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山东省莱芜市幅 1：50 000 水文地质图数据集

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摘要：本数据集选取山东莱芜市幅 1：50 000 地形图空间数据库、莱芜市幅 1：50 000 地质图部分数据作为底图，采用本次水文地质调查取得的最新数据编制而成。除水文地质图外，数据集还包括机（民）井、泉、钻孔、水质分析及水量计算等数据表，主要分类及数据量为机（民）井 209 个、泉 14 个、水库 13 个、长期监测点 13 处（监测数据 936 点次）、地下水水位及水量统测 100 点次、环境地质点 6 个、样品采集（全分析、同位素及岩石）90 组等。本数据集主要使用 MapGIS 6.7 平台辅助制图，数据量约 169 MB，坐标系为 CGCS 2000 国家大地坐标系，投影方式为高斯−克吕格投影（6 度带）。数据集不仅用二维方式标注了关键水文地质信息，还在主图及部分镶图引入三维地势表达方式。

关键词：水文地质；数据集；1：50 000；莱芜市幅

数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

自 1950 年代我国第一张水文地质图（1：3 000 000）诞生以来，我国陆续有计划地开展了 1：50 000、1：100 000 农田供水水文地质填图、1：200 000 水文地质填图及主要平原−盆地、西南岩溶 1：250 000 水文地质填图等工作（陈梦熊，1964），形成了一大批高水平成果，为我国社会经济及水文地质事业发展做出重要贡献（陈梦熊，焦淑琴，1984；陈梦熊，1988；郝爱兵等，2017）。但随着国民生活需求及社会经济水平的不断增加和提升，现有中、小比例尺水文地质调查成果图件已不能满足经济建设的需要。由于全球气候、区域生态环境变化及人类活动的干扰，地下水循环条件已发生极大改变，特别是在受降水影响大的基岩山区，地下水的径流模式、汇水条件等均发生变化，地下水资源量、可开采量较上世纪 80 年代大幅下降（刘春蓁等，2007），现有区域水文地质调查成果图件已不能真实反映当前水文地质条件，为此中国地质调查局近年在全国重点流域及地区部署开展了 1：50 000 水文地质调查填图工作，逐步提升水文地

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质调查精度，丰富现有水文地质成果（吴爱民等，2016）。

本数据集依托 2016—2018 年开展实施的“沂蒙山革命老区 1∶50 000 水文地质调查”项目，在了解国内外 1∶50 000 水文地质编图进展，收集、分析、吸收前人资料，实测优选井、泉、地下河等地下水露头及河流等各项数据，以真实、客观、美观实用为原则，并遵照现有编图规范编制而成。

该数据集的编制在现行水文地质调查规范（1∶50 000）（报批稿）指导下，探索了调查内容及数据在水文地质图上表达方式的客观性、准确性及易读性（陈梦熊，2001）。并结合前人编图理论，国内水文地质行业调查及编图习惯，从水文地质图主图内容编制、表达方式、镶图配置及图示图例、修饰内容布置等方面入手，展示了当前国内最新编图理论和编制水平，为《水文地质图编制规范（1∶50 000）》的修改完善提供了参考依据，对国内标准图幅 1∶50 000 水文地质图编制起到了示范作用。

山东省莱芜市幅 1∶50 000 水文地质图数据集基本信息简介见表 1。

表 1　数据库（集）元数据简表

条目	描述
数据库（集）名称	山东省莱芜市幅1∶50 000水文地质图数据集
数据库（集）作者	吕琳，中国地质调查局水文地质环境地质调查中心 李伟，中国地质调查局水文地质环境地质调查中心 刘元晴，中国地质调查局水文地质环境地质调查中心 王新峰，中国地质调查局水文地质环境地质调查中心 马雪梅，中国地质调查局水文地质环境地质调查中心 邓启军，中国地质调查局水文地质环境地质调查中心
数据时间范围	2016.06—2017.12
地理区域	山东省莱芜市；东经：117°30′~117°45′；北纬：36°10′~36°20′
数据格式	*.wp，*.wl，*.wt，*.msi，*.eps，*.xlsx
数据量	168 MB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	国土资源调查项目“沂蒙山革命老区1∶50000水文地质调查”（DD20160289）
语种	中文
数据库（集）组成	该数据集主要由水文地质图主图、水文地质综合柱状图、镶图、水文地质剖面图、图例、修饰部分组成，其中镶图包括流域水文地质结构图、水文地质纲要图、地下水化学图、地下水资源图；水文地质剖面图共2条：Ⅰ−Ⅰ′、Ⅱ−Ⅱ′；图例包括水文地质主图图例、各镶图图例，以及水文地质剖面图图例；修饰内容主要包括中国地质调查局局徽及图幅索引。本数据集还包含一个Excel表格（山东省莱芜市幅1∶50 000水文地质图数据集），内有五个Sheet表格：莱芜市幅机（民）井调查点一览表（部分），莱芜市幅泉调查点一览表（部分），莱芜市幅钻探（本次施工）一览表，莱芜市幅水质分析一览表，莱芜市幅地下水资源量一览表和莱芜市幅岩溶大泉流量表。

2　数据采集和处理方法

2.1　基础数据

莱芜市幅 1∶50 000 水文地质图在编制过程中充分参考了工作区 1∶200 000 水文地质图、1∶50 000 地质图、1∶50 000 地形图及其它地理地形、地质、水文地质资料，并以现行编图理论、图例规范（GBT 14538−1993、GB958−99）为指导，将图面信息分为 3 部分：基础地理信息、基础地质信息及水文地质信息。其中，基础地理信息包括主

图、镶图中的居民区、地名、水系、道路、等高线、三维地势等，元数据提取自 1∶50 000 地形图、相关区域 DEM 数据，更新截止时间为 2013 年，坐标系为 CGCS 2000 国家大地坐标系及 1985 年国家高程基准；基础地质信息包括主图、柱状图及剖面图中的岩性分区、地层界线、断层、产状、岩性符号和花纹等，元数据提取自 1∶50 000 地质图，数据完成时间为 2011 年，坐标系为 1984 年西安坐标系及 1985 年国家高程基准；支撑水文地质图编制的基础数据包括应用于主图、镶图、柱状图及剖面图中的实测及汇总分析成果等信息，数据完成时间为 2016 年，主要分类及数据量为机（民）井 209 个、泉 14 个、水库 13 个、长期监测点 13 处（监测数据 936 点次）、地下水水位及水量统测 100 点次、环境地质点 6 个、样品采集（全分析、同位素及岩石）90 组等（见表 2）；鉴于项目还未完成，附表 1—附表 5 列出了部分实测数据，并在水文地质图中根据编制需求标出代表性数据（刘焕贵等，2017）；含水岩组富水性划分、地下水系统边界、富水块段圈划、地下水流向、地下水等水位线、断层水文地质性质、地下水资源量、水化学类型分区及 TDS 等值线等作为成果数据放置于水文地质图主图及镶图上。坐标系为 CGCS 2000 国家大地坐标系及 1985 年国家高程基准，比例尺 1∶50 000。

表 2　基础数据量统计表

数据类型	数据子分类	单位	数据量
机（民）井	机井	个	65
	民井	个	33
	大口井	个	109
泉	上升泉	个	12
	下降泉	个	2
	已干涸的泉	个	2
水库		座	13
环境地质点	岩溶塌陷	个	6
	水污染	个	4
地质地貌点	地貌	个	3
长期监测点		处/点次	13/936
地下水水位统测		点次	108
样品采集	水全分析	组	50
	水同为素	组	20
	岩石	组	15
	土壤	组	15

2.2　数据分析

水文地质数据分析是数据集编制过程中的重要环节，其分析结果是数据集的编制基础和理论依据。以下分数据整理、分析及结果三部分进行说明。

（1）数据整理

据《水文地质调查规范（1∶50 000）》，现阶段水文地质调查原始数据以调查卡片形式存储，介质分纸质和电子文档。为方便分析，统一将数据以电子表格形式调查点类型整理存储，主要包括机（民）井、泉、水库、地下水水位及水量统测、样品采集等，内容涵盖调查点编号、位置、坐标、高程、水位埋深、井开采量、样品测试结果等。

（2）数据分析

水文地质数据分析的复杂性与所在工作区地形及地质条件复杂程度相关，且调查人员以往经验丰富程度及其对现场调查的直观认识的正确与否，直接决定了数据分析的方向性和分析结果的可用性；而数据分析过程则更多的扮演了验证和纠偏的角色。此外，每类数据的分析过程及方法具有独立性，而分析结果却具有关联性，且可以相互验证。以下列出主要数据的分析过程。

据调查点高程、水位埋深计算水位高程，并结合现场调查结果、地形及地质条件确定地下水流向、河流与地下水补给–排泄关系，绘制地下水埋深等值线，分析地下水补给–径流–排泄特征，并以此作为划分地下水系统的基础之一；据调查点现场访问结果、地形地貌、地质构造分布、岩溶发育情况、地层岩性及井开采量数据划分区域含水岩组及富水性等级，并以此为基础圈定富水地段，并确定断层水文地质性质；据现场调查情况、环境地质点数据圈画岩溶塌陷区及采空塌陷区；据样品分析结果数据绘制 TDS 等值线、划分地下水水化学类型、筛选地下水污染点及污染项、圈画地下水污染区、计算含水岩组碳酸岩盐含量百分数。

（3）分析结果

除地下水资源量计算结果外，数据分析结果主要以图表形式表达，并将在符合水文地质规律的前提下不断完善，最终将结果应用于数据集的编制。据水文地质数据分析，得到主要结果如下：地下水系统界线、含水岩组划分界线、富水性分区、富水地段界线、地下水流向、河流与地下水补给–排泄关系、地下水埋深等值线、岩溶塌陷区界线、采空塌陷区界线、TDS 等值线、地下水水化学类型分区、地下水污染区界线等。

2.3 数据处理

根据水文地质行业及技术人员读图习惯，数据集图面结构从左至右可大致划分成 3 列，详见图 1。第一列由上到下排列综合水文地质柱状图、流域水文地质结构图、水文地质纲要图，主要呈现地层、含水岩组划分，区域地形地貌、地表水系分布及水文地质结构，工作区所处的区域地质构造背景及其对地下水运动的影响因素等信息，帮助读者了解掌握基础地层、含水岩组、区域地质构造及水文地质结构情况；第二列由上至下为图幅名称及编号、水文地质主图、水文地质剖面图，主要从平面及垂向上详细表现含水岩组分布及富水性情况，地下水补给、径流、排泄的主要方向、方式和途径；第三列由上至下为图例、地下水化学图及地下水资源图，主要表现地下水水化学分析及地下水系统资源量计算结果等应用性成果，具体结构见图 1。莱芜市 1∶50 000 水文地质图主图展示效果见图 2。

结合图面结构及图面内容表现形式，数据处理过程遵循先主图后镶图、先底图后专业图的原则，数据处理平台主要有 MapGIS、ArcGIS、CorelDRAW，具体过程如下：

（1）底图准备

自 1∶50 000 地形图数据库及 1∶50 000 地质图矢量化数据库提取基础地理信息及地质信息，将基础地质数据坐标系用三参数法变换校正至 CGCS 2000，按相关规范调整图元表现形式，并验证精度，修饰图面内容。

（2）主图编制

按水文地质实测数据和成果数据类型生成、绘制单独矢量文件，主要包括含水岩组及其富水性等级分区、钻孔、长期观测点、地下水系统界线、地下水富水块段界线、水

文地质剖面线等，以及有代表意义的机（民）井、泉、岩溶水文地质点，并将其叠加至底图上。按规范调整图元表现形式，并修饰图面，内容主要包括实测数据相关信息的标注。数据投影坐标系为 CGCS 2000，投影方式高斯-克吕格，6°带，中央经线 117°，1985 年国家基准高程。

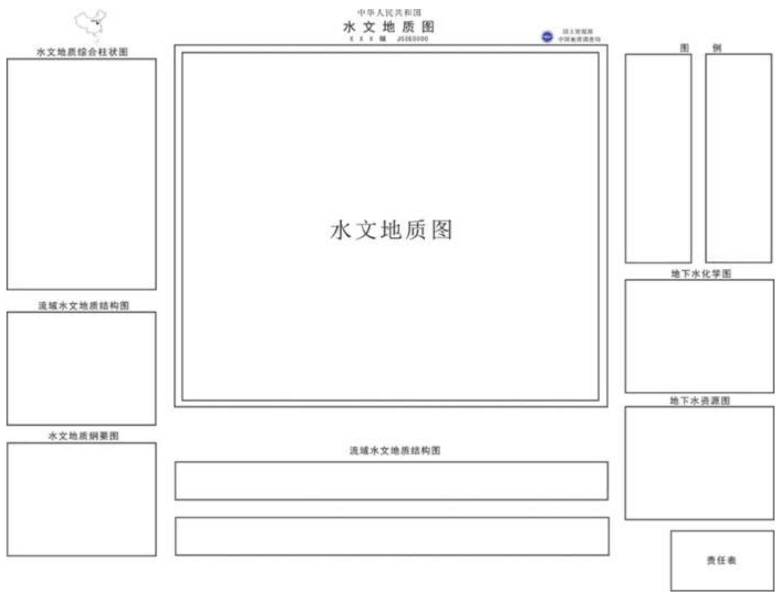

图 1　水文地质图图面结构示意图

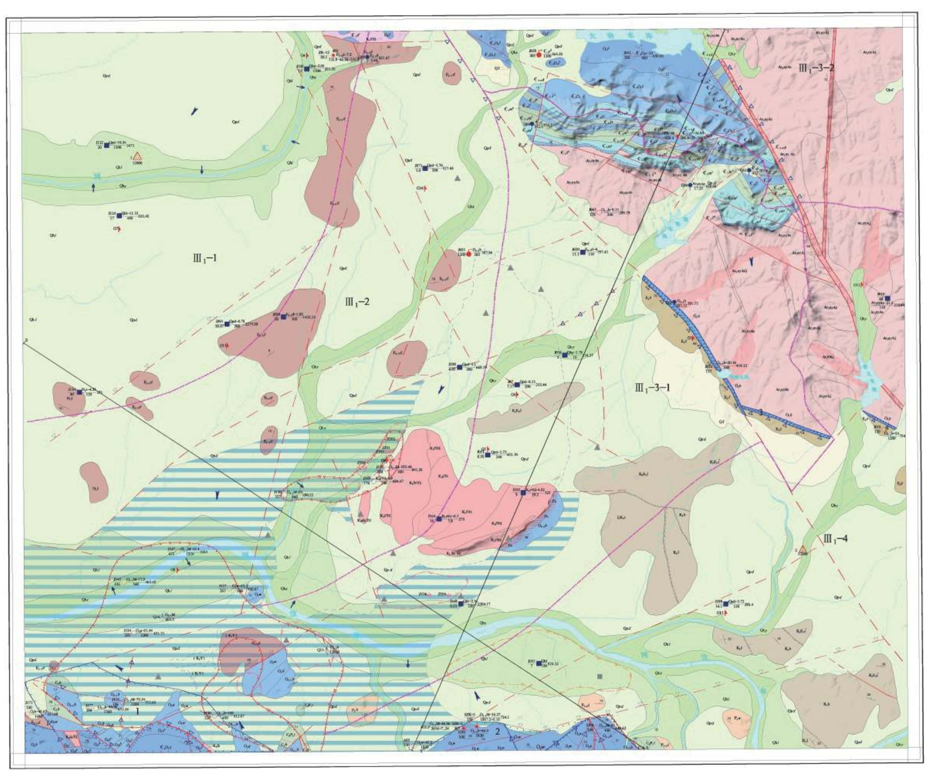

图 2　莱芜市幅 1：50 000 水文地质图

（3）镶图编制

本数据集镶图包括综合水文地质柱状图、流域水文地质结构图、水文地质纲要图、地下水化学图、地下水资源图及水文地质剖面图。以下对其处理过程做分别说明。

水文地质综合柱状图：以 1∶50 000 地质图综合柱状剖面图为基础，结合含水岩组及其富水性等级划分，对柱状图充填颜色及花纹进行修改，并以含水岩组为单位对其进行水文地质特征描述，主要包括岩性、含水层范围、涌水量、水化学类型、重要水文地质现象等。该图原数据为 MapGIS 格式。

流域水文地质结构图：以三维立体形式表现工作区所在流域的水平及垂向水文地质结构。该图分为上、下两部分，上部为以 DEM 生成的三维表面，主要呈现流域地形地貌、水系分布及主要城市；下部以 1∶500 000 水文地质图为表面，展现流域水文地质条件及含水岩组、地质构造分布情况，并以断块方式展示典型水文地质剖面，以期呈现垂向含水岩组分布特征。该图应用 ArcGIS 10.0 和 CorelDRAW X4 平台联合编制，最后输出 JPG 图片，转换成 msi 文件，并插入水文地质图数据集。

地下水化学图：以主图基础地理图层为底图（河流、地名），叠加水化学类型分区、TDS 等值线、地下水取样点、水化学超标组分、矿泉水等信息，最后通过投影变换至 1∶200 000 比例尺。

地下水资源图：以主图基础地理图层为底图（河流、地名），叠加地下水系统界线、富水块段界线、泉、水源地、长期监测点，及其相应的资源量计算结果等信息，最后通过投影变换至 1∶200 000 比例尺。

镶图对于减轻主图图面负担，展示主图表达信息以外的区域水文地质背景、基础地质及水文地质条件、地下水水质及水量分析计算结果方面具有重要作用和意义。

（4）水文地质剖面图编制

以实测地质剖面、工作区前人水文地质资料为基础，图切水文地质剖面，并添加本次实测水文地质数据及符号，主要包括钻孔、机（民）井的孔深、降深、涌水量、TDS 值，以及泉、重要岩溶水文地质点等，并形成单独的图例。

（5）图面整饬

在完成图面内容编制的基础上，综合考虑图面整体的美观性及协调性，对图面各构成部分进行图元大小、显示颜色、标注文字的字体字号、图例摆放、镶图间距等内容进行整饬和微调，在保证数据真实性及准确性的基础上，使图面的美观性及协调性最大化。

（6）数据自检

为保证数据的精度、准确性及可靠性，对数据集所有数据进行自检，主要包括主图图元位置精度、标注数据及文字的准确度、图面内容协调美观程度。对检出问题形成完整的报告，并针对具体问题形成系统的整改方案，最后按确定的整改方案逐步实施整改。

3　数据内容描述

3.1　数据分类及数据格式

按本数据集图面结构组成，将数据实体分为水文地质图主图、水文地质综合柱状图、流域水文地质结构图、水文地质纲要图、地下水化学图、地下水资源图、水文地质剖面图、图例、修饰，共计 9 类；按数据格式分为：影像文件（.msi）、区文件（.wp）、线文件（.wl）、点文件（.wt），共 4 类（庞健峰等，2017）。

本数据集最终集成平台为 MapGIS 6.7，其中除水文地质图主图三维地势、流域立体结构图以 msi 格式文件导入外，其他数据均为 MapGIS 矢量文件格式（*.wp、*.wl、*.wt）。

3.2 数据实体结构及命名

为方便用户调阅，以图面结构分类按数据格式进行合并，形成综合图层，名称以各图面结构组成图件名称命名，例如将水文地质图主图所有点图层合并，包括地名、高程点、地层代号、产状、机（民）井、泉、岩溶水文地质点及其相应标注和修饰内容等，图层名称为"水文地质主图.wt"，以相同操作方法合并线文件、区文件，形成"水文地质主图.w1"、"水文地质主图.wp"图层。

3.3 数据系统库说明

本数据集所用系统库为《水文地质图编图规范（1∶50 000）》（送审稿）附带系统库，包含符号库、线型库、图案库和颜色库。在操作过程中，根据实际需要，创建了部分符号、线型及图案，其中，符号编号 1781−1793，线型编号 666−667，图案编号 838−852。

3.4 坐标系统说明

坐标系为 CGCS 2000 国家大地坐标系及 1985 年国家高程基准，而数据集主要编制平台为 MapGIS 6.7，建设时间早于国家大地坐标系颁布时间，无法内置该坐标系，故通过手动添加相关参数自行建立国家大地坐标系，主要参数如下：长半轴 a=6378137 m，扁率 f=1/298.257222101。

4 数据质量控制

数据集质量主要涉及以下两方面内容：水文地质主图内容位置精度，以及全图内容表达、显示的准确程度。其中，前者通过在主图图面选取控制点、与相对参考系（如河流、道路交叉口等）的对比进行位置精度评估。本次选取控制点 16 个，相对参考系 6 处，计算结果显示控制点平均误差<0.5 mm，相对参考点平均误差<0.8 mm，满足 1∶50 000 水文地质图的精度要求。图面表达和显示内容种类多、数量大、程度复杂，鉴于制图平台的功能限制，目前并没有成熟的行之有效的检查方法，只能通过人工识别，分步多遍进行审查复核，直至没有错误。该数据集已通过大量工作进行了图面显示内容的全面审核，质量可靠，满足图件编制要求。

5 涉密信息的处理说明

根据国家颁布定密原则，1∶50 000 水文地质图为机密图件，如公开需进行脱密处理；故本数据集将地名、高程点、等高线、图框坐标标注，以及主要水利、矿产、道路桥梁等涉密工程信息全部移除。此外，对除上述图元外的其他数据，进行属性删除操作，消除泄密隐患。

6 结论

山东省莱芜市幅 1∶50 000 水文地质图数据集的编制建设，以新一轮区域水文地质调查数据为基础，吸收、采纳前人数据资料，结合工作区实际水文地质特征，全程采用数字化制图手段，并以最新编图理论为指导，在水文地质主图、镶图中引入了三维地势

表达方式，创新性提出了水文地质纲要图概念。该数据集的建设，实践了现有编图规范在 1：50 000 水文地质图编制过程的可行性，积极探索了 1：50 000 水文地质调查成果集成、表达的新思路和新方式，为大比例尺标准图幅水文地质图编制理论完善、过程质量控制、图面内容表达方式等提供了必要的参考。

致谢：山东省莱芜市幅 1：50 000 水文地质图数据集是一项系统性工作，是项目组全体成员辛勤工作和慷慨付出的成果。另外，在数据集编制过程中得到了本单位技术委员会专家的指导和建议，在此对他们表示诚挚的谢意。同时，对山东地矿工程勘察院、山东鲁南地质工程勘察院、山东鲁北地质工程勘察院在项目实施阶段给予的数据、资料方面的支持表示感谢。

参考文献

陈梦熊. 1964. 综合水文地质图编图原则的探讨[J]. 地质论评, 22(3): 224−232.

陈梦熊, 熊淑琴. 1984. 我国水文地质编图工作的发展与成就[J]. 中国地质 (10): 19−23.

陈梦熊. 1988. 我国岩溶地区水文地质图编图经验[J]. 中国岩溶, 7(3): 199−204.

陈梦熊. 2001. 地下水资源图编图方法指南[M]. 北京: 地质出版社.

郝爱兵, 张二勇, 王璜. 2017. 三位一体推进水文地质调查科技创新[J]. 水文地质工程地质, 44(5): 3.

刘春蓁, 刘志雨, 谢正辉. 2007. 地下水对气候变化的敏感性研究进展[J]. 水文, 27(2): 1−6.

刘焕贵, 赖华福. 2017. 江西省崇义聂都瓦窑坑白钨矿区资源储量数据集[J]. 中国地质, 44(S1): 96−104.

庞健峰, 丁孝忠, 韩坤英, 曾勇, 陈安蜀, 张艳玲, 张庆和, 姚东升. 2017. 1：100 万中华人民共和国数字地质图空间数据库[J]. 中国地质, 44(S1): 8−18.

吴爱民, Giovanni Conte, LucioMartarelli, 马荣. 2016. 意大利水文地质调查编图指南解读及其借鉴意义[J]. 水文地质工程地质, 43(5): 166−171.

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Dataset of the 1∶50 000 Hydrogeological Map of Laiwu City, Shandong Province

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Abstract: This dataset is prepared based on the latest data obtained from a new round of hydrogeological survey with the 1∶50 000 Spatial Database of Topographical Map and some data of 1∶50 000 Geological Map of Laiwu City, Shandong Province, as the base map. In addition to the hydrogeological map, the dataset includes data sheets on pumping (domestic) wells, springs, boreholes, water quality analysis and calculation of water volume including 209 pumping (domestic) wells, 14 springs, 13 reservoirs, 13 long-run monitoring points (936 point-times monitoring data), 100 point-times of simultaneous-measurement of groundwater level and groundwater volume, 6 environmental geological points, and 90 sets of samples acquired (total analysis, isotope and rock). For this dataset, the platform MapGIS 6.7 is used to prepare maps, the data size is about 169 MB, and the national geodetic coordinate system CGCS 2000 and Gauss-Kruger Projection (6-degree belt) are adopted. Furthermore, not only is 2D method used to mark critical hydrogeological information in the dataset, 3D method is introduced in the master map and part mosaic maps to express relief.

Key words: hydrogeological; dataset; 1∶50 000; Laiwu City
Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

Since 1950s when the first hydrogeological map (1∶3 000 000) of China was prepared, a series of hydrogeological mapping projects have been conducted successively across the country according to plan, including 1∶50 000 and 1∶100 000 hydrogeological maps for irrigation of farmland, 1∶200 000 hydrogeological mapping, and 1∶250 000 hydrogeological mapping of the main plain-basins and the southwest Karst region (Chen MX, 1964). In this

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way, many high-level achievements have been obtained, thus contributing greatly to the development of society, economy and the hydrogeological undertakings of China (Chen MX and Jiao SQ, 1984; Chen MX, 1988; Hao AB et al., 2017). However, with the constantly increasing demand from population and the continuously developing society and economy, existing medium and small-scale hydrogeological maps fail to meet the needs of economic development. Due to the changes in global climate and regional ecological environments as well as disturbance caused by human activities, the conditions for groundwater circulation have dramatically changed. This is important in bedrock mountainous areas, which tend to be greatly affected by rainfall with changes in the conditions of runoff patterns, water catchment, etc. As a result, the groundwater resource and its exploitable quantity in such areas have declined drastically compared with that of the 1980s (Liu CZ et al., 2007). Accordingly, existing maps obtained from regional hydrogeological surveys cannot authentically reflect current hydrogeological conditions. Therefore, China Geological Survey (CGS) has deployed nationally and performed 1∶50 000 hydrogeological surveys and mapping in critical basins and regions, so as to gradually increase the accuracy of hydrogeological surveys and enrich existing hydrogeological achievements (Wu AM et al., 2016).

The dataset reported here has been prepared with the support of the project "1∶50 000 Hydrogeological Survey in Old Revolutionary Base Area of Yimeng Mountain" conducted during the period from 2016 to 2018. It is based on the awareness of the progress made in the preparation of 1∶50 000 hydrogeological maps both domestically and abroad, the collection, analysis and assimilation of the information achieved by previous researchers, as well as field measurement and selection of data points on rivers and such outcropped groundwater as wells, springs and underground rivers. Furthermore, the dataset is prepared with truth, objectivity, elegant appearance and practice as the principle according to current specifications for map preparation.

This dataset was prepared with the guidance of the current *Specification of the People's Republic of China for Hydrogeological Survey* (1∶50 000) (submitted for approval); the preparation, objectivity, accuracy and readability of the expression mode of the contents and data on the hydrogeological maps have been explored (Chen MX, 2001). Besides, this dataset was prepared with a combination of the theories on map preparation of previous researchers as well as practices of survey and map preparation in the Chinese hydrogeological sector. In this way, the dataset demonstrates the latest ideas and current level of mapping in China, from content preparation and expression mode of the master map, configuration of the mosaic maps, graphical representations/legends, layout of decorations, etc., thus providing reference for the revision and improvement of the *Specification for Preparation of Hydrogeological Maps (1∶50 000)* and playing a demonstrative role in the preparation of the standard 1∶50 000 hydrogeological maps in China.

A brief introduction to the dataset of the 1∶50 000 hydrogeological map of Laiwu City, Shandong Province, is shown in Table 1.

Table 1 Metadata Table of Database (Dataset)

Item	Description
Database (dataset) name	Dataset of the 1∶50 000 Hydrogeological Map of Laiwu City, Shandong Province
Database (dataset) authors	Lyu Lin, Hydrogeological and Environmental Geological Survey, China Geological Survey Li Wei, Hydrogeological and Environmental Geological Survey, China Geological Survey Liu Yuanqing, Hydrogeological and Environmental Geological Survey, China Geological Survey Wang Xinfeng, Hydrogeological and Environmental Geological Survey, China Geological Survey Ma Xuemei, Hydrogeological and Environmental Geological Survey, China Geological Survey Deng Qijun, Hydrogeological and Environmental Geological Survey, China Geological Survey
Data acquisition time	June 2016—December 2017
Geographical area	Laiwu City, Shandong Province; East Longitude: 117°30′~117°45′; North Latitude: 36°10′~36°20′
Data format	*.Wp, *.wl, *.wt, *.msi, *.jpg, *.xlsx
Data size	169 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	China Geological Survey Project "1∶50 000 Hydrogeological Survey in Old Revolutionary Base Area of Yimeng Mountain" (DD20160289)
Language	Chinese
Database (dataset) composite	The dataset mainly consists of hydrogeological master map, bar graph of comprehensive hydrogeology, mosaic maps, hydrogeological cross sections, legends and decorations. The mosaic maps include basin hydrogeological structural maps, the hydrogeological outline map, groundwater chemical map, and groundwater resource map. There are two hydrogeological cross sections with numbers of I-I′ and II-II′, respectively. The legends include those for the master map, mosaic maps and cross sections. The decorations mainly include CGS logo and map indexes. In addition, there is one Excel table (Dataset of 1∶50 000 Hydrogeological Maps of Laiwu City, Shandong Province) in the dataset, which includes five sheets named Pumping (Domestic), Well Survey Points of Laiwu City (Part), Spring Survey Points of Laiwu City (Part), Drilling (this construction) of Laiwu City, Water Quality Analysis of Laiwu City, Groundwater Resource of Laiwu City, and Big Karst Spring Flow of Laiwu City.

2 Methods for Data Acquisition and Processing

2.1 Basic Data

The preparation of 1∶50 000 Hydrogeological Maps of Laiwu City is based on 1∶200 000 hydrogeological maps, 1∶50 000 geological maps, 1∶50 000 topographical maps and other information on geographical topography, geology and hydrogeology of the work area. Furthermore, current theories on map preparation and legend specifications (GBT 14538-1993 and GB 958-99) are taken as guidance for the preparation. The information contained in the maps is divided into three parts: basic geographic information, basic geological information and basic hydrogeological information. The basic geographical information includes residential areas, place names, water systems, roads, contour lines and 3D relief contained in the master map and mosaic maps. For the basic geographical information, the metadata were extracted from the 1：50 000 topographical maps and DEM data in related regions, which were last updated in 2013; the National geodetic coordinate system CGCS 2000 and the 1985 national elevation reference have been adopted. The basic geological information includes lithology-based zones, stratum borderline, faults, occurrence, lithological symbol and pattern exhibited on the master map, bar graphs and cross sections. For the basic geological information, the metadata were extracted from the 1：50 000 geological maps; the data were acquired completely in 2011; the national geodetic coordinate system CGCS 2000 and 1985 national elevation reference were adopted. The basic data used for the preparation of hydrogeological maps include measured data and collected analysis results, which were applied to the master map, mosaic maps, bar graphs and cross sections. The data were acquired completely in 2016, including 209 pumping (domestic) wells, 14 springs, 13 reservoirs, 13 long-run monitoring points (936 point-times monitoring data), 100 point-times of simultaneous-measurement of groundwater level and volume, 6 environmental geological points, and 90 sets of samples acquired (total analysis, water isotope analysis and rock chemical analysis) (see Table 2). Given that the project has not yet been completed, part measured data are listed in the attached Tables 1–5, and representative data are marked on the hydrogeological map as required by the preparation (Liu HG et al., 2017). The water-yield property-based zones of water-bearing rock formations, boundary of groundwater systems, delineation of water-yield sections, groundwater flow direction, groundwater water-level contours, fault hydrogeological properties, groundwater resources quantity, zones by hydrochemical type and TDS contour are displayed on the master map and mosaic maps as result data. For the basic hydrogeological information, the national geodetic coordinate system CGCS 2000 and 1985 national elevation reference were adopted and the scale is 1：50 000.

Table 2 Statistical Table of Basic Data

Data category	Data sub-category	Unit	Data size
Pumping (domestic) well	Pumping well	–	65
	Domestic well	–	33
	Large diameter well	–	109
Spring	Ascending spring	–	12
	Descending spring	–	2
	Dried spring	–	2
Reservoir		–	13
Environmental geological point	Karst collapse	–	6
	Water pollution	–	4
Geological landform point	Landform	–	3
Long-run monitoring point		place/point-time	13/936
Simultaneous-measurement of groundwater level		point-time	108
Sampling	Water quality analysis	set	50
	Water isotope analysis	set	20
	Rock	set	15
	Soil	set	15

2.2 Data Analysis

Hydrogeological data analysis is an important step during dataset preparation since the analysis results will provide the operational and theoretical basis for the preparation. We will describe data collation, analysis and results hereunder.

(1) Data collation

In accordance with the Specification of the People's Republic of China for Hydrogeological Survey (1：50 000), the raw data obtained from the hydrogeological survey at the current stage shall be stored in the form of paper and electronic survey cards. For convenience of analysis, all data are collated and stored in the form of electronic spreadsheets by survey point categories, which include pumping (domestic) wells, springs, reservoirs, simultaneous measurement of water level and volume, sampling, etc. The contents cover the information of survey points, such as number, location, coordinates, elevation, water-level depth, exploiting volume from wells, and testing result from samples.

(2) Data analysis

The complexity of the hydrogeological data analysis is related to the complexity of the topography and the geological conditions of the work area. Furthermore, the experience of survey staff and their intuitional understanding of field survey will directly determine the analytical orientation and utility of the results, while the process of data analysis plays the role of validation and deviation correction. Although independent analysis processes and methods are adopted for each category of data, the analysis results are correlated and can be used for mutual validation. The process used to analyze critical data is as follows:

Calculate water-level elevation according to the elevation of survey points and water-level depth.

Determine the flow direction of groundwater and the recharge-discharge relationship between rivers and groundwater and plot the groundwater depth contour by combining the results of field survey, topography and geological conditions.

Analyze recharge–runoff–discharge characteristics of the groundwater, which is one of the bases to divide the groundwater system.

Divide water-bearing formation and water-yield level within the region according to the results obtained from field visits, landform and topography, distribution of geological structure, karst development, stratum lithology and well exploitation of the survey points. Then the water-yield sections and fault hydrogeological properties can be determined.

Delineate the karst collapse zones and the goaf collapse zones based on field survey and environmental geological points.

Then according to the results of sample analysis, plot TDS contour, determine the groundwater chemical types, screen groundwater pollution points and pollution items, delineate groundwater pollution area, and calculate the percentage of carbonate content in the water-bearing formation.

(3) Analysis results

Except for the calculation results of groundwater resources, the results of the data analysis are mainly expressed as graphics and charts, which will constantly be improved with the premise of meeting the hydrogeological law. These results will finally be applied to the preparation of the dataset. Main results obtained from analysis of the hydrogeological data include the groundwater system boundary, the boundary of water-bearing formation, water-yield-property-based zones, the boundary of water-yield sections, groundwater flow direction, the recharge-discharge relationship between rivers and groundwater, groundwater depth contour, the boundary of karst collapse areas, the boundary of goaf collapse areas, TDS contour, groundwater zones by hydrochemistry, and the boundary of groundwater pollution areas.

2.3 Data processing

Based on the map-reading habit of the hydrogeological sector and the technical staff, the map of the dataset can generally be divided into three columns from left to right. Please refer to Fig. 1 for details. In the first column, there are the bar graph of comprehensive hydrogeology, the basin hydrogeological structural map and the hydrogeological outline map arranged successively from top to bottom, aiming to display the stratum, division of water-bearing formation, regional landform and topography, distribution of surface water systems and hydrogeological structure, as well as the regional geological structure background of the work area and its impact on groundwater movement. Thus the readers can understand the basic stratum, water-bearing formation, regional geological structure and hydrogeological structure of the work area. In the second column, there are map-sheet name and number, hydrogeological master map and hydrogeological cross section arranged successively from top to bottom, aiming to display vertically and horizontally in detail the distribution of water-bearing formation and water-yield property, as well as the main direction, pathways and mode of groundwater recharge–runoff–discharge. In the third column, there are legends, groundwater chemical map and groundwater resource map arranged from successively top to bottom, aiming to display the applicable results from groundwater chemical analysis and calculation of groundwater resources. Please refer to Fig.1 for the structure in detail. The master map of 1∶50 000 hydrogeological map of Laiwu City is shown in Fig. 2.

With the combination of the map structure and the expression mode of the map content, a “master map prior to mosaic map” and a “base map prior to professional map” were taken as the principle during data processing. MapGIS, ArcGIS and CorelDRAW are adopted for data processing, and the detailed process is as follows:

(1) Prepare base map

Extract basic geographical and geological information from the database of 1∶50 000 topography maps and the vectorized database of 1∶50 000 geological maps. Transform the coordinate system for basic geological data to CGCS 2000 by using three-parameter method. Adjust the expression mode of primitive, validate the accuracy and decorate the map contents as per applicable specifications.

(2) Prepare master map

Generate and plot separate vector files based on measured data and results of

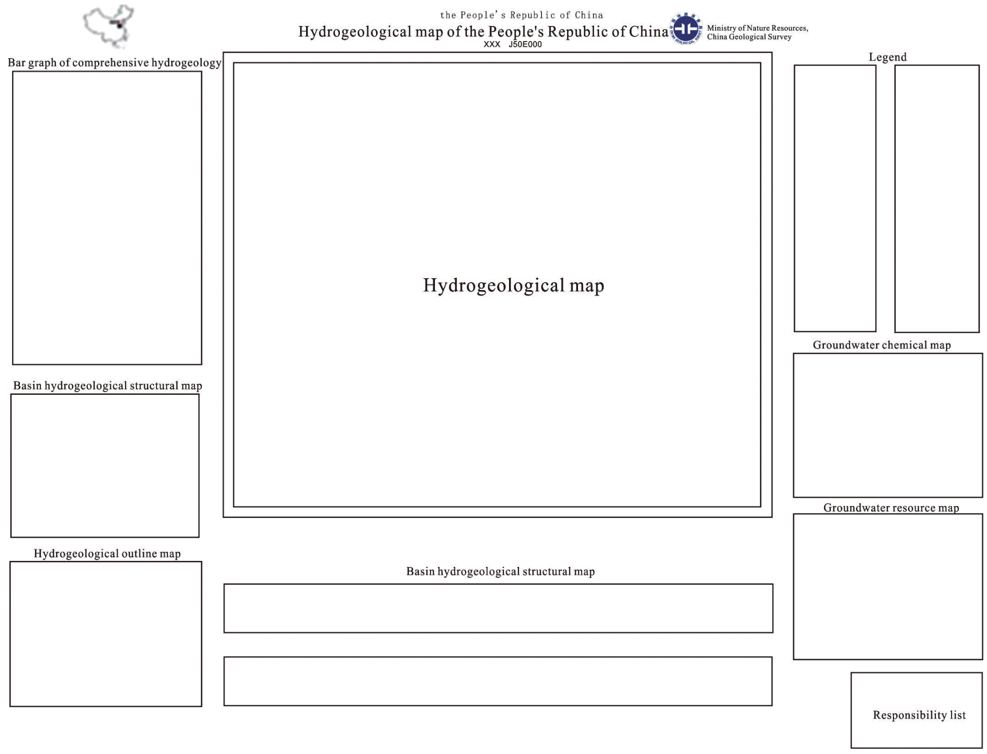

Fig. 1 Schematic Diagram of Hydrogeological Map Structure

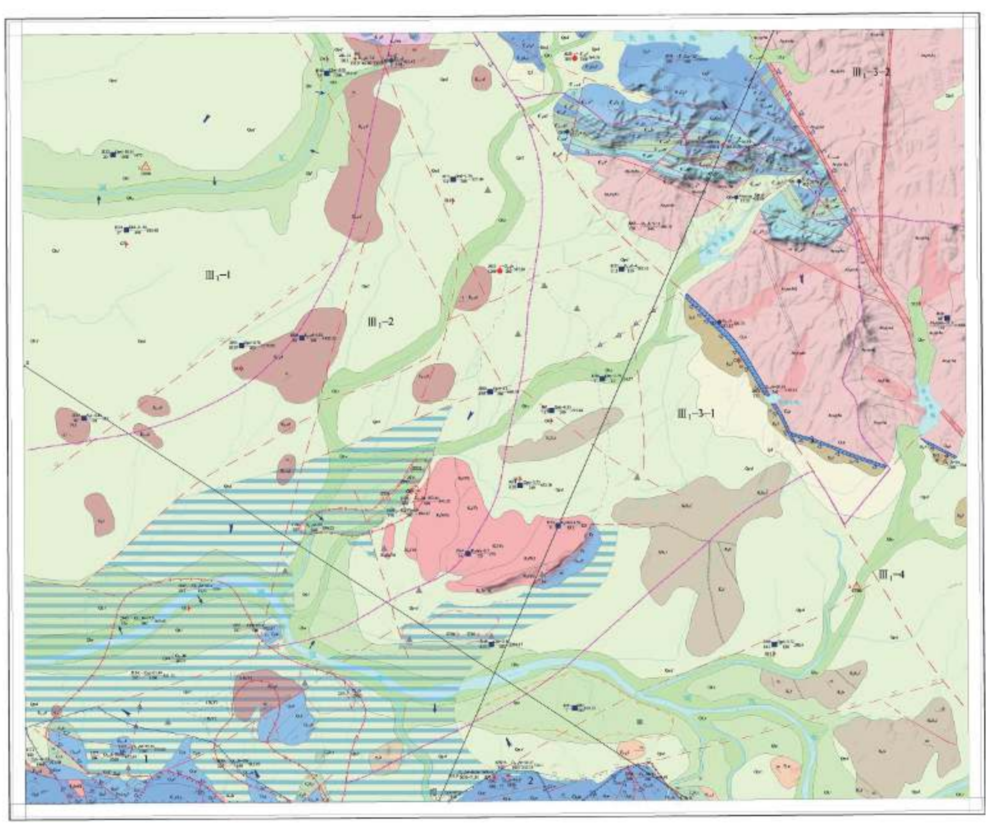

Fig. 2 1：50 000 Hydrogeological Map of Laiwu City

hydrogeology, which mainly include water-bearing formation and zones of its water-yield property level, boreholes, long-run observation points, the boundary of groundwater systems, and the boundary of groundwater water-yield sections, hydrogeological cross-section lines, as well as representative pumping (domestic) wells, springs, and karst hydrogeological points. Then superpose these files onto the base map. Adjust the expression mode of primitive and conduct modification of the map as per applicable specification, which mainly includes information marking of measured data. The CGCS 2000 coordinate system is adopted for data projection with the projection mode of Gauss-Kruger Projection (6-degree belt, 117°central longitude). The 1985 national reference elevation is adopted.

(3) Prepare mosaic maps

The mosaic maps of the dataset include the bar graph of comprehensive hydrogeology, the basin hydrogeological structural map, the hydrogeological outline map, the groundwater chemical map, the groundwater resource map and the hydrogeological cross section. These mosaic maps are processed separately as follows:

Bar graph of comprehensive hydrogeology: fill color and revise pattern of the bar graph based on the composite columnar section of the 1：50 000 geological map and by combining the water-bearing formation and its water-yield property level classification. Then describe the hydrogeological features by water-bearing formation, mainly including lithology, range of aquifer, water yield, hydrochemical type, and important hydrogeological phenomena. The format of raw data of the bar graph is MapGIS.

Basin hydrogeological structural map: used to display horizontal and vertical hydrogeological structures of the basin of the work area in 3D form. The map consists of an upper part and a lower part; the upper part is a 3D surface generated by DEM, aiming to show basin landform and topography, distribution of water systems and main cities; the lower part is a 1：500 000 hydrogeological map that shows the hydrogeological conditions and the distribution of the water-bearing formation and geological structures within the basin. In this part, typical hydrogeological cross sections are displayed in the form of a fault block, presenting the distribution features of the vertical water-bearing formation. ArcGIS 10.0 and CorelDRAW X4 are applied to jointly prepare this map. JPEG (.jpg) images are output finally and will be converted into .msi files and then inserted into the dataset of the hydrogeological map.

Groundwater chemical map: take the basic geographical layer of the master map as base map (river and place name). Superpose the information on zones categorized by hydrochemical type, TDS contour, groundwater sampling points, hydrochemical components beyond their limits and mineral water onto the base map. Finally transform the scale to 1：200 000 through projection.

Groundwater resource map: take the basic geographical layer of the master map as base map (river and place name). Superpose the information on the boundary of groundwater systems, boundary of water-yield sections, spring, water source, long-run monitoring points, calculation results of corresponding resource quantity, etc. onto the base map. Finally transform the scale to 1∶200 000 through projection.

The mosaic map plays an important role in reducing the burden of the master map and displaying the information excluded from the master map, including regional hydrogeological background, back geology and hydrogeological conditions, and analysis and calculation results of groundwater quality and volume.

(4) Prepare hydrogeological cross sections

Cut the hydrogeological cross sections based on measured geological cross sections and hydrogeological information in the work area obtained by previous researchers. Then add the hydrogeological data measured in this project and related symbols, which includes boreholes, depth of pumping (domestic) wells, drawdown depth, water yield, TDS value, springs, and main karst hydrogeological points. Then establish separate legends.

(5) Map modification

After completing the map contents, modify and finely tune various components of the map including primitive size, color, font and size of words, legend placement, and the intervals between mosaic maps, so as to maximize the map's aesthetic appearance and harmony while ensuring the authenticity and accuracy of the data.

(6) Conduct self-check of data

To ensure that data are accurate, precise and credible, conduct self-check for all data contained in the dataset, which includes the precision of primitive position, accuracy of marking data and words, and map content harmony and aesthetic appearance in the master map. Prepare a complete report for the problems found out by self-check and develop a systemic correction plan against specific problems. Finally, gradually implement the approved correction plan.

3 Data Description

3.1 Data Classification and Format

The data entities can be divided into nine categories by the structural composition of the map in the dataset, including the hydrogeological master map, the bar graph of comprehensive hydrogeology, the basin hydrogeological structure map, the hydrogeological outline map, the groundwater chemical map, the groundwater resource map, the hydrogeological cross section, legend and decoration. They can be divided into four categories by data format including image file (.msi), polygon file (.wp), line file (.wl), and point file (.wt) (Pang JF et al., 2017).

The dataset is finally integrated by MapGIS 6.7. Except for the 3D relief in the hydrogeological master map and the basin 3D structure map, which are imported in the format of .msi, all the other data are imported in the format of MapGIS vector files (*.wp, *.wl and *.wt).

3.2 Structure and Naming of Data Entities

For the users' convenience in accessing and viewing the maps, the data entities are classified by map structure and combined by data format. Thus composite map layers are generated and named according to the maps containing the map structures. For instance, all point layers in the hydrogeological master map including place name, elevation point, stratum number, occurrence, pumping (domestic) well, spring, karst hydrogeological points and their specific markings and decorations are combined into a layer with the name of "hydrogeological master map.wt". By the same operation, line files and zone files are combined to form layers with the name of "hydrogeological master map.wl" and "hydrogeological master map.wp", respectively.

3.3 Description of System Database

The system database used in the dataset is the one attached to the *Specification for Compilation of Hydrogeological Maps* (1：50 000) (submitted for approval), including symbol database, line-type database, pattern database and color database. During the operation, some symbols, line-types and patterns are created for practical needs and the symbol numbers created range from 781 to 1793, line type numbers from 666 to 667 and the pattern numbers from 838 to 852.

3.4 Description of Coordinate System

The national geodetic coordinate system CGCS 2000 and 1985 national elevation reference are adopted as the coordinate system and the MapGIS 6.7 is used to prepare the dataset. Since MapGIS 6.7 was built before the release date of CGCS 2000, CGCS 2000 cannot be built in MapGIS 6.7. Therefore, CGCS 2000 was established manually by adding related parameters, which mainly include the semi-major axis a = 6,378,137 m and the oblateness f = 1/298.257222101.

4 Data Quality Control

The quality of the dataset is mainly determined by the position precision of contents in the hydrogeological master map and the accuracy of expression and display of the contents in the entire map. The former is assessed by comparing the positions of control points selected in the master map and the relative reference systems (e.g. rivers and intersections of roads). There are 16 control points selected and six relative reference systems. As indicated by the calculation results, the mean error at the control points is less than 0.5 mm and the mean error at the relative reference points is less than 0.8 mm, meeting the precision requirement for the 1：50 000 hydrogeological map. Since there are massive and complex contents of various varieties to be expressed and displayed in the map, while MapGIS 6.7 owns limited functions, there is not a well-developed inspection method. Thus the dataset can only be reviewed and reexamined through manual identification repeatedly in a stepwise process, until no errors are found. The contents displayed on the map have been comprehensively reviewed with great effort and the result shows that the dataset is credible in quality, meeting the requirements on map preparation.

5 Processing of Confidential Information

According to the secret determination principle issued by China, the 1：50 000 hydrogeological maps are confidential and must be decrypted before they are publicized. Therefore, the confidential information in this dataset are all deleted including place names, elevation points, contours, markings and coordinates in picture boxes, as well as secrecy-involved works such as main water conservancy works, mines and bridges. In addition, the properties of other data except for the aforementioned primitive data have been deleted, so as to eliminate potential risks of disclosure.

6 Conclusions

The dataset of 1：50 000 hydrogeological map of Laiwu City, Shandong Province, was prepared based on the data obtained from a new round of regional hydrogeological survey as well as assimilation and adoption of data and information achieved by previous researchers. With combination of actual hydrogeological features of the work area, a digitized mapping method was adopted throughout the map preparation. Furthermore, under the guidance of the latest mapping theory, 3D is introduced into the hydrogeological master map and mosaic maps to express relief with the concept of the hydrogeological outline map innovatively proposed. By the preparation of the dataset, the current preparation specification has been practiced in 1：50 000 hydrogeological mapping and it is indicated that the current preparation specification is feasible. Meanwhile, the new concept and method to integrate and express results obtained from 1：50 000 hydrogeological survey have been positively explored, providing necessary reference to theory improvement, process quality control and methods of map content expression for the preparation of large-scale standard hydrogeological maps.

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References

Chen Mengxiong. 1964. Discussion on the Principles of Comprehensive Hydrogeological Maps[J]. Geological Review, 22(3): 224−232 (in Chinese).

Chen Mengxiong, Xiong Shuqin. 1984. Development and Achievements of Hydrogeological Mapping in China[J]. Geology in China, (10): 19−23 (in Chinese).

Chen Mengxiong. 1988. Experience in Mapping Hydrogeological Maps in Karst Areas of China[J]. Chinese karst, 7(3): 199−204 (in Chinese).

Chen Mengxiong. 2001. Guidelines for Mapping Groundwater Resources Maps [M]. Beijing: Geological Publishing House (in Chinese).

Hao Aibin, Zhang Eryong, Wang Huang. 2017. Trinity promotes scientific and technological innovation in hydrogeological survey[J]. Hydrogeological Engineering Geology, 44(5): 3(in Chinese).

Liu Chunzhen, Liu Zhiyu, Xie Zhenghui. 2007. Recent Advances in Research on Sensitivity of Groundwater to Climate Changes[J]. Journal of China Hydrology, 27(2): 1−6 (in Chinese with English abstract).

Liu Huangui, Lai Huafu. 2017. The resource reserves dataset of the Wayaokeng scheelite mining area, Niedu, Chongyi, Jiangxi Province[J]. Geology in China, 44(S1): 118−127.

Pang Jianfeng, Ding Xiaozhong, Han Kunying, Zeng Yong, Chen Anshu, Zhang Yanling, Zhang Qinghe, Yao Dongsheng. 2017. The national 1:1 000 000 geological map spatial database[J]. Geology in China, 44(S1): 10−23.

Wu Aimin, Giovanni Conte, Lucio Martarelli, Ma Rong. 2017. Understanding and Discussions on Hydrogeological Map of Italy-Guidelines to Survey and Mapping[J]. Hydrogeology & Engineering Geology, 43(5): 166−172 (in Chinese with English abstract).