综合地层柱状剖面图、主图地质剖面图、大地构造图、沉积断面图、大地电磁测深断面图、岩相古地理图、第四系等厚度线图及胶河古河道分布图、构造纲要图、地层沉积格架图、火山机构示意图等。

3.3　数据类型

实体类型名称: 点、线、面。

点实体: 各类地质体符号及标记、地质花纹。

线实体: 断裂构造、地质界线、岩相界线等。

面实体: 沉积岩、火山岩、侵入岩、第四系等。

3.4　数据属性

山东省万家—蓝村地区 4 幅 1：50 000 区域地质图数据库包含地质实体要素信息、地理要素信息和地质图整饰要素信息。地理要素信息属性沿用国家测绘地理信息局收集数据的属性结构。地质实体要素信息属性按照《地质信息元数据标准》(DD2005−05)、《数字地质图空间数据库建库标准》(DD2006−06) 要求, 按照属性结构建立数据库属性, 全程采用数字地质调查综合平台 (DGSS) 完成。属性结构具体描述如下:

地质体面实体 (_GeoPolygon): 地质体面实体标识号、原编码、地质体面实体类型代码 (地质代码)、地质体面实体名称、地质体面实体时代、地质体面实体下限年龄值、地质体面实体上限年龄值、子类型标识。

地质 (界) 线 (_GeoLine): 要素标识号、原编码、地质界线 (接触) 代码、地质界线类

型、界线左侧地质体代号、界线右侧地质体代号、界面走向、界面倾向、界面倾角、子类型标识。

产状 (_Attitude): 要素标识号、原编码、产状类型名称代码、产状类型名称、走向、倾向、倾角、子类型标识。

同位素测年 (_Isotope): 要素标识号、原编码、样品编号、样品名称、年龄测定方法、测定年龄、被测定出地质体单位及代号、测定分析单位、测定分析日期、子类型标识。

河、湖、海、水库岸线 (_Line_Geography): 要素标识号、原编码、图元类型、图元名称、子类型标识。

火山岩相带 (_Volca_Facies): 要素标识号、原编码、火山岩岩相类型及代码、产出的地层单位及代号、火山岩相岩石类型、岩石结构、岩石构造、流面产状、流线产状、形成时代、含矿性、子类型标识。

标准图框 (内图框)(_Map_Frame): 图名、图幅代号、比例尺、坐标系统、高程系统、左经度、下纬度、图形单位。

火山口 (_CRATER.WT): 要素标识号、原编码、火山口类型、火山口名称、火山口大小、火山口产出的地质体单位及代号、火山口岩石类型、火山口形成时代、子类型标识。

4 数据质量控制和评估

本数据库建设资料丰富、齐全、可靠。填图精度按照《1：50 000 区域地质调查工作指南 (试行)》和《1：50 000 覆盖区区域地质调查工作指南 (试行)》进行野外实测。地质点采集以充分控制重要的地质体、非正式填图单位和特殊地质图、重要地质界线等为原则。图面表达一般只表达直径大于 100 m 的闭合地质体, 宽度大于 50 m、长度大于 250 m 的线状地质体, 以及长度大于 250 m 的断层构造。对特殊地质体及非正式填图单位规模不论大小, 均在图上表示; 厚度较小者, 用适当的花纹、符号放大或归并表示。一般地质点在野外手图上所标定的点位与实地位置误差不得大于 25 m。填图精度达到 1：50 000 区域地质调查填图的具体要求。相关测试在天津地质调查中心实验测试室、中国冶金地质总局山东局测试中心、山东省地震工程研究院、Beta Analytic Inc 等相关实验室完成。上述工作数据来源可靠, 属性库建设完善。图件修编遵照《区域地质图图式图例》(GB/T958−2015)、《地质图用色标准及用色原则》(DZ/T0179−1997)、《1：50 000 地质图地理地图编绘规范》(DZ/T0157−95) 等规范进行。

数据库建设严格执行质量检测制度, 落实三级检查制度。填图路线原始记录、实际材料图、收录资料属性录入进行 100% 自检、互检。项目组检查由项目负责人主持, 在自检互检的基础上, 进行必要室内检查, 抽检 70%, 符合地质调查项目质量管理要求。单位质量检测, 由山东省第四地质矿产勘查院安排, 项目组积极协助, 抽检率 31%。各级检查及作者修改情况均要填写质量检查记录卡片, 单位对综合性图件进行 100% 审核, 对存在的问题责成责任人予以解决, 并对重要疑难问题邀请有关专家咨询解决。2018 年 10 月, 中国地质调查局天津地质调查中心组织专家采用室内、现场两者相结合的检查方法对山东省万家—蓝村地区 4 幅区调野外工作进行了总体野外验收。2019 年 3 月, 中国地质调查局天津地质调查中心评审了山东省万家—蓝村地区 4 幅区域地质调查数据库,

项目成果受到专家组一致认可, 数据库综合评分为良好级。

5 数据价值

(1) 白垩系划分和重新厘定研究取得了突破性进展。研究区为胶莱盆地潜覆盖区, 第四系厚度 0.5～30 m, 前人以往工作程度低, 近地表陆相“红层”岩石地层单位归属尚有存疑 (徐伟祥, 2019), 本次工作开展路线地质填图和前人钻孔资料的深入分析 (胶参 2 井和 3 井), 其岩性以紫红色调为主、以泥岩、粉砂岩为主, 局部夹细砂岩、流纹质凝灰岩, 偶夹薄层砂砾岩组合, 为一套湖相细碎屑岩沉积, 结合其孢粉组合、火山岩夹层流纹质熔结凝灰岩的 LA-ICP-MS 锆石 U-Pb 年龄测定, 将其归属为王氏群辛格庄组, 时代为早白垩世。

(2) 恢复了胶莱盆地李党家-马山凸起白垩纪岩相古地理特征。调查区第四系广泛覆盖, 地表调查以人工点状露头开展, 基岩不连续。为研究基底之上白垩纪沉积-火山地层, 收集利用了东营胜利石油管理局 20 世纪 80 年代胶参 1 井 (井深 1 576.46 m, 未揭穿至基底)、胶参 2 井 (井深 1 703.27 m, 揭穿基底) 和胶参 3 井 (井深 1 703.27 m, 揭穿基底) 综合录井资料, 分层精度达 0.5 m, 完全满足精度要求。通过研究上述钻孔岩石组合、层序地层、沉积相分析, 特别是胶参 2 井和胶参 3 井地层单位划分及区域对比, 恢复了胶莱盆地李党家—马山凸起白垩纪岩相古地理, 为整个胶莱坳陷原型盆地恢复和岩相古地理研究提供新的思路。

(3) 采用锆石 LA-ICP-MS 高精度同位素测年, 获得王氏群辛格庄组火山岩夹层年龄（表 2）。楼子村粗面玄武岩 (夹层) 获得锆石 U–Pb 同位素年龄为 119.82±0.71 Ma; 小王戈庄玄武岩 (夹层) 获得锆石 U–Pb 同位素年龄为 116±1.5 Ma; 乔家屯流纹质凝灰岩 (夹层) 获得锆石 U–Pb 同位素年龄为 118.32±0.71 Ma(徐伟祥, 2019)。指示发育这些火山岩的辛格庄组形成时代为早白垩世。

(4) 深入研究了第四系。根据沉积物岩性、展布形态, 形成时代, 结合地貌特征以及叠置关系, 划分 12 个组级单位。 在第四纪白云湖组获得^{14}C 同位素年龄为 1 540 a B.P.、2 280 a B.P.、2 320 a B.P.年龄; 黑土湖组获得^{14}C 同位素年龄 3 780 a B.P.; 大站组获得光释光年龄为 95.8 ka B.P.、89.3 ka B.P.及 33.8 ka B.P., 对第四系的时代归属提供了有利证据 (表 2)。

表 2　山东省万家镇幅、南村镇幅、高密市幅、蓝村镇幅 1∶50 000 地质图空间数据库测试分析数据表

数据类型	数据量/个	数据基本特征
锆石U–Pb同位素年龄数据	3	火山岩LA–ICP–MS锆石U–Pb同位素年龄
光释光年龄数据	3	更新世黄土光释光（OSL）年龄
^{14}C同位素年龄数据	4	全新世炭质粘土^{14}C同位素年龄

山东省万家镇幅 (J50E021024)、南村镇幅 (J51E021001)、高密市幅 (J50E02 2024)、蓝村镇幅 (J51E02 2001)1∶50 000 数字地质图空间数据库为该地区的大地质调查、资源环境等工作提供基础数据支撑, 在科技创新领域发挥了引领作用, 具有重要的参考价值。

6 结论

(1) 山东省万家—蓝村地区 4 幅 1∶50 000 区域地质图是中国地质调查局新一轮地质矿产调查的成果图幅, 项目组积极探索创新区域地质填图成果表达方式, 形成了万家—蓝村地区 4 幅区域地质图, 对区域地质调查起到了示范作用。

(2) 对中生代陆相沉积地层进行了多重地层划分和重新厘定, 将区内地层划分为古元古代荆山群、中生代莱阳群、青山群、王氏群及第四系, 突出表达了特殊岩性层, 划分了 17 个组级单位和 7 个特殊岩性层。查明了调查区中生代各组的空间叠置关系, 建立了莱阳群、青山群及王氏群的岩石地层格架。对研究区火山岩进行了岩性–岩相和火山构造填图, 识别出爆发相、溢流相、喷发–沉积相、潜火山岩相和侵入相五种岩相类型, 识别出郚家村Ⅴ级中心式小型火山构造, 侵入王氏群辛格庄组沉积地层。

(3) 通过对中生代地层岩石组合特征、层序地层、沉积构造等方面调查, 重新编录了胶参 1 井、胶参 2 井、胶参 3 井钻孔数据, 恢复了李党家–马山凸起白垩纪岩相古地理特征, 确定了中生代陆相盆地填充序列、沉积相及物源区等, 结合区域构造特征、古生物特征等, 总结了白垩纪不同时期沉积环境的变化及中生代陆相盆地的演化规律。

(4) 通过可控源音频大地电磁测深剖面, 基本控制了招平断裂带隐伏延伸方向的深部电性特征, 查明了招平断裂南段延伸进入调查区。认为: 招平断裂自平度麻兰进入第四系覆盖区, 经平度凹陷, 继续沿南西方向到达李党家—马山凸起, 进入调查区到达蓼兰镇北陈家, 被七级断裂错断。在七级断裂以南, 与胶河断裂为同一条断裂, 沿 NNE 方向延伸, 依次被 NW 向大栏断裂、高密断裂所错断, 穿过胶参 1 井东侧 (构成莱阳群杜村组与王氏群辛格庄组界线), 大致沿墨水河方向延伸出调查区。

致谢：山东省万家—蓝村地区 4 幅 1∶50 000 区域地质图数据库是一项集体成果, 野外一线地质工作人员付出了辛勤的努力。在区域地质图数据库制作过程中, 得到多位地质矿产专家的指导和帮助。感谢审稿专家对本文图件和文字提出的宝贵修改意见和建议。

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Spatial Database of 1∶50 000 Digital Geological Maps of Wanjia Town (J50E021024), Nancun Town (J51E021001), Gaomi City (J50E022024) and Lancun Town (J51E022001) Map-sheets, Shandong Province

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Abstract: Wanjia—Lancun area in Shandong Province is located between Laiyang depression and Zhucheng depression in Jiaolai Basin. The spatial database of 1∶50 000 digital geological maps of Wanjia Town (J50E021024), Nancun Town (J51E021001), Gaomi City (J50E022024), and Lancun Town (J51E022001) map sheets, Shandong Province (also referred to as the Database) was established according to the unified standards and requirements of the '*Guidelines for 1∶50 000-Scale Regional Geological Survey in Quaternary Coverage Area (Trial)*' and the '*Guidelines for 1∶50 000-Scale Regional Geological Survey (Trial)*' by relying on the project titled '*1∶50 000-Scale Regional Geological Survey of Wanjia Town, Nancun Town, Gaomi City, and Lancun Town Map Sheets, Shandong Province*' initiated by the China Geological Survey in 2016. During development of the Database, previous geological data were fully utilized, a digital mapping system was adopted for field geological mapping, and standard 1∶50 000 geological maps and work instructions were developed by means of indoor map preparation combined with field geological mapping. The aim of the Database is to complete the lithologic mapping of early Cretaceous strata, including

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Yangjiazhuang Formation and Ducun Formation of Laiyang Group, Bamudi Formation of Qingshan Group, and Xingezhuang Formation of Wangshi Group. A volcanic edifice was discovered for the first time in Xingezhuang Formation of Wangshi Group, and the zircon U–Pb ages of volcanic intercalations in Xingezhuang Formation were determined to be early Cretaceous. The paleogeographic characteristics of Cretaceous lithofacies of Lidangjia—Mashan dome was restored according to the previous drilling data of Well JC–1, Well JC –2 and Well JC –3. Furthermore, the sedimentary tectonic framework of Wanjia—Lancun area was established. The database contains four standard 1∶50 000 geological maps, with a data size of about 22.3 MB. LA-ICP-MS zircon U–Pb isotopic ages of three volcanic rocks, and three optically stimulated luminescence (OSL) datings and four ^{14}C isotopic ages of Quaternary were obtained in Jiaolai Basin The maps were prepared under the CGCS2000 national geodetic coordinate system and Gauss-Kruger projection. The Database fully reflects the results of 1∶50 000-scale regional geological survey and will provide basic geological maps for research, environment and energy exploration in Wanjia—Lancun area, and therefore, is of great significance.

Key words: geological survey engineering; 1∶50 000; digital geological map; Wanjia Town map-sheet; Nancun town map-sheet; Gaomi city map-sheet; Lancun town map-sheet; Shandong

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

1 Introduction

Jiaolai Basin is a late Mesozoic–Cenozoic superimposed down-faulted basin in Shandong Province (Liu YQ, 2001; Li JL et al., 2007; Peng N et al., 2015; Xu KM et al., 2017). Wanjia—Lancun area (also referred to as the study area) is in the coverage area of Jiaolai Basin (Fig. 1). Geotectonically, it lies in the North China plate–Jiaoliao Uplift–Jiaolai Basin and crosses four fifth-order tectonic units, namely Xiagezhuang depression, Pingdu depression, Lidangjia—Mashan dome, and Gaomi depression (Li GQ and Fan DJ, 1994; Song MC, 2008; Zhang ZQ et al, 2014; Sun WQ et al., 2019; Xu WX, 2019). The outcrops in this area mainly include the Cretaceous and Quaternary and a relatively small amount of surface bedrock, and most of the area is covered by the Quaternary (Fig. 2). There is a set of Cretaceous continental-facies clastic rock–volcanic sedimentary formations (Liu MW et al., 2003; Tang FH et al., 2003; Tong YM, 2007; Zhang YQ et al., 2008; Cao K, 2010; Du SX et al., 2020). The strata are underdeveloped in this area owing to paleogeographic constraints and tectonic transformation. Only the cap rock structures of the Mesozoic and later eras are distributed in this area, and they mainly include NW-trending faults. According to regional gravity and magnetic data (Chen QH et al., 1994; Huang TL, 2000), there exist Qiji (Town) fault, Dalan fault, and Gaomi fault in NW trending, as well as Zhaoyuan—Pingdu fault in NNE trending. Magmatic rocks are undeveloped in this area, and the magmatic-tectonic events are represented by the Mesozoic volcanic eruption and NE-trending emplacement of intermediate-basic vein rocks (Xu WX, 2019).

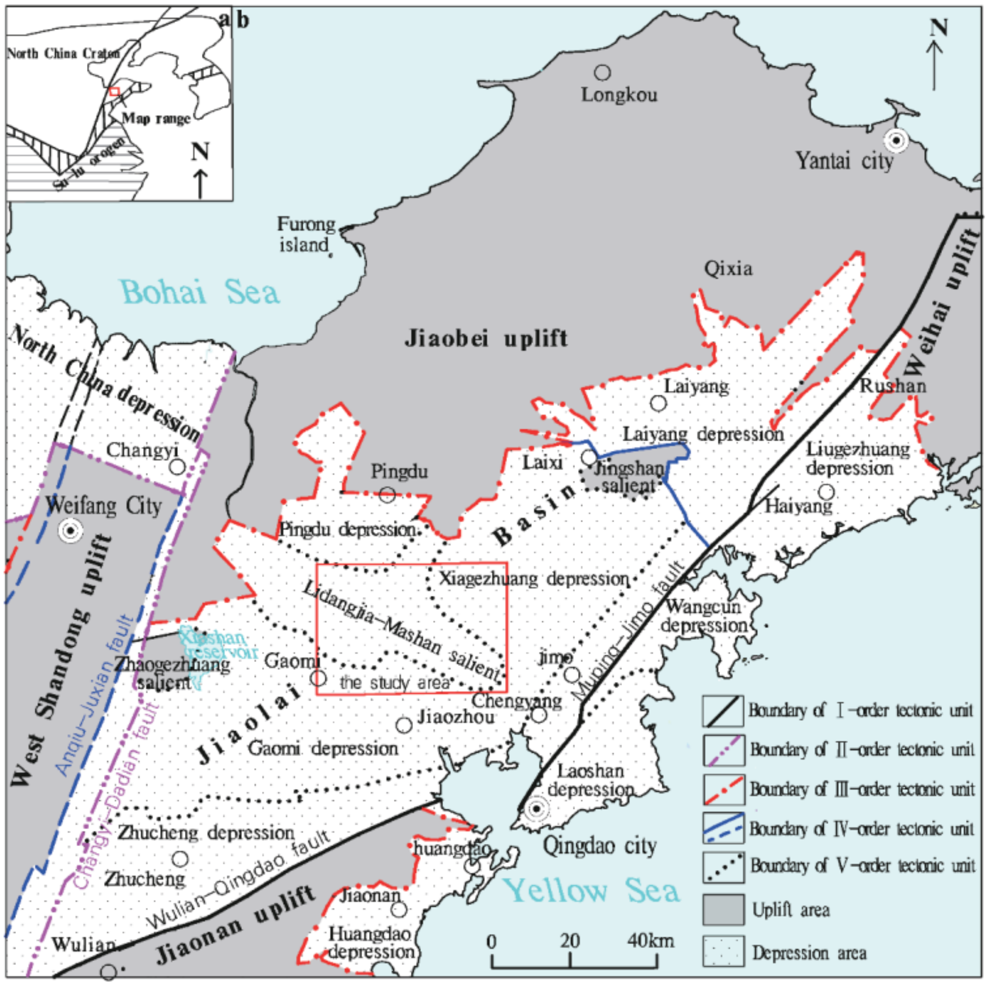

Fig. 1 Geotectonic location map of Wanjia—Lancun area in Jiaolai Basin, Shandong province (modified after Zhang ZQ et al., 2014)

a—Regional location map of the area; b—Geotectonic location map of the area

The regional geological survey of the study area was carried out during 1990–2000. The 1∶200 000-scale regional geological survey of Qingdao, Gaomi, and Lingshanwei map-sheets was completed in 1992, the 1∶250 000-scale regional geological survey of Weifang, Qingdao City, and Lingshanwei map-sheets was completed in 2004, and the 1∶200 000-scale regional geophysical and geochemical exploration and artificial heavy concentrate survey were mainly carried out in the 1980s–1990s. The multiple strata divisions of the study area were conducted by previous researchers, the lithostratigraphic framework was established, and intrusions were divided according to lithodemic units. However, previous studies on Jiaolai Basin tended to focus on Laiyang depression (Li RH et al., 2001; Zhai SD, 2003; Peng WQ et al, 2014; Zhou JB et al., 2016; Zhang JL et al., 2017) and Zhucheng depression (Zhang ZQ, 2000; Ji YN, 2010; Kuang HW et al., 2014; An W et al., 2016; Zhang YX et al., 2018), while the central coverage area of Jiaolai Basin between them lacks adequate basic geological research. The 1∶50 000-scale regional geological survey of Wanjia Town (J50E021024), Nancun Town (J51E021001), Gaomi City (J50E02 2024), and Lancun Town (J51E02 2001) map-sheets in

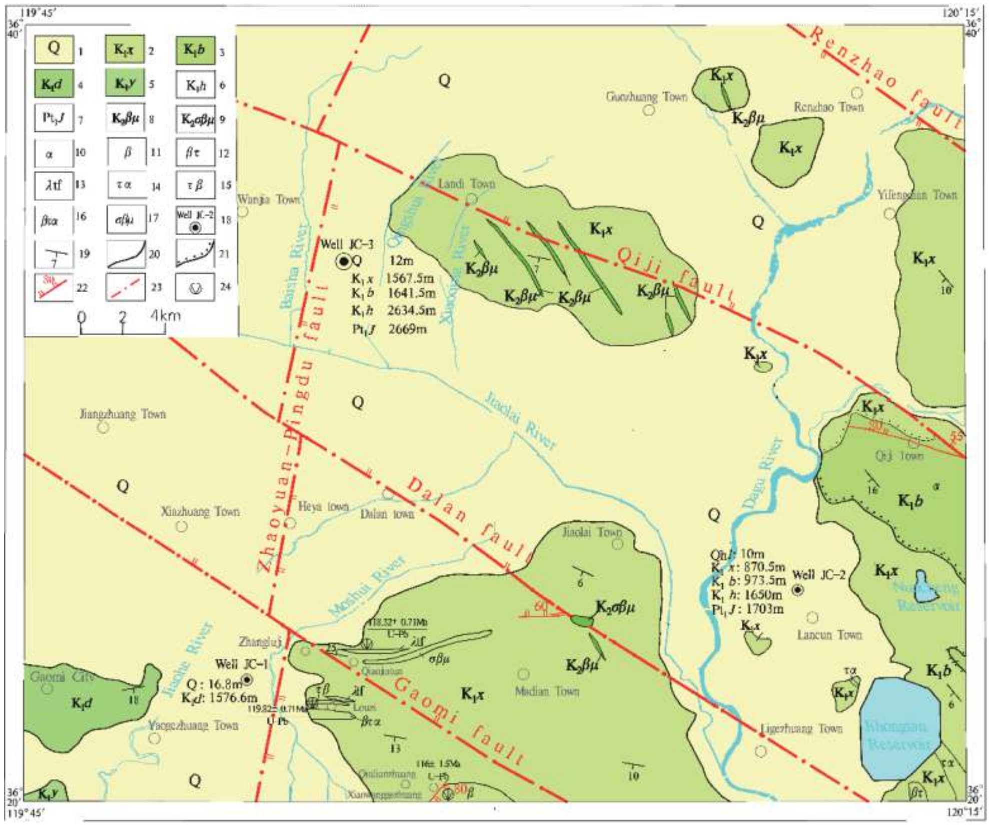

Fig. 2 Geological sketch of Wanjia—Lancun area in Jiaolai Basin, Shandong Province (according to Xu WX, 2019)

1—Quaternary; 2—Early Cretaceous Xingezhuang Formation; 3—Early Cretaceous Bamudi Formation; 4—Early Cretaceous Ducun Formation; 5—Early Cretaceous Yangjiazhuang Formation; 6—Early Cretaceous Houkuang Formation; 7—Paleoproterozoic Jingshan Group; 8— Late Cretaceous diabase dike; 9—Late Cretaceous subvolcanic rock (basalt); 10—Andesite; 11—Basalt; 12—Basaltic trachyte; 13—Rhyolitic tuff; 14—Trachyandesite; 15—Trachybasalt; 16—Basaltic trachyandesite; 17—Olivine basalt; 18—Borehole; 19—Stratigraphic attitude; 20— Geological boundary; 21—Angular unconformity boundary; 22—Normal fault; 23—Faults inferred from geophysical exploration; 24—U–Pb zircon dating

Wanjia—Lancun area of Shandong Province was carried out based on previous survey results. The 1∶50 000 geological maps achieved are the results of the geological survey project initiated by the China Geological Survey in 2016—2018. Great efforts have been made to allow them to reflect the achievements of the geological survey and scientific research obtained from a new round of mineral surveys. The purpose is to provide basic geological maps for resource and environmental research and energy exploration in the area and to provide references for scientific research and field geological survey. The brief metadata table of the Database (Xu WX et al., 2020) is shown in Table 1.

2 Data Acquisition and Processing Methods

2.1 Basic Data Acquisition

The four 1∶50 000 regional geological maps of the study area were prepared based on the geological mapping results of 1∶50 000-scale regional geological surveys of Wanjia Town

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	Spatial Database of 1∶50 000 Digital Geological Maps of Wanjia Town (J50E021024), Nancun Town (J51E021001), Gaomi City (J50E02 2024) and Lancun Town (J51E02 2001) Map-sheets, Shandong Province
Database (dataset) authors	Xu Weixiang, Shandong Provincial No.4 Institute of Geological and Mineral Survey Gao Meixia, Shandong Provincial No.4 Institute of Geological and Mineral Survey Zhang Deming, Shandong Provincial No.4 Institute of Geological and Mineral Survey Hu Bing, Shandong Provincial No.4 Institute of Geological and Mineral Survey Zhang Kai, Weifang Foundation Engineering Corporation, Shandong
Data acquisition time	2016.07–2018.12
Geographic area	119°45′–120°15′ E, 36°20′–36°40′ N
Data format	MapGIS 6.7; vector formats (*.wt, *.wl, *.wp), *.msi
Data size	299 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	The project titled 1∶50 000-Scale Regional Geological Survey of Wanjia Town, Nancun Town, Gaomi City, and Lancun Town Map-sheets, Shandong Province initiated by the China Geological Survey (No.: DD20160044-4)
Language	Chinese
Database (dataset) composition	The Database consists of four regional geological map libraries in MapGIS format of Wanjia Town, Nancun Town, Gaomi City and Lancun Town map-sheets. Each of these maps consists of a master map, mosaic maps, and map decorations and legends. The contents in a master map mainly include geological polygon entities; geological (boundaries) lines; attitude; craters; isotopic dates; shorelines of rivers, lakes, seas, and reservoirs; volcanic facies zones; standard map frames (inner map frame); geological labels; attitude annotation; geological leader lines; and isotope annotation. The mosaic maps include synthetic histograms, geological profiles of master maps, geotectonic maps, sedimentary cross sections of Lidangjia—Mashan dome, histograms of key boreholes, CSAMT profiles, lithofacies paleogeographic maps, the Quaternary isopach maps, paleochannel distribution map, geological structure outline maps, stratigraphic sedimentary framework maps, and volcanic edifice diagrams. The map decorations and legends include legends of master maps, legends of mosaic maps, index map, duty table, the emblem of the China Geological Survey, and map-sheet index

(J50E021024), Nancun Town (J51E021001), Gaomi City (J50E02 2024), and Lancun Town (J51E02 2001) map-sheets, Shandong Province according to the requirements of the '*Guidelines for 1∶50 000-Scale Regional Geological Survey (Trial)*' and the '*Guidelines for 1∶50 000-Scale Regional Geological Survey in Quaternary Coverage Area (Trial)*' and the guidance of the '*Notice of Intensifying 1∶50 000-Scale Regional Geological Survey of Metallogenic Belts*' issued by the China Geological Survey. The geographic base maps of the four maps are the 1：50 000 topographic map updated in 2013 issued by the National Geomatics Center of China, with Xi'an 1980 and National Height Datum 1985 adopted as the coordinate system and the elevation system, respectively. The original data was acquired using the Xi'an 1980 coordinate system. The result maps were then converted to CGCS2000 national geodetic coordinate system according to national applicable requirements. The geological survey was conducted along routes with a length of 1 779.25 km, and the Digital Geological Survey Platform (DGSS) was adopted amid geological mapping. The four 1：50 000 regional geological maps were prepared, whereby the strata, rocks, and structures were reflected in a more detailed way. The data acquired were classified into four types according to their formats, namely image files (.msi), polygon files (.wp), line files (.wl), and point files (.wt) (Pang JF et al., 2017; Lyu L et al., 2018).

2.2 Data Processing

2.2.1 Regional Geological Maps

Regional geological maps consist of separate layers, and three data formats (i.e., points, lines, and polygons) are used to splice different maps (Zhou HZ et al., 2019). The contents to be presented on the maps mainly include strata, magmatic rocks, and structures. The sedimentary rocks are mainly distributed in the Cretaceous and Quaternary strata. The strata were divided into different formations and members, and lithostratigraphic maps of these strata were plotted, whereby much attention was paid to the presentation of informal mapping units. The magmatic rocks mainly include volcanic rocks and dikes. The volcanic rocks were mapped by two mapping methods, namely lithostratigraphic and volcanic facies. During the mapping, the volcanic rocks were divided according to volcanic lithology and rock association, and much attention was paid to the expression of sedimentary intercalations. The dikes were represented by age combined with lithology. The structures were mapped based on geological activities. Several concealed faults were interpreted according to the characteristics of regional gravity and magnetic anomalies, and Zhaoyuan—Pingdu fault was effectively verified by a controlled source audio-frequency magnetotellurics (CSAMT) method. The 1：50 000-scale regional geological survey covered an area of 1 657 km^2.

2.2.2 Mosaic Maps

(1) Synthetic histograms: used to express in detail the lithologic characteristics and biotic association characteristics of lithostratigraphic units in the master map. They were prepared through comprehensive research on the relationship between lithologic association characteristics and biotic association characteristics of lithostratigraphic units in the map-sheet.

(2) Geological profiles of the master map: Transverse cutting profiles throughout the whole study area were arranged along the overall trend vertical to main formations and structures in the map-sheet to effectively reflect the overall characteristics of formations and structures in the map-sheet. They determine the Cretaceous continental-facies sedimentary–volcanic strata and the Quaternary. In terms of expression methods, positions were represented using standard profile line types combined with standard codes, the lithology

of each layer was expressed using corresponding patterns, and attitude factors were also expressed on the geological profiles.

(3) Histograms of key boreholes: The Cretaceous strata above the basement in the study area were studied based on the comprehensive logging data of Well JC–1, Well JC–2, and Well JC–3 implemented by the Shengli Petroleum Administration Bureau, including research on rock association characteristics, stratigraphic sequence division, and research on sedimentary facies. Based on this, the histograms of Well JC–1, Well JC–2, and Well JC–3 were prepared (Fig. 3).

(4) Sedimentary cross section of Lidangjia—Mashan dome: The sedimentary cross section of Lidangjia—Mashan dome (Gaomi volcanic depression) was prepared by comparing the logging data of Well JC–2 and Well JC–3 and combining the overall regional geology (Fig. 4). It can be concluded that Lidangjia—Mashan dome was a large lake in the late stage of Early Cretaceous. It subsided for a long time, and as a result, a set of huge thick lacustrine sediments

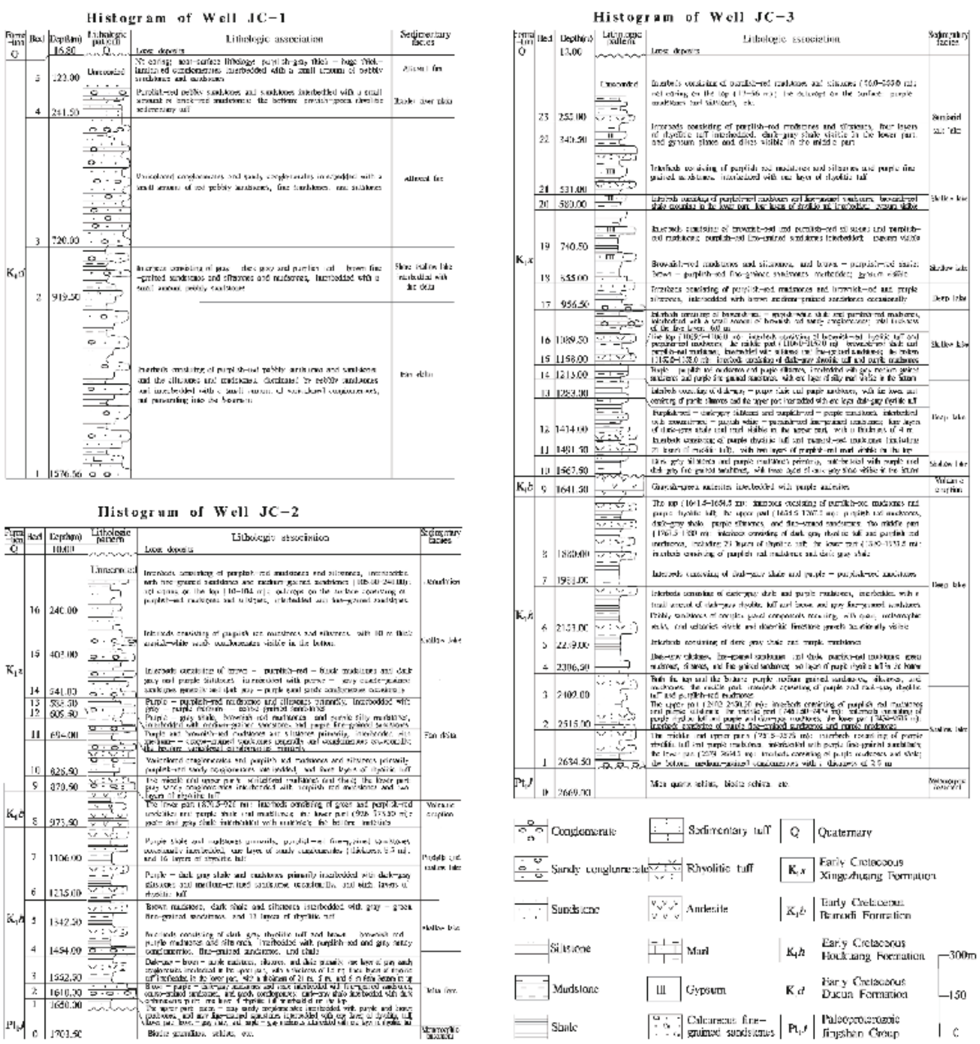

Fig. 3 Histograms of boreholes drilled in the study area (prepared based on comprehensive logging maps of Well JC–2 and Well JC–3 implemented by the Shengli Petroleum Administration Bureau)

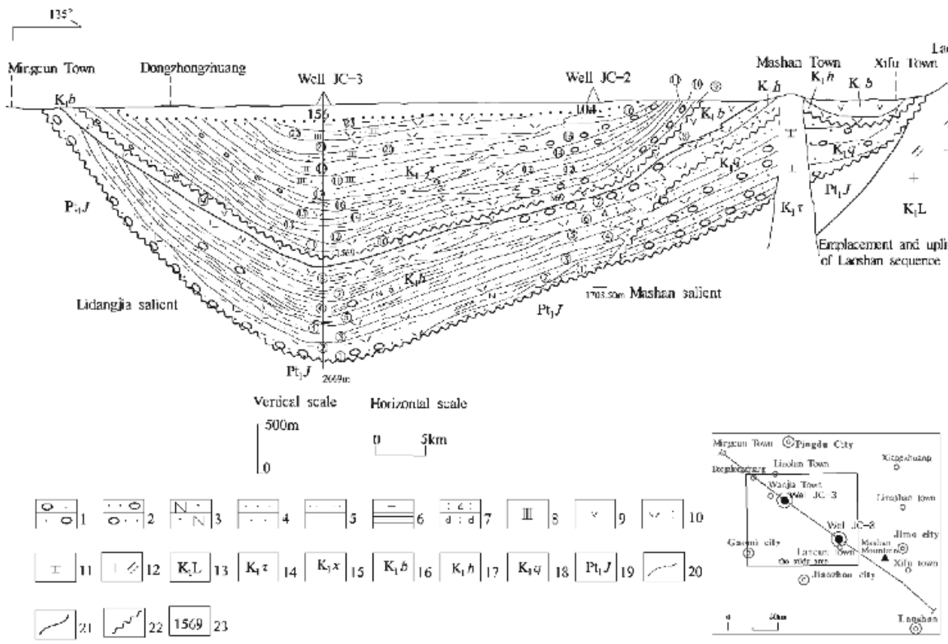

Fig. 4　Sedimentary cross section of Lidangjia—Mashan dome

1—Sandy conglomerate; 2—Pebbly sandstone; 3—Arkose; 4—Sandstone; 5—Siltstone; 6—Shale; 7—Sedimentary tuff; 8—Gypsum; 9—Andesite; 10—Rhyolitic tuff; 11—Trachyte; 12—Adamellites; 13—Early Cretaceous Laoshan sequence; 14—Early Cretaceous trachyte; 15—Early Cretaceous Xingezhuang Formation of Wangshi Group; 16—Early Cretaceous Bamudi Formation of Qingshan Group; 17—Early Cretaceous Houkuang Formation of Qingshan Group; 18—Early Cretaceous Qugezhuang Formation of Laiyang Group; 19—Paleoproterozoic Jingshan Group; 20—Boundary between strata; 21—Boundary between formations; 22—Unconformity boundary; 23—Basement depth (m) revealed by drilling

were formed. This set of sedimentary strata constitutes Houkuang Formation and Bamudi Formation of Qingshan Group, and Xingezhuang Formation of Wangshi Group according to the analysis of rock association characteristics. Regionally, the sedimentary time of the lacustrine Xingezhuang Formation corresponds to the early stage of the Shiqianzhuang Formation–Fanggezhuang Formation–Linjiazhuang Formation–Xingezhuang Formation–Hongtuya Formation in the area, thus revealing the Cretaceous sedimentary characteristics of the paleo-dome.

(5) Cretaceous lithofacies paleogeographic maps of various stages. According to data from Well JC–1, Well JC–2, and Well JC–3, as well as the surface survey results, early Cretaceous lithofacies paleogeographic maps of the study area were restored, including one map of Yangjiazhuang Formation and Ducun Formation of Laiyang Group, one map of Houkuang Formation of Qingshan Group, one map of Bamudi Formation of Qingshan Group, one map of Xingezhuang Formation of Wangshi Group, and one map of Hongtuya Formation of Wangshi Group - Paleogene, providing new ideas for the restoration of the prototype basin and lithofacies paleogeographic characteristics of the entire Jiaolai basin.

(6) Quaternary isopach map and paleochannel distribution maps: The variation in the thickness of the Quaternary strata in the study area was researched based on previous hydrological-engineering-environmental borehole data. Accordingly, the Quaternary isopach

map was prepared. It was revealed that the Quaternary basin formed in Xiazhuang-Jiangzhuang area. Furthermore, the paleochannel transition map of Jiaohe River was restored according to the investigation and verification conducted based on *Records of Gaomi Water Conservancy* (1993) and other data.

(7) Cagniard apparent resistivity depth profiles determined by CSAMT: A CSAMT profile was prepared to study the location and spatial distribution characteristics of Zhaoyuan—Pingdu fault in the concealed area. It basically determines the deep electrical characteristics of the fault along the extending direction of the fault. An effective depth of 1 500–2000 m was verified.

(8) Taijiacun volcanic edifice: The volcanic structures in the study area are covered by the circum-Pacific Meso-Cenozoic volcanic activity zone (I), Liaoning-Shandong Meso-Cenozoic volcanic zone (II), Mesozoic volcanic eruption area in east Shandong (III), and Gaomi volcanic depression (IV) (Song MC et al., 2003). Volcanic activities were undeveloped. A fifth-order volcanic edifice was discovered for the first time in Xingezhuang Formation of Wangshi Group, which was a small central volcano developed along fissures in the volcanic depression.

(9) Sedimentary framework map of Cretaceous strata: Stratigraphic framework helps to analyze the formation mechanism, sedimentary model, and structural evolution of basins. The stratigraphic framework of the study area was established based on first-hand field data as well as the regional structural characteristics and data from adjacent map-sheets. The profile lines of stratigraphic framework start from Yaogezhuang Town, Gaomi Town and pass through Well JC–1, Heya, Jiaolai River, Well JC–3, Wanjia Town, and Landi Town, with a general trending of NNE 12°. According to the stratigraphic framework map, the Mesozoic continental-facies strata in the study area are as thick as 3 000 m, and the NW-trending Gaomi fault determines the sedimentation of the Qingshanian and Wangshian basins. Dalan fault and Qiji fault jointly form a step-shaped fault, which determines and destroys the Qingshanian and Wangshian basins. Meanwhile, Qiji fault serves as the boundary between Mashan dome and Pingdu depression and determines the sedimentation of Pingdu depression.

3 Description of Data Samples

3.1 Naming of Data

The data in the Database is mainly named in three formats, namely *.wp, *.wl, and *.wt. The Cagniard apparent resistivity-depth profiles determined by CSAMT in mosaic maps were imported in.msi format.

3.2 Contents in Map Layers

The contents in master maps include geological polygon entities (_GeoPolygon); geological (boundaries) lines (_GeoLine); attitude (_Attitude); craters (_CRATER); isotopic dates (_Isotope); shorelines of rivers, lakes, seas, and reservoirs (_Line_Geography); volcanic facies zones (_Volca_Facies); standard map frames (inner map frame) (_Map_Frame); geological labels (GEOLABEL.WT); attitude annotation (A_ATTITUDE.WT); geological leader lines (A_GEOLINE.WL); isotope annotation (A_ISOTOPE.WT).

Contents of the mosaic maps include synthetic histograms, geological profiles of master maps, geotectonic maps, sedimentary cross sections, CSAMT profiles, lithofacies paleogeographic maps, the Quaternary isopach maps, paleochannel distribution map of Jiaohe River, geological structure outline maps, stratigraphic sedimentary framework maps, and volcanic edifice diagrams.

3.3 Data Classes

Names of entity classes: points, lines, and polygons.

Points: symbols and labels of various geological bodies, and lithologic patterns.

Lines: fault structures, geological boundaries, lithofacies boundaries, etc.

Polygons: sedimentary rocks, volcanic rocks, intrusions, Quaternary system, etc.

3.4 Data Attributes

The Database contains the data of geological entity features, geographical features, and features of geological map decorations. The data of geographical features were organized by following the attribute structures adopted by the National Administration of Surveying, Mapping and Geoinformation of China to collect data. The attributes of the Database were organized based on the attribute structures according to the requirements of *Code of Geological Information Metadata* (DD 2006-05) and *Spatial Database Establishment Code of Digital Geological Maps* (DD 2006-06). The detailed attribute structures are as follows:

The attribution structure of a geological polygon entity (_GeoPolygon): the ID No., original code, type code (geological code), name, era, minimum age, maximum age, and subtype ID of the geological polygon.

The attribution structure of a geological (boundary) line (_GeoLine): feature ID No.; original code; the code and type of the geological boundary (contact); codes of geological bodies on the left and right side of the geological boundary; the strike, dip, and dip angle of the interface; subtype ID.

The attribution structure of attitude (_Attitude): feature ID No.; original code; the name code and name of attitude type; the strike, dip and dip angle of the attitude; subtype ID.

The attribution structure of an isotope for isotopic dating (_Isotope): feature ID No., original code, No. and name of the sample, dating method, age dated, the unit and code of the geological body dated, and the unit and date of dating analysis.

The attribution structure of a shoreline of rivers, lakes, seas, and reservoirs (_Line_Geography): feature ID No.; original code; primitive type and name; subtype ID.

The attribution structure of a volcanic facies zone (_Volca_Facies): feature ID No.; original code; the type and code of volcanic lithofacies; units and codes of strata produced; the rock type, rock texture, and rock structure of volcanic lithofacies; attitude of planar flow structure; attitude of streamlines; formation era; ore-bearing features; subtype ID.

The attribution structure of a standard map frame (inner map frame) (_Map_Frame): map name, code of map-sheet, scale, coordinate system, elevation system, left longitude, lower latitude, and map units.

The attribution structure of a crater (_CRATER.WT): feature ID No.; original code; the type, name and size of the crater; the unit and code of geological bodies produced in the crater, the rock types and formation era of the crater; subtype ID.

4 Data Quality Control and Evaluation

The Database was established based on rich, complete, and reliable data, with the mapping accuracy achieved by field survey according to the *Guidelines for 1∶50 000-Scale Regional Geological Survey (Trial)* and the *Guidelines for 1∶50 000-Scale Regional Geological Survey in Quaternary Coverage Area (Trial)*. Geological points were collected on the principle of fully controlling the key geological blocks, informal mapping units, special geological maps, and major geological boundaries. In general, the required contents to be presented on the map face only included sealed geological blocks with a diameter greater than 100 m, linear geological bocks with a width greater than 50 m and a length greater than 250 m, and fault structures with a length greater than 250 m. All special geological blocks and informal mapping units were present in the map, regardless of their sizes. Among them, those with a small thickness were presented with appreciable patterns or symbols after being amplified or incorporated. The error in the location of a geological point (i.e., the difference between its location marked on the freehand field map and its actual location) should not exceed 25 m in general. The mapping accuracy met the specific requirements of 1∶50 000-scale regional geological survey and mapping. Relevant tests were completed at the experiment and testing lab of the Tianjin Center of the China Geological Survey and the labs of Testing Center of Shandong Bureau of China Metallurgical Geology Bureau, Shandong Institute of Earthquake Engineering, and Beta Analytic Inc. The above data were acquired from reliable sources, and the attribute databases were completely established. The maps were modified and prepared in accordance with the requirements of *Geological Legends Used for Regional Geological Maps* (GB/T 958-2015), *Standard and Principle of Coloring in Geological Map* (DZ/T 0179-1997), and *Specification for Preparation of 1∶50 000 Geological Maps and Geographic Base Maps* (DZ/T 0157-95).

A three-level quality inspection system consisting of self-check, mutual check, and spot check was strictly implemented during the construction of the Database. Self-check and mutual check were conducted for all of the original records of mapping routes, primitive data maps, and attribute inputting of recorded data. The inspection at the level of the project team was organized by the project manager. Necessary indoor inspections were carried out based on self-check and mutual check, with a spot-check rate of 70%, meeting the requirements of quality management for geological survey projects. The inspection at the level of the organization responsible for the project was arranged by the Shandong Provincial No.4 Institute of Geological and Mineral Survey, during which the project team provided active support. The spot-check rate at this level was 31%. Quality inspection records were made for all levels of inspection and revisions by the author. The organization responsible for the project reviewed all the comprehensive maps. It instructed relevant person in charge to solve existing problems and consulted experts to solve important and difficult problems. In October 2018, the Tianjin Center of China Geological Survey organized experts to conduct an overall field acceptance check of the project by indoor inspection combined with field inspection. In March 2019, the Tianjin Center of China Geological Survey reviewed the Database, during which the results of this project were unanimously approved by the experts and the Database was rated good.

5 Data Value

(1) A breakthrough was made in the study of the division and redetermination of the Cretaceous strata. The study area lies in the potential coverage area of Jiaolai Basin, with a Quaternary thickness of 0.5–30 m. The lithostratigraphic units of continental-facies near-surface “red beds” were still in doubt owing to previous low exploration level of the study area (Xu WX, 2019). With the geological mapping along survey routes and the in-depth analysis of previous borehole data (Well JC–2 and Well JC–3) conducted in this project, it can be revealed that the lithology of the “red beds” mainly consist of purplish-red mudstones and siltstones, interbedded with fine-grained sandstones and rhyolitic tuff locally and thinly laminated sandy conglomerate associations occasionally, indicating a set of lacustrine fine-grained clastic rock sediments. Based on this, as well as LA-ICP-MS zircon U–Pb dating of sporo-pollen association and rhyolitic ignimbrites as volcanic intercalations, the lithostratigraphic unit of the “red beds” was determined to be early Cretaceous Xingezhuang Formation of Wangshi Group.

(2) The Cretaceous lithofacies paleogeographic characteristics of Lidangjia–Mashan dome in Jiaolai Basin were restored. The study area is widely covered by the Quaternary, with discontinuous bedrock. The surface survey was carried out on dotted artificial outcrops. Comprehensive logging data of key boreholes were acquired and utilized to study the Cretaceous sedimentary-volcanic strata above the basement, including Well JC–1 (depth: 1 576.46 m, not penetrating into the basement), Well JC–2 (depth: 1 703.27 m, penetrating into the basement), and Well JC–3 (depth: 1 703.27 m, penetrating into the basement) implemented by the Shengli Petroleum Administration Bureau in the 1980s. The precision of strata division of the Cretaceous sedimentary-volcanic strata reached 0.5 m, completely meeting relevant precision requirements. The Cretaceous lithofacies paleogeographic characteristics of Lidangjia–Mashan dome in Jiaolai Basin were finally restored based on the study and analysis of the rock association, sequence stratigraphy, and sedimentary facies revealed by the boreholes mentioned above, especially the stratigraphic unit division and regional comparison revealed by Well JC–2 and Well JC–3. This will provide new ideas for the restoration of the prototype basin and the study of lithofacies paleogeographic characteristics in the entire Jiaolai Depression.

(3) The age of volcanic intercalations in Xingezhuang Formation of Wangshi Group was determined by high-precision LA-ICP-MS zircon isotopic dating (Table 2). The zircon U–Pb isotopic ages of the trachybasalts (intercalations) in Louzicun, the basalts (intercalations) in Xiaowanggezhuang, and the rhyolitic tuff (intercalations) in Qiaojiatun were determined to be

119.82±0.71 Ma, 116±1.5 Ma, and 118.32±0.71 Ma, respectively (Xu WX, 2019), indicating that Xingezhuang Formation where these volcanics are developed was formed in the early Cretaceous.

(4) The Quaternary was deeply studied. Twelve formations were determined according to the lithology, distribution pattern, and formation era of the sediments as well as landform features and overlapping relationship. The ^{14}C isotopic ages of Quaternary Baiyunhu Formation were determined to be 1 540 a B.P., 2 280 a B.P., and 2 320 a B.P. The ^{14}C isotopic age of Heituhu Formation was determined to be 3 780 a B.P. The luminescence ages of Dazhan Formation were determined to be 95.8 ka B.P., 89.3 ka B.P., and 33.8 ka B.P. All these provide favorable evidence (Table 2) for the time of the Quaternary.

The Database will provide basic data for survey of the geology and resource environment in the study area and will play a leading role in scientific and technical innovation, and thus can be used as important references.

6 Conclusion

(1) The 1∶50 000 regional geological maps of the four map-sheets in Wanjia—Lancun area in Shandong Province are the results of a new round of geological and mineral surveys initiated by the China Geological Survey. The project team actively explored innovative means to present regional geological mapping results, and four regional geological maps of Wanjia—Lancun area were formed, setting a model for regional geological surveys.

(2) Multiple strata division and redetermination were made for the Mesozoic continental-facies sedimentary strata. The strata in the study area were divided into the Paleoproterozoic Jingshan Group, the Laiyang Group, the Qingshan Group, and the Wangshi Group of the Mesozoic, and the Quaternary. Special lithologic strata were highlighted and 17 formations and seven special lithologic strata were determined. The spatial overlapping relationships of Mesozoic formations in the study area were ascertained, and the lithostratigraphic framework of Laiyang Group, Qingshan Group, and Wangshi Group was established. The lithology-lithofacies and volcanic structures of the volcanic rocks in the study area were mapped. As a result, five types of lithofacies were identified, namely explosive facies, effusive facies, eruption-sedimentary facies, subvolcanic facies, and intrusive facies. Meanwhile, Taijiacun volcanic edifice—a fifth-order small central volcanic edifice—was also identified, which intruded into the sedimentary strata of Xingezhuang Formation of Wangshi Group.

Table 2 Test and analysis data of the spatial database of 1∶50 000 geological maps of Wanjia town, Nancun town, Gaomi city and Lancun town map-sheets, Shandong province

Data type	Data volumn	Basic characteristics of data
Zircon U–Pb isotopic dating data	3 samples	LA–ICP–MS zircon U–Pb isotopic ages of volcanic rocks
Optically stimulated luminescence (OSL) dating data	3 samples	OSL ages of Pleistocene loess
^{14}C isotopic dating data	4 samples	^{14}C isotopic ages of Holocene carbonaceous clay

(3) The data records of Well JC–1, Well JC–2, and Well JC–3 were collated again and the Cretaceous lithofacies paleogeographic characteristics of Lidangjia—Mashan dome were further restored based on the survey of rock association characteristics, sequence stratigraphy, and sedimentary structures of Mesozoic strata. The sedimentary sequence, sedimentary facies, and provenance of the Mesozoic continental basin were determined. Furthermore, the changes of sedimentary environment in different periods of the Cretaceous and the evolutionary pattern of the Mesozoic continental-facies basins were summarized in combination with the regional structural characteristics and paleontological characteristics.

(4) The deep electrical resistivity structures of Zhaoyuan—Pingdu fault along its concealed direction of extension were basically determined by CSAMT profiles. In this way, the route along which the southern section of Zhaoyuan—Pingdu fault extends into the study area is ascertained. It is believed that Zhaoyuan—Pingdu fault enters the Quaternary coverage area from Malan Town, Pingdu City, then continues to extend into Lidangjia—Mashan dome along a SW direction after passing through Pingdu depression, and then extends into the study area and arrives at Beichenjia Village, Liaolan Town, where it is offset by Qiji fault. Zhaoyuan—Pingdu fault and the Jiaohe fault are the same fault in the south of Qiji fault. It extends along NNE trend and is successively offset by NW-trending Dalan fault and Gaomi fault. Then it passes through the east side of Well JC–1 (forming the boundary of Ducun Formation of Laiyang Group and Xingezhuang Formation of Wangshi Group), and then extends beyond the study area in a similar direction to the Moshui River.

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