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基于 MapGIS 建立的中国地质环境图系数据库

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摘要：中国地质环境图系数据库，是中国首套统一结构、统一格式、统一编码的涵盖地质环境、地质灾害、地下水、矿山地质环境、地质遗迹 5 个专业领域的全国性数据库。该套数据库是基于 1∶1 000 000 数据源的地理信息库，以分省 1∶500 000 环境地质调查、县市地质灾害调查、重点地区 1∶50 000 地质灾害调查、新一轮地下水资源评价、第二轮全国矿山地质环境摸底调查和矿产资源集中开采区矿山地质环境调查、首轮地质遗迹调查等数据为基础，集成近 20 年来水工环地质调查监测数据和最新综合研究成果，根据统一的建库技术要求建立而成。该套数据库具有统一的系统库（符号库、颜色库、图案库、线型库），属性按照统一的编码规则和要求建立，图件按照统一的图饰图例进行了规范化处理，共包含 163 个专业图层，图元数量共 337 833 个，容量约 8.8 GB。该套数据库为实现成果图件的动态管理与更新、构建数字地质环境奠定了基础，可为地质环境保护管理、国土空间规划、生态修复、地质灾害防治提供详细的基础信息资料。

关键词：地质环境；数据库；MapGIS；图层；属性数据

数据服务系统网址：http://dcc.cgs.gov.cn

1 引言

在以往环境地质和地质灾害综合研究与编图成果 (段永侯，1992；李炳元，1994；张宗祜等, 2004，2006；邓起东，2007；徐友宁等，2011；张发旺等，2012；殷跃平，2013) 的基础上，为系统总结 1999 年国土资源大调查以来多年的调查研究成果，完善和提升对中国区域地质环境特征、地质灾害的发育分布规律等的认识，促进水工环地质理论创新、学科发展和成果转化应用，更好地服务于地质环境保护管理和地质灾害防治，由原国土资源部地质环境司组织，编制完成了《中国地质环境图系》(郝爱兵等，2019)，共包含 36 个图件。

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通讯作者简介：李瑞敏，女，1964 年生，教授级高工，主要从事地质环境编图研究与应用工作；E-mail：lirm@cigem.cn。

以往编图大多没有统一数据基础，不同比例尺、不同空间尺度的数据难以集成和共享，数据难以更新和管理。本次编制的《中国地质环境图系》是能够全面反映中国地质环境现状的规范化的纸质和电子化地质环境系列图，根据统一的技术要求 (李瑞敏，2015；曾青石，2015)，按照“地质环境条件类”“地质灾害类”“地下水类”“矿山地质环境类”和“地质遗迹类”等 5 个专业领域、全国和重要地区 2 个尺度编制而成，构建了基于统一地理数据基础的数据资源目录、元数据库和空间数据库，具有统一结构、统一格式和统一编码，为图系的存储、管理、更新、网络发布、数据共享和云端服务奠定了基础，能够有效服务地质环境保护管理和地质灾害防治。

随着空间信息技术和 GIS 技术应用的迅速发展，数字编图及空间属性数据库建设技术在地质行业得到了广泛的应用 (韩坤英等，2005；柯学等，2008；梁国玲等，2008；王欢等，2017；叶天竺等，2017；庞健峰等，2017)。《中国地质环境图系》的编制和数据库建设，以 MapGIS 地理信息系统平台为基础，基于 MapGIS 建立的空间数据库存储大量图面上不能体现出的数据信息，管理方便、浏览简捷。

2 数据库建设原则与方法

2.1 建库原则

(1) 一致性原则

数据整合中的任何术语、要素类型、属性项或字段名称应保持概念和语义的一致，整合过程中采用的规范、规则及方法应保持一致。

(2) 集约性原则

数据库符合数据库标准要求，没有或尽量减少数据冗余。

(3) 独立性原则

数据库本身独立于业务应用系统或应用软件，即数据库数据不会因业务应用系统的要求不同而在结构和数据内容上有所改变，数据体中不包含任何依赖于业务应用系统或应用软件的内容。

(4) 适用性原则

数据应符合国家标准和行业标准，能满足不同应用系统的调用。

2.2 建库方法

数据库标准是整个数据库建设的前提和条件，更是数据库建设的基础。本项目数据库建设主要以《全国地质环境图系编制技术要求》和《全国地质环境图系空间数据库建设技术要求》为基础，严格参考国家或行业相应的技术标准，以确保整个数据库的正确性、可靠性和可扩展性。本次数据库建设所用的软件为 MapGIS 6.7，结合 MapGIS 二次开发软件 SECTION 进行属性编辑。属性库编辑采用图面属性编辑和图元利用关键字关联 EXCEL 表格相结合的方法进行。中国地质环境图系元数据信息见表 1。

3 数据基础和建库流程

3.1 数据基础

3.1.1 地理图层

采用的数据源是国家测绘地理信息局的中国 1∶1 000 000 矢量数据集 (2002 年版)，

表 1 数据库 (集) 元数据简表

条目	描述
数据库(集)名称	中国地质环境图系数据库
数据作者	李瑞敏，中国地质调查局地质环境监测院 徐慧珍，中国地质调查局地质环境监测院 曾青石，中国地质调查局地质环境监测院 王祎萍，中国地质调查局地质环境监测院 李媛，中国地质调查局地质环境监测院 荆继红，中国地质科学院水文地质环境地质研究所 张进德，中国地质调查局地质环境监测院 董颖，中国地质调查局地质环境监测院
数据时间范围	2012—2017年
地理区域	全国、重要地区，经纬度范围为：东经73°～135°，北纬2°～54°
数据格式	MapGIS
数据量	8.8 GB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局全国环境地质编图研究项目（1212011220127，12120112200893）、重要地区地质环境图件编制项目（12120112200894）、全国水文地质类图件编制项目（1212011220941）、全国地质环境图系管理系统开发项目（12120112200895）、全国地质资源环境承载能力评价与监测预警项目（DD20160328）资助。
语种	中文
数据库(集)组成	系统库：颜色库为4 467个、花纹库954个、线型库641个、符号库2 912个；专业要素：包含地质环境条件类、地质灾害类、地下水类、矿山地质环境类、地质遗迹类等5类36个图件的163个专业图层，337 833个图元

它是通过对国内 1∶1 000 000 矢量数据及属性信息进行分析提取、数据整合、加工、更新，结合国家基础地理信息系统数据库技术规范和应用需求，形成的基础地理信息数据。收集现势资料，用于地理图数据的核改与更新，现势资料主要包括：近 10 年的《中华人民共和国行政区划简册》及行政区划变更整理资料、《中华人民共和国行政区划图集》《中国地理地图集》《中国公路交通图集》《中华人民共和国分省系列地图》《分省公路里程地图集》《国家公路网地图集》及其他现势资料。

本套图系地理底图采用西安 80 坐标系，椭球基本参数为 1975 年国际大地测量与地球物理联合会第十六届大会推荐的数据，即 IAG 75 地球椭球体；投影类型为兰伯特等角圆锥投影。

3.1.2 专业图层

专业图层数据源以分省 1∶500 000 环境地质调查、县市地质灾害调查、重点地区 1∶50 000 地质灾害调查、新一轮地下水资源评价、第二轮全国矿山地质环境摸底调查和矿产资源集中开采区矿山地质环境调查、首轮地质遗迹调查等数据为基础，集成了各省 (自治区、直辖市) 最新部署开展的大量的水工环地质调查评价数据。

3.2 建库流程

空间数据库建库工作流程包括：收集资料、确定系统库、编制属性结构表、录入属性、图形矢量化、投影变换、点线面编辑以及拓扑处理、图面整饰、矢量图形属性挂接、数据集成等多个环节。这些环节环环相扣，缺一不可，如果发现错误应及时纠正，确认无误后，方可进入下一环节。主要工作流程见图 1。

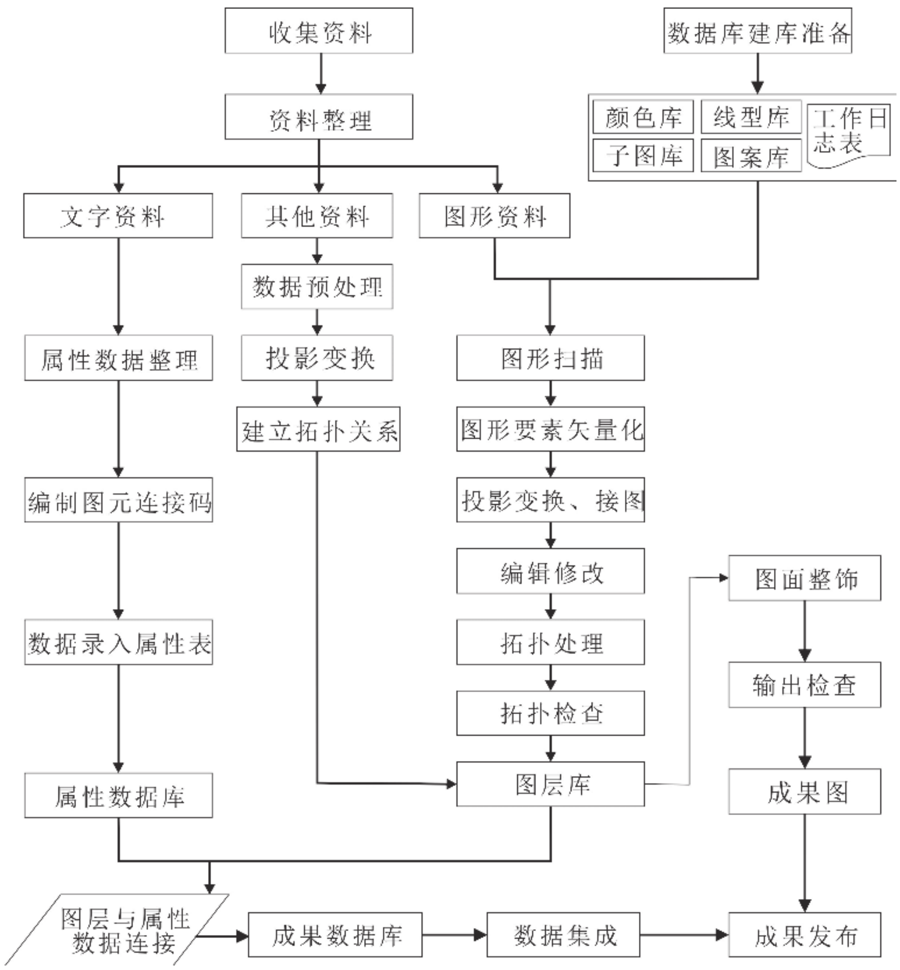

图 1　图系数据库建库流程图

4　数据库结构及内容

4.1　数据库结构和系统库

4.1.1　数据库结构

数据库的数据划分为 4 级，第一级为空间尺度，第二级为地质环境图系类别，第三级为图件名称，第四级为图层。

空间尺度：全国、区域。

图系类别：地质环境条件类，地质灾害类，地下水类，矿山地质环境类和地质遗迹类。

图件名称：如地质环境分区图、水文地质图等。

图层：即要素类，如地质环境分区、滑坡灾害点等。

4.1.2　系统库

图系具有统一的系统库，包含符号库、颜色库、图案库和线型库，系统库名称为“slib_环境图系”。该系统库的建立是整理以往使用的 10 余个水工环、地质灾害、矿山地质环境、地质遗迹等 MapGIS 系统库的基础上，经归纳、整合、编辑等标准化处理，形成了现有的涵盖地质环境条件、地质灾害、地下水、矿山地质环境和地质遗迹 5 大类图件的标准符号库。系统库的总记录数为：颜色库为 4 467 个、花纹库 954 个、线型库 641 个、符号库 2 912 个。

4.2 编码规则

4.2.1 专业图层编码规则

专业图层的编码在着重考虑稳定性、唯一性、兼容性、实用性和可扩展性的基础上，确定编码由空间尺度、比例尺、图系类别、图名、图层名称和坐标系等 6 类因素构成，共占 9 位，其中空间尺度 2 位，比例尺 1 位，图系类别 1 位，图名 2 位，图层名称 2 位，坐标系 1 位。

(1) 空间尺度代码

全国代码：A0。

区域代码：松嫩平原 B1，长江三角洲经济区 B5，环渤海经济区 B6，长江中游城市群 B7，成渝经济区 B9，黄淮海平原 BB，北部湾经济区 BE，鄂尔多斯盆地 BF，江汉洞庭平原 BG，海西经济区 BH，三峡库区 BJ，珠江三角洲经济区 BK，长吉图经济区 BM。

(2) 比例尺代码

1∶5 000 000 代码为 G，1∶4 000 000 代码为 H，1∶2 500 000 代码为 I；1∶1 000 000 代码为 K，1∶500 000 代码为 L；其他比例尺代码为 X。

(3) 图系类别代码

地质环境条件类：1；地质灾害类：2；地下水类：3；矿山地质环境类：4；地质遗迹类：5。

(4) 图名

用两位数字表示，如果超过，则顺序添加字母进行 (99，9A，9B，9C，…9Y，A1，A2，…，AY，B1，B2，…，YY)。

如果是集成后的图名，则用 00 表示。

(5) 图层

专业图层用 2 位数字表示，编码规则与图名相同。

(6) 采用的坐标系

用 1 位数字表示，0.地理坐标系；1.平面直角坐标系。

如：全国 1∶5 000 000 地质灾害类中国崩塌滑坡泥石流分布图的滑坡灾害点图层，空间尺度：全国代码为 A0，比例尺：1∶5 000 000 代码为 G，图系类别：地质灾害类代码为 2，图名：中国崩塌滑坡泥石流分布图代码为 01，图层名称：滑坡灾害点代码为 01，坐标系：平面直角坐标系代码为 1，因此综合以上该图层表示为：A0G201011。

4.2.2 图元编码规则

采用专业图层名称+5 位数字编码。如：全国 1∶5 000 000 地质灾害类中国崩塌滑坡泥石流分布图滑坡灾害点图层的编码表示为：A0G201011，则图元编码为 A0G20101100001、A0G20101100002……依次类推。

4.3 属性表的结构

属性表内容包括要素类代码和几何特征两部分。要素类代码包含数据项名称、数据项代码、定义或描述；几何特征包含数据类型与长度、约束条件、值域、单位等。

以工程地质图的岩体工程地质分类图层为例，数据项名称包含统一编号、岩体类型、岩石强度和岩体结构。岩体工程地质分类图层属性结构表如表 2 所示。

表 2　岩体工程地质分类图层属性结构表

序号	数据项名称	数据项代码	定义或描述	数据类型与长度	约束条件	值域	单位
1	统一编号	HJCAABQ	按要求编号	C14	M	自由文本	/
2	岩体类型	GCCC	岩体类型代码	C1	M	1 ~ 4	/
3	岩石强度	YSQD		C10	O	见填写说明	/
4	岩体结构	YTJG		C10	O	见填写说明	/

数据项填写说明：

(1) 统一编号：按照要素类图元编码规则进行编码。

(2) 岩体类型：填写代码，取值：1-岩浆岩建造、2-碎屑岩建造、3-碳酸盐岩建造、4-变质岩建造。

(3) 岩石强度：单选：坚硬岩石、较坚硬岩石和软弱岩石。

(4) 岩体结构：单选：块状结构、厚层状结构和薄层状结构。

4.4　要素图层

中国地质环境图系数据库要素图层包括地理要素图层和专业要素图层。

地理要素图层主要有：境界要素.WL、水系.WL(WP)、水系 (井、泉).WT、居民地.WT(WL 或 WP)、铁路.WL、公路.WL、地貌 (山峰高程点).WL、地貌 (地形等高线).WL 等。

专业要素图层有 163 个，图元数共 337 833 个，详细专业要素图层见表 3。

4.5　元数据建设

中国地质环境图系每张图件都按要求进行了元数据建设，基于地质环境元数据标准研究成果，以《地质信息元数据标准》和地质环境“元数据”为核心，建立地质环境元数据库，实现基础数据 (数字化资料)、数据产品和信息产品、业务数据等对象的名称、描述、关键字、空间位置、摘要、时间等信息存储。

元数据编辑内容包括：

(1) 元数据信息

包括元数据名称、元数据创建日期、联系单位、标识信息、数据质量信息、内容信息等内容。

(2) 标识信息

包括地理标识符、数据表示方式、专题类别、标识、联系信息、关键词、西边经度、东边经度、南边纬度、北边纬度、数据采集的起始时间、数据采集的终止时间、静态浏览图文件名、数据集访问限制、数据集用途限制、数据集使用限制、数据集安全等级、数据集格式名称、数据集格式版本、数据集维护更新频率等内容。

(3) 数据集质量信息

包括数据质量验收说明、数据源说明、数据处理步骤说明等内容。

(4) 空间参照系信息

包括 SI_基于地理标识的空间参照系名称、SC_基于坐标的空间参照系坐标名称、坐标系类型、坐标系名称、垂向坐标参照系名称等内容。

(5) 内容信息

包括要素 (实体) 类型名称、属性列表等。

表 3　地质实体要素图层

序号	类别	地质实体要素图层
1	地质环境条件类	地质环境分区线.WL，地质环境分区.WP，地质环境安全程度.WL，地面沉降高易发区.WL，断层线.WL，地质界线.WL，岩溶环境地质分区.WP，岩溶环境地质分区界线.WL，典型岩溶现象及资源.WT，典型岩溶现象及资源-峡谷.WL，主要岩溶地质灾害及环境地质问题.WT，荒漠化.WP，石漠化.WP，第四纪等厚线.WL，第四纪盆地.WP，晚新生代火山岩.WP，晚新生代火山.WT，活动断裂类型及活动性.WL，活动地块边界.WL，活动地块分区.WP，地震.WT，地震地表破裂带.WL，震源机制解数据.WT，GPS观测数据.WT，岩体工程地质分类.WP，土体工程地质分类.WP，活动断裂分布.WL，地震震中分布.WT，火山口分布.WT，应力场和地壳运动特征.WT，新构造运动地壳升降幅度.WT，崩滑流分布.WT，冰丘、冰锥分布.WT，岩溶现象分布.WT，人为工程地质现象.WT，地下水埋藏界线及深度.WL，泉点分布.WT，侵蚀性泉或钻孔分布.WT，多年冻土及积雪分布.WP，CO_2地质储存示范工程分布.WP，沉积盆地分布.WP，一二级构造线.WL，CO_2地质储存示范工程分布数据.WT，钻孔分布.WT，岩性分布.WP，第四系成因类型及时代-面.WP，第四系成因类型及时代-线.WL，第四系岩性-面.WP，第四系岩性-线.WL，新构造运动形迹-构造线.WL，新构造运动形迹-点.WT，地貌形态-线.WL，地貌形态-点.WT，地貌形态-面.WP，滑坡和泥石流.WT，冻土分布区.WP，前第四纪基岩及其高程分区-面.WP，前第四系基岩及其高程分区-线.WL，掩埋的第四系堆积物分布.WP，掩埋的第四系堆积物界线.WL，第四系等厚线.WL，黄土等厚线.WL，最大海侵范围线.WL，泉.WT，地质点.WT，其他线.WL，其他点.WT，环境地质区划.WP，环境地质区划界线.WL，岩体类型.WT，土体类型.WT，岩土体类型界线.WL，活动断裂.WL，地震.WT，环境地质问题(面).WP，环境地质问题(线).WL，环境地质问题(点).WT，地下水水文地球化学异常及污染点.WT，土壤地球化学异常点.WT，地质资源.WT，硒元素分区.WP，硒元素等值线.WL，植被分区界线.WL，地方病.WP
2	地质灾害类	崩滑流灾害点.WT，崩滑流隐患点.WT，年均降雨量等值线.WL，崩滑流易发分区.WP，累计地面沉降.WP，沉降速率等值线.WL，沉降中心值.WT
3	地下水类	地下水资源类型.WP，地下水资源类型界线.WL，天然补给资源模数.WP，径流模数.WP，水文地质分区.WP，水文地质分区界线.WL，省(市区)地下水资源量.WT，主要平原(盆地)地下水资源量表.WT，主要城市地下水供水比重.WT，咸水分布区.WP，冻土分布区.WL，冰川、雪被分布区.WP，地下水含盐量及主要水化学类型分区.WP，不合理开发利用地下水相关的环境地质问题(点).WT，不合理开发利用地下水相关的环境地质问题(线).WL，不合理开发利用地下水相关的环境地质问题(面).WP，地下水典型微量元素环境背景.WP，地下水特征污染物.WT，地下水硝酸盐氮含量等值线表.WL，地下水亚硝酸盐氮含量等值线.WL，地下水氨氮含量等值线.WL，地下水高锰酸盐含量等值线.WL，地下水挥发酚含量等值线.WL，地下水氰化物含量等值线.WL，浅层地下水类型及富水性.WP，深层地下水类型及富水性.WP，咸水区分布.WP，中低纬度冻结层水.WP，潜水含水层零星分布.WP，承压埋藏深度等值线.WL，地表水分水岭.WL，地下河.WL，顶板埋深等值线.WL，多年冻结层厚度等值线.WL，泉点.WT，热储类型分区.WP，地热资源量.WP，隆起山地型地热带分布.WP，沉积盆地型地热区(田)分布.WP，主要断裂.WL，温泉.WT，地热井.WT，大地热流点.WT
4	矿山地质环境类	非金属矿山.WT，金属矿山.WT，煤炭矿山.WT，矿群.WT，矿产资源开发区.WP，矿产资源集中开采区.WP，地貌单元.WP，矿山地质环境保护与治理区划.WP，已经实施的治理工程.WT，矿山地质环境一级保护区.WP，矿山地质环境二级保护区.WP，矿山地质环境三级保护区.WP
5	地质遗迹类	地质遗迹-地层剖面.WT，地质遗迹-岩石剖面.WT，地质遗迹-构造剖面.WT，地质遗迹-重要化石产地.WT，地质遗迹-重要岩矿石产地.WT，地质遗迹-岩土体地貌.WT，地质遗迹-水体地貌.WT，地质遗迹-构造地貌.WT，地质遗迹-火山地貌.WT，地质遗迹-冰川地貌.WT，地质遗迹-海岸地貌.WT，地震遗迹.WT，地质灾害遗迹.WT，古人类化石产地.WT，古生物群化石产地.WT，古植物化石产地.WT，古生物遗迹化石产地.WT

(6) 分发信息内容

包括分发联系方、订购说明、介质名称、介质说明等内容。

(7) 引用和负责单位联系信息

包括引用资料名称、引用资料的本身的生产和发行日期、负责单位的联系信息、电话、详细地址、城市、行政区、国家、邮政编码等内容。

5 数据质量控制和评述

5.1 数据质量控制

在数据库建设过程中按照三级检查方式进行数据库检查，主要内容包括：

一级检查：作业组自查、互检。要求 100% 的全面检查。

二级检查：是在作业组自查、互检的基础上，由项目负责人或项目质检人员对作业组生产的数据进行 100% 的全面检查。

三级检查：是在二级检查的基础上，对作业组生产的数据进行的再一次检查。三级检查由生产单位的质量管理部门或质检员负责，按抽样比例进行检查。

对每级检查或验收发现的问题应进行全面修改，并经复检通过后方可提交下一级检查或验收。

每张图件建库工作人员需填写工作日志表，将每天的工作内容全面、完整的记录下来，并由作业组长签名认可。

该数据库参加人员单位及质量控制人员名单见表 4。

表 4 图系数据库参加人员单位及质量控制人员列表

序号	图名	参加单位	参加人员
1	中国地质环境分区图	中国地质环境监测院	徐慧珍、王祎萍、刘琼、高萌萌、李小磊、夏遥、曹峰
2	中国地质环境安全程度图	中国地质环境监测院	孟晖、张若琳、石菊松、李春燕
3	中国岩溶环境地质图	中国地质科学院岩溶地质研究所	毕雪丽、时坚、周立新、许琦、陈阵、毕奔腾、杨辰、韦延兰、杨象鹏
4	中国荒漠化土地分布图	中国国土资源航空物探遥感中心	孙永军、高会军、邢宇、李侠、时文文
5	中国及毗邻海区活动断裂分布图	中国地质科学院地质力学研究所	吴中海、周春景、马晓雪、王继龙、黄小龙、吴小林、胡萌萌、哈广浩、刘杰
6	中国工程地质图	中国地质科学院水文地质工程地质研究所	梁国玲、张礼中、张春英、朱吉祥、石磊
7	中国及毗邻海域主要沉积盆地二氧化碳地质储存适宜性评价图	中国地质调查局水文地质环境地质调查中心	郭建强、金晓琳、贾小丰、张森琦、李旭峰、刁玉杰、范基姣、张徽、张杨、胡丽莎、张超、张成龙
8	中华人民共和国及其毗邻海区第四纪地质图	中国地质科学院水文地质工程地质研究所	梁国玲、张礼中、张春英、朱吉祥、石磊
9	中国沿海地区环境地质图	中国地质调查局天津地质调查中心	孟庆华、杨齐青、谢海澜、王小丹、夏雨波、刘宏伟、柳富田、孟利山、白耀楠、杜东
10	环渤海重点经济区环境地质图	中国地质调查局天津地质调查中心	孟庆华、杨齐青、谢海澜、王小丹、夏雨波、刘宏伟、柳富田、孟利山、白耀楠、杜东
11	长江三角洲经济区环境地质图	中国地质调查局南京地质调查中心	苏晶文、姜月华、黄金玉、张泰丽、贾军元、周权平、李云、刘红樱、朱意萍

续表 4

序号	图名	参加单位	参加人员
12	海峡西岸经济区(核心区)环境地质图	中国地质调查局南京地质调查中心	邢怀学、葛伟亚、李亮、田福金、李云峰、常晓军、唐小雯
13	长江中游城市群环境地质图	中国地质调查局武汉地质调查中心	路韬、刘凤梅、邵长生、杨艳林、张傲、王岑
14	珠江三角洲经济区环境地质图	中国地质调查局武汉地质调查中心	刘凤梅、黄长生、赵信文、刘广宁
15	北部湾经济区环境地质图	中国地质调查局武汉地质调查中心	刘凤梅、黎清华、刘怀庆
16	成渝经济区环境地质图	中国地质调查局成都地质调查中心	李明辉、徐如阁、王东辉、田凯、陈绪钰
17	长吉图经济区环境地质图	中国地质调查局沈阳地质调查中心	赵海卿、代雅建、石旭飞、郭晓东
18	关中盆地城市群环境地质图	中国地质调查局西安地质调查中心	曾庆铭、朱桦、李清
19	黄淮海平原土壤硒环境图	中国地质环境监测院	王轶、王祎萍、高萌萌、李小磊、刘琼、仝晓霞、夏遥、曹峰
20	中国崩塌滑坡泥石流分布图	中国地质环境监测院	尹春荣、曲雪妍、杨旭东、佟彬、房浩、张艳玲
21	中国崩塌滑坡泥石流易发程度图	中国地质环境监测院	房浩、李媛、杨旭东、曲雪妍、尹春荣、佟彬
22	中国地面沉降现状图	中国地质环境监测院	王云龙、郭海朋、朱菊艳、王桂杰、王海刚、秦同春、臧西胜
23	三峡库区崩塌滑坡泥石流分布图	中国地质环境监测院	杨建英、叶润青、程温鸣、吴润泽、付小林、霍志涛
24	长江三角洲地区地面沉降现状图	上海地质调查研究院	严学新、杨天亮、吴建中、朱晓强、龚绪龙、吴孟杰、沈慧珍、闵望、黄鑫磊、林金鑫、赵云捷
25	中国地下水资源图	中国地质科学院水文地质环境地质研究所	张宗祜、秦毅苏、荆继红、孙继朝、戴喜生、刘春燕
26	中国地下水环境图	中国地质科学院水文地质环境地质研究所	孙继朝、荆继红、汪珊、李政红、刘春燕
27	中国水文地质图	中国地质科学院水文地质环境地质研究所	程彦培、董华、张健康、温雪茹、岳晨、盖立强、易卿、倪增石、刘坤、邱玉玲、靳凤清、裴玉杉
28	中国地热资源分布图	中国地质科学院水文地质环境地质研究所	王贵玲、刘志明、蔺文静、张薇、梁继运、刘峰、李龙
29	黄淮海平原水文地质图	中国地质科学院水文地质环境地质研究所	程彦培、董华、张健康、温雪茹、岳晨、盖立强、易卿、倪增石、刘玲霞、王春晓、刘坤、邱玉玲、靳凤清、裴玉杉
30	鄂尔多斯盆地水文地质图	中国地质调查局西安地质调查中心	朱桦、赵振宏、李清、曾庆铭
31	松嫩平原水文地质图	中国地质调查局沈阳地质调查中心	赵海卿、代雅建、石旭飞、郭晓东
32	江汉洞庭平原水文地质图	中国地质调查局武汉地质调查中心	喻望、肖攀、关义涛、姚腾飞
33	中国矿山地质环境问题图	中国地质环境监测院	张进德、张志鹏、任鹰、余洋
34	中国矿山地质环境保护与治理区划图	中国地质环境监测院	张进德、张志鹏、任鹰、余洋
35	中国重要地质遗迹资源分布图	中国地质环境监测院	董颖、黄卓、季燕南、陈梓慧、曹晓娟、王剑昆、杨宏斌
36	中国重要古生物化石产地分布图	中国地质环境监测院	季燕南、曹晓娟、董颖、唐灿、黄卓、杨宏斌、刘嵘、陈梓慧、娄连惠、王剑昆

为保证数据质量，项目组还开发了单机版图系管理系统，该系统包含数据检查模块，检查内容包括：①数据的标准化：包括图层命名、数据项的命名、数据类型、字段长度等；数据的逻辑性包括值域范围；数据必填项的填写情况等内容；图层缺少和数据项缺失情况，统一编号的重复情况和图层名吻合情况。②拓扑的一致性：坐标点重叠、弧段相交、弧段自相交、弧段重叠、悬挂弧段等内容。数据检查可以是图系，也可以是单个图层、单个图件。检查完毕后会自动生成检查报告，供建库人员对照检查修改。

5.2 质量评述

各图层具有统一的地图参数和系统库，图元编号保持唯一，各要素的采集无错漏现象，线画 (点位) 整体或部分偏移的距离不超过图上 0.2 mm，数据具有严格的拓扑结构，不存在拓扑错误，属性图层名称以及点、线、面的属性结构与建库标准一致，与图元一一对应，数据较为完整，图元与属性挂接完整，属性数据出错率小于 2%。数据库建设过程中质量监督与管理措施到位，建库过程严格按照自检、互检、抽检 3 级质量管理制度执行，过程文档和有关质量检查记录齐全，形成的数字化成果总体质量较好，可信度高、实用性强，能够很好地服务于水工环研究领域。

6 数据库共享发布

该套数据库目前主要通过地质云平台“全国地质环境图系专题”进行共享和发布，为地质云各级用户提供了各专业成果数据信息，实现了数据资源目录、元数据信息、说明书管理和图层空间属性查询等功能，兼顾专业技术人员和社会公众需求，满足了不同层次用户的服务需求；为地质云各级用户提供了全国地质环境图系的技术指南文档，从而提高了编图工作的规范化和标准化程度，搭建了与用户沟通的桥梁和系统问题反馈的机制。

7 结论

(1) 1999 年国土资源大调查以来，在全国范围内开展了一系列地质环境调查，积累了海量的数据，本次图系数据库建设集成并梳理了全国最新的调查数据，筛选出有效数据，统一了坐标系。数据涉及专业内容丰富，数据量较大，为地质环境保护管理、国土空间规划、生态修复、地质灾害防治提供详细的基础信息资料。共包含 163 个图层，337 833 个图元，容量约 8.8 GB。

(2) 首次建立了由全国、重要地区 2 个层次和地质环境条件类、地质灾害类、地下水类、矿山地质环境类和地质遗迹类 5 个专业领域构成的中国地质环境图系框架，在“统一地理数据基础”“统一编图技术要求”“统一建库技术要求”的基础上进行图件编制和数据库建设，保证了图系编制及数据库建设的标准化和规范化。

(3) 构建了基于统一地理数据基础的数据资源目录、元数据库和空间数据库，具有统一结构、统一格式和统一编码，为图系的存储、管理、更新、网络发布、数据共享和云端服务奠定了基础。

(4) 研发了单机版和网络版图系管理系统，提高整个图系编制工作的科学管理、辅助编图和动态更新，在一定程度上提高编图工作效率和服务水平，对编图成果数据的存储管理、共享发布和社会化服务提供有力的支撑。

致谢：《中国地质环境图系》编制及数据库建设，是一项极其复杂的工作，是由10余家中国地质调查局局属单位、数百名专业技术人员共同参与完成，在此对参与这项工作的中国地质环境监测院、中国地质科学院水文地质环境地质研究所、中国地质科学院岩溶地质研究所、中国地质科学院地质力学研究所、中国地质科学院水文地质环境地质调查中心、中国国土资源航空物探遥感中心、中国地质调查局天津地质调查中心、中国地质调查局南京地质调查中心、中国地质调查局武汉地质调查中心、中国地质调查局成都地质调查中心、中国地质调查局沈阳地质调查中心、中国地质调查局西安地质调查中心等单位及相关技术人员表示感谢。本项目的实施得到了自然资源部、中国地质调查局的支持，众多相关领域专家和学者提出过许多宝贵建议，在此一并表示感谢!

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Database of Geological Environmental Map System of China Based on MapGIS

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Abstract: The Database of Geological Environmental Map System of China is China's first national database with uniform structure, format and codes, covering five professional fields, namely, geological environment, geologic hazards, groundwater, geological environment of mines and geological relics (geoheritage). Using 1∶1 000 000 data sources as the geographic information base, this database is built on 1∶500 000 environmental geological surveys in different provinces, county- and city-level geologic hazard surveys, 1∶50 000 geologic hazard surveys in key areas, the latest groundwater resources assessment, the second national survey of the geological environment of mines and investigation of such in areas with concentrated mining, and the first survey of geological relics. According to uniform requirements, it integrated the data of hydrological, engineering and environmental geological surveys and monitoring data over the past 20 years as well as the latest related research results. It has a unified system library (symbol, color, pattern and line libraries), with attributes established according to uniform coding rules and requirements, and with maps standardized according to uniform finishing and legend. The database contains 163 professional map layers with a total number of 337 833 elements and a capacity of 8.8 GB. It lays a solid foundation for the dynamic management and updating of maps and the construction of a digital geological environment, and provides detailed fundamental information for the protection and management of China's geological environment, spatial planning of national territory, ecological restoration and the prevention and control of geologic disasters.

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Key words: geological environment; national database; MapGIS; map layer; attribute data
Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

The Geological Environment Department of the former Ministry of Land and Resources of China (Now merged into the Ministry of Natural Resources) compiled the *Geological Environmental Map System of China* (also referred to as the *map system*, Hao AB et al., 2019), which includes a total of 36 maps, based on the past achievements in research and mapping of environmental geology and geologic hazards (Duan YH et al., 1992; Li BY et al., 1994; Zhang ZH et al., 2004, 2006; Deng QD et al., 2007; Xu YN et al., 2011; Zhang FW et al., 2012; Yin YP et al., 2013). The *map system* aims to review the results of land and resource surveys since 1999, improve and enhance the understanding of the characteristics of regional geological environment as well as the development and distribution patterns of geologic hazards in China. It also aims to promote the innovation, development and application of hydrological-engineering-environmental geological theories so to facilitate geological environment protection and the prevention and control of geologic hazards.

As most mapping practices in the past lacked a unified data standard, it is difficult to integrate and share the data of different graphical and spatial scales, bringing problems for data updating and management. The *Geological Environmental Map System of China* represents a standardized series of paper-based and electronic geological environment maps able to reflect the present situation of China's geological environment in an all-round way. In compliance with unified technical requirements (Li RM, 2015; Zeng QS, 2015), the *map system* is compiled in five professional categories, namely, "geological environmental conditions", "geologic hazards", "groundwater", "geological environment of mines" and "geological relics", with two scales, i.e., the whole country and key areas. It has established a data resource catalogue, metabase and spatial database based on the unified geographical data framework, with uniform structure, format and codes. It lays a solid foundation for the storage, management, updating, publishing, data sharing and cloud service of the map system, holding great significance for China's geological environmental protection and the prevention and control of geologic hazards.

With the rapid development of spatial information technology and GIS technologies, digital mapping and the construction of spatial attribute databases have been widely used in geology (Han KY et al., 2005; Ke X et al., 2008; Liang GL et al., 2008; Wang H et al., 2017; Ye TZ et al., 2017; Pang JF et al., 2017). The compilation and database construction of the *Geological Environmental Map System of China* is based on the MapGIS geological information platform, and stores in its MapGIS-based spatial database massive data unable to be shown on the map surface, ensuring easy management and browsing.

2 Principles and Methods of Database Construction

2.1 Principles of Database Construction

(1) Principle of Consistency

Any terminology, element type, attribute item or field name in data consolidation shall be consistent in concept and semantics, with consistent specifications, rules and methods adopted in the integration process.

(2) Principle of Economy

The database shall meet standard requirements and does not contain redundant data, or minimizes redundant data to the largest extent possible.

(3) Principle of Independence

The database itself is independent of the business application system or software, that is, data in the database will not change in structure or content as a result of different requirements of business application systems, and the data body does not contain any content that depends on the business application system or software.

(4) Principle of Applicability

Data shall conform to national and industry standards and shall be capable of being used by different application systems.

2.2 Method of Database Construction

Standard is the premise and condition for database construction. Database construction of this project is based on the *Technical Requirements for Compiling National Geological Environmental Map System* and the *Technical Requirements for Constructing National Geological Environmental Map System Spatial Database*, with strict adherence to relevant national or industrial technical standards, so as to ensure the correctness, reliability and scalability of the whole database. MapGIS 6.7 is adopted as the software for database construction, and attribute editing is conducted using SECTION, a software developed based on MapGIS. In the editing of the attribute database, map surface attribute editing and keyword connections with EXCEL tables in map elements are adopted. See Table 1 for metadata information of the Geological Environmental Map System of China.

3 Data Foundation and Database Construction Process

3.1 Data Foundation

3.1.1 Geographic Layers

The data used is derived from the 1：1 000 000 Chinese vector dataset (2002 edition) of the National Administration of Surveying, Mapping and Geoinformation. It is formed based on the analysis and extraction, data consolidation, processing and updating of the 1：1 000 000 vector data and attribute information in line with the technical specifications and application requirements of the National Fundamental Geographic Information System (NFGIS) database. Current information is collected for the verification and updating of the geographic map data, which mainly includes the following publications in the last 10 years: *the Administrative*

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dateset) name	Database of Geological Environmental Map System of China Based on MapGIS
Database (dateset) authors	Li Ruimin, China Institute for Geoenvironmental Monitoring, China Geological Survey Xu Huizhen, China Institute for Geoenvironmental Monitoring, China Geological Survey Zeng Qingshi, China Institute for Geoenvironmental Monitoring, China Geological Survey Wang Yiping, China Institute for Geoenvironmental Monitoring, China Geological Survey Li Yuan, China Institute for Geoenvironmental Monitoring, China Geological Survey Jing Jihong, Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences Zhang Jinde, China Institute for Geoenvironmental Monitoring, China Geological Survey Dong Ying, China Institute for Geoenvironmental Monitoring, China Geological Survey
Data acquisition time	2012—2017
Geographic area	The whole country and key areas (73°–135° E, 2°–54° N)
Data format	MapGIS
Data size	8.8 GB
Data service system URL	http://dcc.cgs.gov.cn
Fund Project	China Geological Survey Projects titled “National Environmental Geological Mapping Research”(121201122017, 12120112200893), “Mapping of Geological environment in Key Areas” (12120112200894), “Compilation of National Hydrogeological Maps ” (1212011220941), “National Geological Mapping Management System Development” (12120112200895), and “Assessment of Environmental carrying Capacity and Monitoring and Early Warning of National Geological Resources” (DD20160328).
Language	Chinese
Database (dataset) composition	System database: 4 467 colors, 954 patterns, 641 line styles, 2 912 symbols; professional elements: include 5 categories, namely, geological environmental conditions, geologic hazards, groundwater, geological environment of mines, and geological relics, with 163 professional map layers of 36 maps, and 337 833 primitives.

Divisions of the People’s Republic of China and materials on changes in administrative divisions, the *Atlas of Administrative Divisions of the People’s Republic of China*, the *Atlas of Geographical Divisions of the People’s Republic of China*, *Atlas of Highway Traffic in China*, the *Map of Provinces of the People’s Republic of China*, *Atlas of Provinces’ Highway Mileage*, the *Atlas of National Highway Network*, among other recent materials.

This map system adopts the Xi’an 80 coordinate system as its geographic basic map. The basic parameters of the ellipsoid are the data recommended by the 16th General Assembly of the International Union of Geodesy and Geophysics in 1975, i.e. the IAG 75 ellipsoid. The projection type is the Lambert isometric conical projection coordinate system.

3.1.2 Professional Map Layers

The data source of the professional map layer is based on provincial 1∶500 000 environmental geological surveys, county- and city-level geologic hazard surveys, 1∶50 000 geologic hazard surveys in key areas, the latest groundwater resources assessment, the second national survey of the geological environment of mines and the investigation of the geological environment of mines in areas with concentrated mining, and the first survey of geological relics. It integrates a large number of newly commissioned hydrological-engineering-environmental geological surveys and evaluation data from various provinces, as well as from autonomous regions and municipalities directly under the Central Government.

3.2 Database Construction Process

The workflow of building a spatial database includes: collecting data, determining system library, compiling attribute structure tables, inputting attributes, vectorization of graphics, projection transformation, point-line-surface editing, topological processing, surface finishing, attribute connection of vector graphics, data integration, etc., where each step is indispensable and mutually connected. Correction shall be timely made should any error be identified, before entering the next step. Fig. 1 shows the main workflow.

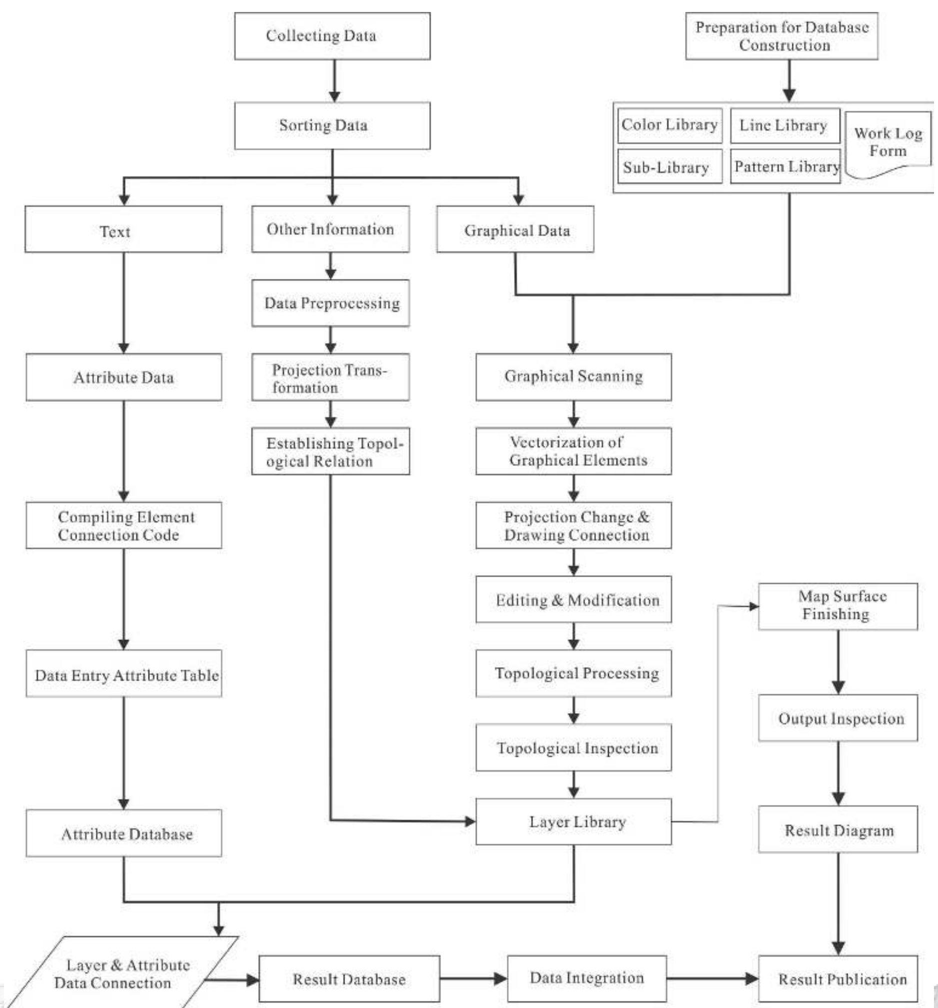

Fig. 1 Database Construction Workflow of the Map System

4 Database Structure and Content

4.1 Database Structure and System Library

4.1.1 Database Structure

Data in the database are divided into 4 levels: the first is spatial scale; the second is geological environmental map system; the third level is map name, and the fourth level is map layer.

Spatial scale: national and regional.

Map type: geological environmental conditions; geologic hazards; groundwater resources; groundwater environment; geological environment of mines; and geological relics.

Map name: e.g., geological environment zoning map, hydrogeological map, etc.

Map layer: i.e. Element type, such as geological environment zoning, landslide hazard point, etc.

4.1.2 System Library

The map system has a unified system library, and contains libraries of symbol, color, pattern and line. The system library is named "slib_environmental map system". Based on over 10 MapGIS system libraries in the past, including hydrological-engineering-environmental geological surveys, geologic hazards, geological environment of mines, geological relics, etc, the existing standard symbol library is formed through standardization processes, such as sorting, integration and editing, covering five categories of geological maps (geoenvironmental conditions, geologic hazards, groundwater, geoenvironment of mines and geological relics). The total number of records in the system library is as follows: 4 467 colors, 954 patterns, 641 line styles and 2 912 symbols.

4.2 Coding Rules

4.2.1 Element Coding Rules

With a special focus on stability, uniqueness, compatibility, practicability and scalability, the code is composed of six factors, namely, spatial scale, scale, map system category, map name, layer name and coordinate system, and occupies nine digits, namely, two digits for spatial scale, one digit for scale, one digit for map system category, two digits for map name, two digits for layer name and one digit for coordinate system.

(1) Spatial scale code

National code: A0.

Area code: Songnen Plain B1, Yangtze River Delta Economic Zone B5, Circum-Bohai Sea Economic Zone B6, Urban Cluster in the Middle Reaches of the Yangtze River B7, Chengdu-Chongqing Economic Zone B9, Huang-Huai-Hai Plain BB, Guangxi Beibu Gulf Economic Zone BE, Ordos Basin BF, Jianghan-Dongting Plain BG, Economic Zone on The West Coast of the Taiwan Strait BH, Three Gorges Reservoir BJ, Pearl River Delta Economic Zone BK, Changjitu Economic Zone BM.

(2) Scale code

G for 1：5 000 000; H for 1：4 000 000; I for 1：2 500 000; K for 1：1 000 000 code, L for 1∶500 000; X for other scales.

(3) Map system category code

Geological and environmental conditions: 1; Geologic hazards: 2; Groundwater: 3; Geological environment of mines: 4; Geological relics: 5.

(4) Map name

Expressed in two digits; if exceeded, letters are added in alphabetical order (99, 9A, 9B, 9C,⋯, 9Y, A1, A2,⋯, AY, B1, B2,⋯, YY).

Integrated map name is represented by 00.

(5) Map layer

Professional map layer is represented by two digits, with the same encoding rules as that of the map name.

(6) Coordinate system

Expressed in one digit. 0 represents geographic coordinate system; 1 represents planar rectangular coordinate system.

Take the landslide hazard point map layer of the China Landslide and Debris Flow Distribution Map (1∶5 000 000) as an example. Spatial scale: national code A0; scale: 1∶5 000 000, code G; map system category: the geologic hazard, code 2; map name: China Landslide and Debris Flow Distribution Map, code 01; map layer name: landslide hazard point, code 01; coordinate system: plane rectangular coordinate system, code 1. Thus the map layer is represented as A0G201011.

4.2.2 Primitive Coding Rules

The database adopts professional layer name+5 digits coding. For example, the coding of the landslide hazard point map layer of the China Landslide and Debris Flow Distribution Map (1∶5 000 000) is expressed as A0G201011. Thus the primitive code is A0G20101100001, A0G20101100002, and so on.

4.3 Structure of Attribute Table

The content of the attribute table includes 2 parts: element code and geometric feature. Element code includes data item name, code, definition or description. Geometric features include data type and length, constraints, range, unit, etc.

Taking the rockmass engineering geological map layer as an example, the data item name includes uniform number, rockmass type, rock strength and rockmass structure, with attribute structure shown in Table 2.

Table 2 Attribute Structure of Rockmass Engineering Geological Map Layer

Number	Data item name	Data item code	Definition or description	Data type and length	Constraints	Range	Unit
1	Uniform number	HJCAABQ	Numbered according to requirements	C14	M	Free text	/
2	Rockmass type	GCCC	Rockmass code	C1	M	1–4	/
3	Rock strength	YSQD		C10	O	See instructions	/
4	Rockmass structure	YTJG		C10	O	See instruction	/

Instruction for filling in data items:

(1) Unified number: coded according to element coding rules.

(2) Rockmass type: fill in the code and select the value: 1-magmatic rock formation, 2-clastic rock formation, 3-carbonate rock formation, 4-metamorphic rock formation.

(3) Rock strength: single choice: hard rock, relatively hard rock, and weak rock.

(4) Rockmass structure: single choice: block structure, thick layered structure and thin layered structure.

4.4 Element Map Layers

The element map layer of the Database of Geological Environmental Map System of China includes the geographical element layer and the professional element layer.

The geographical element layer includes boundary element.WL, water system.WL (WP), water system (wells and springs).WT, residential area.WT (WL or WP), railway.WL, highway.WL, geomorphology (mountain elevation point).WL, geomorphology (topographic contour line).WL, etc.

There are 163 professional element layers (Table 3), with 337 833 primitives.

4.5 Metadata Construction

Metadata construction is conducted for every map in the *Geological Environmental Map System of China* according to requirements. Based on the standards of geological environmental metadata, and centered around the *Geological Information Metadata Standard* and Geological Environmental "Metadata", the geological environment metabase is established to store the names, descriptions, keywords, spatial locations, abstracts and time of basic data (digital data), data products and information products, business data, among others.

Metadata editing includes:

(1) Metadata information

This information includes metadata name, metadata creation date, contact unit, identification, data quality, content,etc.

(2) Identification

This information includes geographic identifiers, data representation, subject category, identification, contact, keyword, west longitude, east longitude, south latitude, north latitude, start time of data collection, end time of data acquisition, file name of static browse, dataset access restriction, dataset purpose restriction, and dataset use restrictions, dataset security level, dataset format name, dataset format version, dataset maintenance & updating frequency,etc.

(3) Dataset quality

This information includes data quality acceptance instructions, data source instructions, data processing steps, etc.

(4) Spatial frame of reference

This information includes SI_name of spatial reference frame based on geographical indication, SC_coordinate name of coordinate-based spatial reference frame, coordinate system type, coordinate system name, name of vertical coordinate reference frame.

(5) Content

This information includes the name of element (entity) type, attribute list.

(6) Information distribution

This information includes distribution contact, ordering instruction, media name, media description, etc.

(7) Citation and contact of relevant institution

This information includes the name of the cited material, production and release date of the cited material, as well as contact information, telephone number, detailed address, city, administrative region, country and postal code of the relevant institution.

Table 3 Element Map Layers of Geological Entities

Number	Type	Element Map Layers of Geological Entities
1	Geological environmental conditions	Geoenvironmental zoning lines.WL, Geoenvironmental zoning.WP, Geological environment safety level.WL, High incidence area of land subsidence.WL, Fault line.WL, Geological boundaries.WL, Karst environmental geology zoning.WP, Geological zoning boundaries of karst environment.WL, Typical karst phenomena and resources.WT, Typical karst phenomena and resources-canyons.WL, Main karst geologic hazards and environmental geological problems.WT, Desertification.WP, Rocky desertification.WP, Quaternary isopachy.WL, Quaternary basins.WP, Late Cenozoic volcanic rocks.WP, Late Cenozoic volcanoes.WT, Type and activity of active faults.WL, Active block boundaries.WL, Active block partitions.WP, Earthquake.WT, Earthquake surface rupture zone.WL, Focal mechanism solution data.WT, GPS observation data.WT, Classification of engineering geology of rock masses.WP, Classification of soil engineering geology.WP, active fault distribution.WL, Epicentral distribution of earthquakes.WT, Crater distribution.WT, Stress field and crustal movement characteristics.WT, Crustal rising and falling amplitude of neotectonic movement.WT, Collapse-slip flow distribution.WT, Distribution of ice dunes and ice cones.WT, Distribution of karst phenomena.WT, Anthropogenic engineering geological phenomena.WT, Groundwater burial boundary and depth.WL, Distribution of springs.WT, Distribution of erosive springs or boreholes.WT, Permafrost and snow cover distribution.WP, CO_2 geological storage demonstration project distribution.WP, Distribution of boreholes.WT, Lithologic distribution.WP, Quaternary genetic types and epoch-polygon.WP, Quaternary genetic types and epoch-line.WL, Quaternary lithology-polygon.WP, Quaternary lithology-line.WL, Neotectonic movement trace-tectonic line.WL, Neotectonic movement trace-point.WT, Geomorphology-line.WL, Geomorphology-point.WT, Geomorphology-polygon.WP, Landslides and debris flows.WT, Permafrost distribution.WP, Pre-Quaternary bedrock and its elevation zonation-polygon.WP, Pre-Quaternary bedrock and its elevation zoning-line.WL, Distribution of buried Quaternary deposits.WP, Buried Quaternary deposit boundary.WL, Quaternary isopachy.WL, Loess isopach.WL, Maximum transgression range line.WL,Spring.WT, Geological point.WT, Additional line.WL, Other point.WT, Environmental geological zoning.WP, Environmental geological zoning boundary.WL, Rock type.WT, Soil type.WT, Rock soil type boundary.WL, Active fault.WL, Earthquake.WT, Environmental geological problem (polygon).WP, Environmental geological problem (line).WL, Environmental geological problem (point).WT, Groundwater hydrogeochemical anomaly and pollution point.WT, Soil geochemical anomaly.WT, Geological resources.WT, Selenium zoning.WP, Selenium isoline.WL, Vegetation zoning boundary.WL, Endemic.WP

Continued table 3

Number	Type	Element Map Layers of Geological Entities
2	Geologic hazards	Disaster points of landslide flow.WT, Hidden trouble points of landslide flow.WT, Average annual rainfall isoline.WL, Landslide flow susceptible area.WP, Cumulative land subsidence.WP, Subsidence rate isoline.WL, Subsidence center value.WT
3	Groundwater	Types of groundwater resources.WP, Boundary of groundwater resource types.WL, Modulus of natural recharge resources.WP, Runoff modulus.WP, Hydrogeological zoning.WP, Hydrogeological zoning boundaries.WL, Groundwater resources of the province (city).WT, Groundwater resources of main plains (Basins).WT, Proportion of groundwater supply in major cities.WT, Saline water distribution area.WP, Permafrost distribution.WL, Glaciers, snow cover areas.WP, Groundwater salinity and major hydrochemical types zoning.WP, Environmental geological problems related to irrational exploitation and utilization of groundwater (point).WT, Environmental geological problems related to irrational exploitation and utilization of groundwater (line).WL, Environmental geological problems related to irrational exploitation and utilization of groundwater (polygon).WP, Environmental background of typical trace elements in groundwater.WP, Groundwater characteristic contaminants.WT, Contours of nitrate and nitrogen in groundwater.WL, Contours of nitrite nitrogen content in groundwater.WL, Contours of ammonia nitrogen content in groundwater.WL, Contours of permanganate content in groundwater.WL, Contours of volatile phenols in groundwater.WL, Contours of cyanide content in groundwater.WL, Types of shallow groundwater and its water abundance.WP, Types of deep groundwater and its water abundance.WP, saline water distribution.WP, Frozen layer water in middle and low latitudes.WP, Sporadic distribution of phreatic aquifer.WP, Contour line of confined buried depth.WL, Surface water dividing line.WL, Underground river.WL, Roof buried depth contour line.WL, Contour line of frozen layer thickness.WL, Spring point.WT, Thermal reservoir-type zoning.WP, Geothermal resources.WP, Uplift-type geothermal distribution.WP, Sedimentary basin-type geothermal area (field) distribution.WP, Main fault.WL, Geothermal well.WT, Geothermal flow point.WT
4	Geological environment of mines	Non-metal mines.WT, Metal mines.WT, Coal mines.WT, Ore groups.WT, Mineral resources development zone.WP, Mineral resources concentrated mining area.WP, Geomorphological unit.WP, Mine geological environment protection and treatment zoning.WP, Already implemented treatment engineering.WT, Mine geological environment first-class protection zone.WP, Mine geological environment second-class protection zone.WP, Mine geological environment third-class protection zone.WP
5	Geological relics	Geological relics-stratigraphic sections.WT, Geological relics-rock profiles.WT, Geological relics-structural profiles.WT, Geological relics-important fossil occurrence.WT, Geological relics-important rock and mineral occurrence.WT, Geological relics-rock and soil physiognomy.WT, Geological relics-water physiognomy.WT. Geological relics-tectonic physiognomy.WT. Geological relics-glacial physiognomy.WT. Geological relics-coastal physiognomy.WT, Seismic relics.WT, Geologic hazard relics.WT, Human fossil occurrence.WT, Biota fossil occurrence.WT, Plant fossil occurrence.WT, trace fossil occurrence.WT

5 Data Quality Control and Review

5.1 Data Quality Control

In the process of database construction, database inspection should be conducted according to a three-level inspection method, with the following main contents.

Level I inspection: self-inspection and mutual inspection by operation group. 100% comprehensive inspection required.

Level II inspection: on the basis of self-inspection and mutual inspection by the operation group, the project leader or project quality inspector shall conduct 100% comprehensive inspection on the data produced by the operation group.

Level III inspection: based on level II inspection, another inspection is conducted on the data produced by the operation group. Level III inspection should be conducted by the quality management department or quality inspector of the production unit in accordance with the sampling proportion.

Problems found at each level of inspection or acceptance should be thoroughly amended and can be submitted to the next level of inspection or acceptance only after passing re-inspection.

Every staff member involved in map database construction should fill in the work log form, record the work contents of each day in full detail, which will be signed and approved by the leader of the operation team.

A list of participating institutions and quality control personnel in database construction is shown in Table 4.

Table 4 Participating Institutions and Quality Control Personnel in the Database Construction *of* the Map System

Number	Map name	Participating institution	Participant
1	China Geological Environment Zoning Map	China Geological Environmental Monitoring Institute	Xu Huizhen, Wang Yiping, Liu Qiong, Gao Mengmeng, Li Xiaolei, Xia Yao and Cao Feng
2	China Geological Environment Safety Level Map	China Geological Environmental Monitoring Institute	Meng Hui, Zhang Ruolin, Shi Jusong, Li Chunyan
3	Karst Environmental Geological Map of China	Institute of Karst Geology, Chinese Academy of Geological Sciences	Bi Xueli, Shi Jian, Zhou Lixin, Xu Qi, Chen Zhen, Bi Benteng, Yang Chen, Wei Yanlan, Yang Xiangpeng
4	Desertification Land Distribution Map of China	China Aero Geophysical Survey and Remote Sensing Center for Land and Resources	Sun Yongjun, Gao Huijun, Xing Yu, Li Xia, Shi Wenwen
5	Distribution Map of Active Faults in China and Adjacent Sea Areas	Institute of Geology, Chinese Academy of Geological Sciences	Wu Zhonghai, Zhou Chunjing, Ma Xiaoxue, Wang Jilong, Huang Xiaolong, Wu Xiaolin, Hu Mengmeng, Ha Guanghao, Liu Jie
6	Engineering Geological Map of China	Institute of Hydrogeology and Engineering Geology, Chinese Academy of Geological Sciences	Liang Guoling, Zhang Lizhong, Zhang Chunying, Zhu Jixiang, Shi Lei
7	Evaluation Map for Suitability of Carbon Dioxide Geological Storage in Major Sedimentary Basins of China and Adjacent Sea Areas	Center for Hydrogeology and Environmental Geology of China Geological Survey	Guo Jianqiang, Jin Xiaolin, Jia Xiaofeng, Zhang Senqi, Li Xufeng, Diao Yujie, Fan Jijiao, Zhang Hui, Zhang Yang, Hu Lisha, Zhang Chao, Zhang Chenglong

Continued table 4

Number	Map name	Participating institution	Participant
8	Quaternary Geological Map of the People's Republic of China and Its Adjacent Sea Areas	Institute of Hydrogeology and Engineering Geology, Chinese Academy of Geological Sciences	Liang Guoling, Zhang Lizhong, Zhang Chunying, Zhu Jixiang, Shi Lei
9	Environmental Geological Map of Coastal Areas of China	Tianjin Center, China Geological Survey	Meng Qinghua, Yang Qiqing, Xie Hailan, Wang Xiaodan, Xia Yubo, Liu Hongwei, Liu Futian, Meng Lishan, Bai Yaonan, Du Dong
10	Environmental Geological Map of the Key Economic Zone Around the Bohai Sea	Tianjin Center, China Geological Survey	Meng Qinghua, Yang Qiqing, Xie Hailan, Wang Xiaodan, Xia Yubo, Liu Hongwei, Liu Futian, Meng Lishan, Bai Yaonan, Du Dong
11	Environmental Geological Map of Yangtze Delta Economic Zone	Nanjing Center, China Geological Survey	Su Jingwen, Jiang Yuehua, Huang Jinyu, Zhang Taili, Jia Junyuan, Zhou Quanping, Li Yun, Liu Hongying, Zhu Yiping
12	Environmental Geological Map of the Economic Zone (Core Area) on the West Coast of the Straits	Nanjing Center, China Geological Survey	Xing Huaixue, Ge Weiya, Li Liang, Tian Fujin, Li Yunfeng, Chang Xiaojun, Tang Xiaowen
13	Environmental Geological Map of Urban Agglomeration in the Middle Reaches of the Yangtze River	Wuhan Center, China Geological Survey	Lu Tao, Liu Fengmei, Shao Changsheng, Yang Yanlin, Zhang Ao, Wang Cen
14	Environmental Geological Map of the Pearl River Delta Economic Zone	Wuhan Center, China Geological Survey	Liu Fengmei, Huang Changsheng, Zhao Xinwen, Liu Guangning
15	Environmental Geological Map of Beibu Gulf Economic Zone	Wuhan Center, China Geological Survey	Liu Fengmei, Li Qinghua, Liu Huaiqing
16	Environmental Geological Map of Chengdu-Chongqing Economic Zone	Chengdu Center, China Geological Survey	Li Minghui, Xu Ruge, Wang Donghui, Tian Kai, Chen Xuyu
17	Environmental Geological Map of Changjitu Economic Zone	Shenyang Center, China Geological Survey	Zhao Haiqing, Dai Yajian, Shi Xufei, Guo Xiaodong
18	Environmental Geological Map of Urban Agglomeration in Guanzhong Basin	Xi'an Center, China Geological Survey	Zeng Qingming, Zhu Hua, Li Qing
19	Environmental Map of Soil Selenium in the Huang-Huai-Hai Plain	China Geological Environmental Monitoring Institute	Wang Yi, Wang Yiping, Gao Mengmeng, Li Xiaolei, Liu Qiong, Tong Xiaoxia, Xia Yao, Cao Feng
20	Distribution Map of Collapse and Landslide Debris Flows in China	China Geological Environmental Monitoring Institute	Yin Chunrong, Qu Xueyan, Yang Xudong, Tong Bin, Fang Hao, Zhang Yanling
21	Prevalence Map of Landslides and Debris Flows in China	China Geological Environmental Monitoring Institute	Fang Hao, Li Yuan, Yang Xudong, Qu Xueyan, Yin Chunrong, Tong Bin
22	Current Situation of Land Subsidence in China	China Geological Environmental Monitoring Institute	Wang Yunlong, Guo Haipeng, Zhu Juyan, Wang Guijie, Wang Haigang, Qin Tongchun, Zang Xisheng

Continued table 4

Number	Map name	Participating institution	Participant
23	Distribution Map of Collapse Landslide and Debris Flow in Three Gorges Reservoir Area	China Geological Environmental Monitoring Institute	Yang Jianying, Ye Runqing, Cheng Wenming, Wu Runze, Fu Xiaolin, Huo Zhitao
24	Current Situation of Land Subsidence in the Yangtze Delta Area	Shanghai Institute of Geological Survey	Yan Xuexin, Yang Tianliang, Wu Jianzhong, Zhu Xiaoqiang, Gong Xulong, Wu Mengjie, Shen Huizhen, Min Wang, Huang Xinlei, Lin Jinxin, Zhao Yunjie
25	China Groundwater Resources Map	Institute of Hydrogeology and Environmental Geology, Chinese Academy of Sciences	Zhang Zonghu, Qin Yisu, Jing Jihong, Sun Jichao, Dai Xisheng, Liu Chunyan
26	China Groundwater Environment Map	Institute of Hydrogeology and Environmental Geology, Chinese Academy of Sciences	Sun Jichao, Jing Jihong, Wang Shan, Li Zhenghong, Liu Chunyan
27	Hydrogeological Map of China	Institute of Hydrogeology and Environmental Geology, Chinese Academy of Sciences	Cheng Yanpei, Dong Hua, Zhang Jiankang, Wen Xueru, Yue Chen, Gai Liqiang, Yi Qing, Ni Zengshi, Liu Kun, Qiu Yuling, Jin Fengqing, Pei Yushan
28	Geothermal Resources Distribution Map of China	Institute of Hydrogeology and Environmental Geology, Chinese Academy of Sciences	Wang Guiling, Liu Zhiming, Lin Wenjing, Zhang Wei, Liang Jiyun, Liu Feng, Li Long
29	Hydrogeological Map of the Huang-Huai-Hai Plain	Institute of Hydrogeology and Environmental Geology, Chinese Academy of Sciences	Cheng Yanpei, Dong Hua, Zhang Jiankang, Wen Xueru, Yue Chen, Gai Liqiang, Yi Qing, Ni Zengshi, Liu Lingxia, Wang Chunxiao, Liu Kun, Qiu Yuling, Jin Fengqing, Pei Yushan
30	Hydrogeological Map of the Ordos Basin	Xi'an Center, China Geological Survey	Zhu Hua, Zhao Zhenhong, Li Qing, Zeng Qingming
31	Hydrogeological Map of Songnen Plain	Shenyang Center, China Geological Survey	Zhao Haiqing, Dai Yajian, Shi Xufei, Guo Xiaodong
32	Hydrogeological Map of Jianghan-Dongting Plain	Wuhan Center, China Geological Survey	Zhang Jinde, Zhang Zhipeng, Ren Ying, Yu Yang
33	Map of Geological Environment Problems in Mines of China	China Geological Environmental Monitoring Institute	Yu Wang, Xiao Pan, Guan Yitao, Yao Tengfei
34	Zoning Map for Protection and Control of Mine Geological Environment of China	China Geological Environmental Monitoring Institute	Zhang Jinde, Zhang Zhipeng, Ren Ying, Yu Yang
35	Distribution Map of Important Geological Remains Resources in China	China Geological Environmental Monitoring Institute	Dong Ying, Huang Zhuo, Ji Yannan, Chen Zihui, Cao Xiaojuan, Wang Jiankun, Yang Hongbin
36	Distribution Map of Important Palaeontological Fossils in China	China Geological Environmental Monitoring Institute	Ji Yannan, Cao Xiaojuan, Dong Ying, Tang Can, Huang Zhuo, Yang Hongbin, Liu Rong, Chen Zihui, Lou Lianhui, Wang Jiankun

To ensure the quality of data, the project team has also developed a stand-alone version of the map system management system, which includes data inspection modules for the following contents. ① Data standardization: including layer naming, data item naming, data type, field length, etc.; data logic, including value range; the required items of data; missing layers and data items, and repetition of uniform number, and matching with layer name. ② Consistency of topology: coordinate overlap, arc intersection, arc self-intersection, arc overlap, dangling arc, etc. Data inspection can be conducted for a map system, or a single map layer or a single map. An inspection report for staff to check and modify will be automatically generated upon the completion of inspection for staff to check and modify.

5.2 Quality Review

Each map layer has uniform map parameters and system library, with unique element number, and no errors or omissions in element acquisition. The overall or partial offset of the graph does not exceed 0.2 mm on the map. The data adheres to a strict topological structure, with no topological errors. The attribute layer name and the attribute structure of point, line and surface are consistent with the standards of database construction, and correspond to each element. The data are relatively complete, with elements well connected to the attributes. The error rate of the attribute data is lower than 2%. Quality supervision and management measures during the process of database construction are well in place. The quality management system of self-inspection, mutual inspection and random inspection are strictly followed in the process of database construction, with complete process documents and quality inspection records, yielding high-quality, reliable and highly applicable digital results with significant value for hydrological-engineering-environmental geological research.

6 Database Sharing and Publishing

At present, the database is mainly shared and published through the *GeoCloud* platform "National Geological Environmental Map System". It provides users at all levels with specialized data information, enabling a series of functions, including data resource catalogue, metadata information, manual management and query of spatial attributes of map layers, while taking into account the needs of both professional technicians and the general public and meeting the needs of users at different levels. The database provides a technical guide to the national geological environmental map system for all users of the *Geocloud*, thus standardizing mapping work, and building a bridge of communication with users and a feedback mechanism for problems in the system.

7 Conclusion

(1) A series of geological environmental surveys have been carried out throughout China since the national land survey in 1999, accumulating vast amounts of data. This database integrates and combs through the latest national survey data, selecting effective data and unifying the coordinate system. The massive data involve rich professional content, providing detailed fundamental information for geological environmental protection and management,

spatial planning of land, ecological restoration and prevention and control of geological disasters. The database contains 163 map layers and 337 833 elements, with a capacity of approximately 8.8 GB.

(2) For the first time, a framework of the geological environmental map system of China has been established at two levels (the whole country and key areas), covering five fields, namely, geological environmental conditions, geologic hazards, groundwater, geological environment of mines and geological relics. Map compilation and database construction are carried out on the basis of the "Unified Geographical Data Framework", "Unified Mapping Technical Requirements" and "Unified Database Construction Technical Requirements", which ensures standardized map system compilation and database construction.

(3) The data catalogue, metabase and spatial database based on uniform geographical data framework are constructed with uniform structure, format and code, laying a foundation for the storage, management, updating, publishing, data sharing and cloud service of the map system.

(4) A stand-alone version of the map system management system is developed to facilitate effective management, aided map compilation, and dynamic updating in the whole compilation process with improved efficiency and service, significantly facilitating the storage and management, sharing, publishing and social service of map data.

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