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1∶2 500 000 华北侵入岩地质图空间数据库

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摘要: 1∶2 500 000 华北侵入岩地质图空间数据库是以华北地区近年完成的 1∶250 000、1∶50 000 基础地质调查资料以及专题研究为依托，结合国内外最新文献成果编制而成。地质图以研究区侵入岩为主要研究对象，通过编图建库的手段表达华北地区侵入岩时空格架、物质组成以及空间分带。图幅采用 MapGIS 6.7 软件制作，侵入岩按“岩性+年代”进行表示，包含侵入岩面元单位 1743 个，地层单位 1534 个，同位素年龄数据 404 个，并对侵入岩面元及同位素年龄赋予了相应属性，总体数据量约 218 MB。地质图重点突出了华北地区岩浆岩分带，详细梳理了不同岩浆岩带的空间分布、岩浆期次、岩石组合、地球化学特征及构造背景等信息，充分反映了近年来地质调查和科研工作新成果，能够为后续地质调查、科学研究以及生产工作提供基础地质图件及信息资料服务，对服务资源和经济社会建设具有一定参考意义。

关键词: 华北；侵入岩；1∶2 500 000地质图；空间数据库；同位素年龄；地质调查工程

数据服务系统网址: http://dcc.cgs.gov.cn

1　引言

伴随着太古宙华北克拉通的形成、元古宙大陆边缘裂解作用、古生代中亚造山带演化、中生代太平洋板块俯冲以及克拉通破坏等构造运动 (Gao S et al., 2004；翟明国和彭澎，2006；孙卫东等，2008；Xiao WJ et al., 2009；Xu B et al., 2015；刘超辉和刘福来，2015)，华北地区发育了多期次、大规模的岩浆活动，直接或间接地导致了该地区多条重要成矿带的形成 (毛景文等，2003；肖文交等，2008；张晓辉和翟明国，2010；郑全波等，2019)，因此长期以来华北地区重大岩浆事件都是地质研究的热点。前人对这些重要岩浆作用的研究多是针对某一具体区域或问题进行，缺少系统的岩浆岩带划分与总结，对华北地区重大岩浆事件的作用期次、时空展布、岩浆序列等方面理解尚不透彻，制约着华北地区基础地质问题的解决。同时，在成果的表达方式上绝大多数以论文形式体现，地质调查资料引用较少，综合性及直观性方面较为不足，不利于成果的转化及社

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会应用。

近年来，通过国土资源大调查、矿产资源潜力评价、全国地质构造区划综合研究与区域地质调查综合集成等项目的实施 (肖克炎等，2013)，华北地区新部署了一系列1∶50 000、1∶250 000 区域地质调查以及不同片区专题研究工作，而同期新一代地质志的编纂则系统性地总结了各省最新基础地质研究进展，这些工作大幅提升了对华北地区地质演化的认识。此外，随着地理信息系统和数字地质制图等新技术和新方法的广泛应用，这些项目也一并提供了多种比例尺的基础地质图及数据库，除 1∶50 000、1∶250 000 等区域地质调查标准图件外，还包括许多小比例尺专题或分省地质图。有效利用此类成果，综合汇总现有区域地质调查和科学研究资料，非常有助于对华北地区岩浆时代、性质及构造成因等问题的深化认识。

1∶2 500 000 华北侵入岩地质图空间数据库即以华北地区新获得的基础地质资料为依托、以华北地区重大岩浆事件和构造背景为切入点，充分利用近年来完成的不同比例尺数字地质图和数据库资料，结合最新地质调查和论文成果，通过编制 1∶2 500 000 侵入岩地质图 (图 1) 并建立相应数据库 (表 1，杨泽黎等, 2020) 的方式，对华北地区以侵入岩为代表的重大岩浆事件及其相关岩浆岩带划分进行研究。一方面建立了华北地区侵入岩时空格架，提升了对华北地区岩浆时空演化、岩石组合特征和构造背景的认识，进而为古亚洲洋演化、燕山期陆内造山以及华北克拉通破坏等重大基础地质问题提供支撑；另一方面也为填补华北地区此前在侵入岩专题地质图空间数据库的空白，以更直观、综合的方式体现相关进展，实现信息资源共享，为华北地区地质调查、科学研究以及生产工作提供基础地质图件及资料服务。

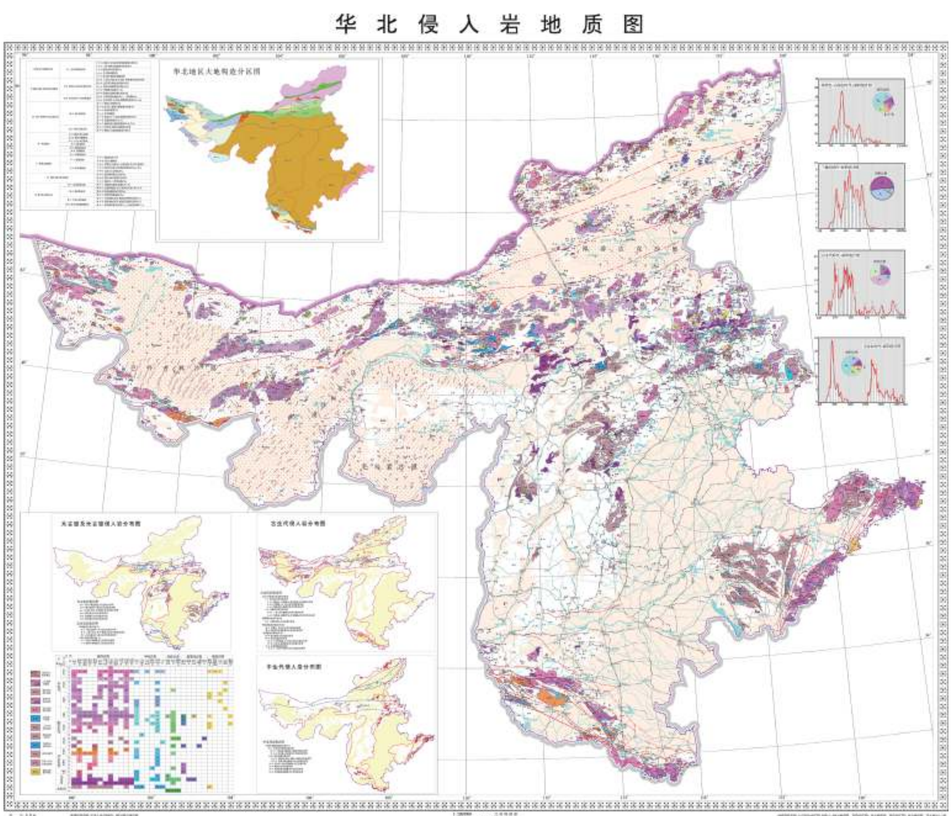

图 1　华北地区 1∶2 500 000 侵入岩地质图示意图

表 1　数据库 (集) 元数据简表

条 目	描述
数据库(集)名称	1∶2 500 000华北侵入岩地质图空间数据库
数据库(集)作者	杨泽黎，中国地质调查局天津地质调查中心 王树庆，中国地质调查局天津地质调查中心 胡晓佳，中国地质调查局天津地质调查中心
数据时间范围	2014–2015年
地理区域	除内蒙古东三盟外的华北地区，经纬度范围为：东经97°10'～122°20'，北纬31°23'～46°45'
数据格式	MapGIS
数据量	218 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“华北重大岩浆事件及其成矿作用和构造背景综合研究”(项目编码：12120144020401)资助
语种	中文
数据库(集)组成	1∶2 500 000华北侵入岩地质图空间数据库包括：系统库、字符库、属性库；构造相分区、岩浆岩分带、地理底图、矿点等相关的数据库子库；前寒武纪岩体、早古生代岩体、晚古生代岩体、三叠纪岩体、侏罗纪–白垩纪岩体、地层等6个专题层

2　数据采集和处理方法

2.1　数据基础

地质图编制按照项目要求，充分收集了华北地区近年来完成的区域地质调查、综合研究以及文献资料。区域地质调查资料包括 2014 年前完成的 13 个 1∶250 000 区域地质调查项目以及 39 个 1∶50 000 区域地质调查项目的图件、报告或阶段性成果，同时紧密跟踪正在开展的 42 个 1∶50 000 和 1 个 1∶250 000 区域地质调查项目进展；专题研究方面则收集了“吕梁–五台山地区地质图 (1∶500 000)”、“华北陆块北缘地质图 (1∶500 000)”、“大兴安岭成矿带 (南段) 地质图 (1∶1 000 000)”、华北地区矿产资源潜力评价与综合项目以及华北地区各省地质志附图等基础图件空间数据库和成果资料；文献方面收集了公开发表的华北侵入岩相关中英文文献约 330 篇，侵入岩年代学及地球化学数据作为编图参考。地质资料的引用截至 2014 年底，部分资料截至 2016 年底，上述区域地质调查项目以及相关地质图件、科研成果为本次编图工作奠定了资料基础。

资料显示，华北地区地壳演化的地质记录始于古太古代 (Wan YS et al., 2005)，其中：①古–中太古代为华北陆核生长阶段，相关岩石主要分布于胶东栖霞地区和河南鲁山地区，以英云闪长岩–奥长花岗岩组合为主；新太古代 2.8～2.5 Ga 为陆壳增生期，形成的岩浆岩组合主要为岛弧型火山岩及大规模的 TTG（英云闪长岩＋奥长花岗岩＋花岗闪长岩）及 GMS（花岗岩＋二长花岗岩＋钾长花岗岩）型侵入岩 (Zhai MG et al., 2005；Geng YS et al., 2006；翟明国，2010)。②元古宙早期仍以陆块拼合为主，中元古代则为裂谷发育期，出现大面积碱性花岗岩、基性岩墙群以及石英正长岩–环斑花岗岩 (二长花岗岩) 组合，新元古代进入相对稳定沉积阶段 (翟明国和彭澎，2006；刘振锋等，2006；刘超辉和刘福来，2015)。③早古生代华北地区南北两侧的兴蒙造山系和秦祁昆造山系均经历了大规模俯冲过程，北侧在二连–东乌旗、苏左旗–锡林浩特、包尔汉图–白乃庙–带形成大量岛弧侵入岩 (Jian P et al., 2008；Xu B et al., 2015)，南侧则出现陆

块俯冲、岛弧和后碰撞岩浆作用记录 (郭彩莲和陈丹玲，2011；Wang XX et al., 2013；王江波等，2018)；而晚古生代随着古亚洲洋在二叠纪末沿索伦山–西拉木伦线的消亡，兴蒙造山带及华北陆块北缘形成了岛弧岩浆岩、碱性花岗岩等构成的大规模岩浆弧 (Zhang SH et al., 2009；Jian P et al., 2010；Liu YJ et al., 2017)。④中生代华北陆块区与南北两大造山系连成整体，逐渐被太平洋构造域控制，三叠纪秦祁昆造山系发生陆内深俯冲，中侏罗世岩浆作用则出现较典型的弧火山岩和 TTG 性质侵入岩组合并具有大陆弧背景，早白垩世则由侏罗纪的挤压转化为伸展背景，同时下地壳拆沉导致岩石圈减薄和巨量岩浆活动，出现后碰撞–后造山背景的 A 型花岗岩 (汤加富等，2004；Gao S et al., 2004；刘福来和薛怀民，2007；孙金凤和杨进辉，2013)。

2.2 数据处理过程

2.2.1 数据准备

华北地区侵入岩地质图编图范围包括除东三盟地区外的内蒙、河北、河南、山东、山西、北京、天津等省市区。地质图采用 MapGIS 6.7 软件编制，数据比例尺为 1：2 500 000，以毫米为单位，使用北京 54 坐标系，投影类型为兰伯特等角圆锥投影，第一标准纬度为 34°、第二标准纬度为 42°、中央子午线经度为 110°、投影原点纬度为 34°。根据以上参数，将前期收集到的 1：50 000、1：250 000 区域地质调查图件以及小比例尺专题和分省地质图通过投影转换、误差校正与 1：2 500 000 华北地理底图套合，再对不同地质图进行拼接形成基础底图。另一方面，详细梳理区域地质调查报告和论文资料中的岩体岩性、坐标、地球化学以及年龄数据并进行汇总，通过坐标投影生成相同参数的.wt 格式点文件以指导后续成图。

2.2.2 图幅编制

(1) 建立标准：侵入岩单位代号、编码按照《区域地质图图例》(GB958−99)，采用“岩性+时代”的表示方法，突出岩体的岩性特征，不同资料中侵入岩体按照标准中的酸性、中性、基性、超基性、碱性等类型进行合理归并，岩体类型命名参照国标《岩石分类和命名方案–火成岩岩石分类和命名方案》(GB/T 17412.1–1998)，即 QAPF 分类图，建立统一的岩石代号。地层则按照时代合并简化，不同地层断代填充不同颜色以示区别，最终归并的地层为新生界 (N–Q)、侏罗系–白垩系 (J–K)、三叠系 (T)、上古生界 (D–P)、下古生界 (Є–S)、元古宇 (Pt)、太古宇 (Ar) 等 7 个单位。图面表达精度方面，面状分布的岩体规模不小于 2 mm×2 mm，线状岩体宽度不小于 2 mm，对规模较小但具有指示构造环境和成因意义的特殊地质体，或比较特殊的岩石类型等，均按相似形原则夸大表示。

(2) 拓扑成图：根据资料汇总形成的基础底图在 MapGIS 6.7 系统下进行矢量化编辑、拓扑造区以及填色整饰，形成相应点.wt、线.wl、面.wp 文件，并按照项目统一要求建立相关属性结构。拓扑成图过程中主要参照 1：250 000 区域地质调查图件、专题地质图以及各省地质志资料进行边界勾绘，1：50 000 地质图以及学术论文数据则作为地质体界线、年代、岩性等问题进行修正的参考，随后按照属性结构填写侵入岩体属性数据并进行人工检查。

(3) 编制角图及图面整饰：①根据华北地区最新研究成果及专题报告编制大地构造分区角图，按照构造单元及区域性断裂划分构造分带。②根据岩浆岩时代及空间分布、构造演化阶段 (克拉通形成、改造、周缘造山作用、陆内造山作用等) 及岩浆岩的演化规

律将华北地区侵入岩划分为4个阶段27个岩浆岩亚带并编制角图。③汇总地质调查成果及论文数据，形成华北地区侵入岩时代及面积统计图。④地质图按照统一要求进行整饰，图例编排的位置、字体的大小采用统一规格，重点突出侵入岩内容。

3　数据样本描述

3.1　数据类型

MapGIS 6.7 文件，地质面.wp，地质线.wl，地质点.wt。

3.2　图层内容

点实体：同位素年代、地质体注记、地质符号、地质花纹、矿点、地理要素、地市名称。

线实体：地质体界线、断层、构造–岩浆岩分带、地理要素等。

面实体：地层、不同时代侵入体、地理要素等。

3.3　属性列表

华北1∶2 500 000侵入岩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，地质实体主要包含侵入岩面元及地层面元，侵入岩面元属性结构包括USERID、TYPE、ROCK_NAME、COLOR_NO、FILL_NO、FILL_COLOR、FILL_HEIGHT、LITHOLOGY、TIME、AGE和AGE_METHOD字段(表2)。其中，USERID为标识码，包含9个字节，前4位表示1∶500 000图幅位于1∶1 000 000国际分幅中的图幅号，图幅号字母用2位数字代替，表示列的数字不变，第5位数字表示1∶500 000国际分幅图幅号后的字母，也分别用数字替代，后4位数字为岩体的顺序；AGE_METHOD为同位素测试方法，“1”代表SHRIMP锆石U–Pb，“2”代表SIMS锆石U–Pb，“3”代表LA–ICP–MS锆石U–Pb，“4”代表蒸发法锆石U–Pb，“5”代表Ar–Ar激光，“6”代表K–Ar法，“7”代表Rb–Sr或Sm–Nd等时线法，“8”代表其他方法。地层保留侵入岩属性结构，但仅在ROCK_NAME及COLOR_NO中分别填写地层时代以及填充颜色。同位素投影点则根据论文或报告描述在属性中填写具体年龄及测试样品岩性。

表2　侵入岩面元属性结构

字段名	类型	字节宽度	小数位	说明
USERID	整型	9		标识码
TYPE	整型	8		岩体岩性代码
ROCK_NAME	字符型	20		岩石总称
COLOR_NO	整型	4		填充颜色
FILL_NO	整型	4		填充图案号
FILL_COLOR	整型	4		填充图案颜色号
FILL_HEIGHT	浮点型	6	2	填充图案高度
LITHOLOGY	字符型	20		侵入体岩性
TIME	字符型	20		侵入体时代
AGE	浮点型	6	2	同位素年龄
AGE_METHOD	整型	2		同位素测试方法

4 数据库构成

1：2 500 000 华北侵入岩地质图数据库以 MapGIS 数据格式建立，数据量约 218 MB。主图中包含侵入岩编图单位 1 743 个，按 5 大主要岩类以“岩性＋年代”表示；地层单位 1 534 个，由 1：500 000 数字地质图中岩石地层单位归并而成；收集的代表性岩体同位素年龄数据 404 个。

除主图外还建立了 3 个子数据库：

(1) 地理底图数据库及地理内容属性库，包括行政区、行政区界线、居民地、公路、铁路、河流、湖泊、海洋、地貌等内容。

(2) 岩浆岩分带数据库及属性库，包括覆盖地层、侵入岩及岩浆岩带划分等内容。

(3) 大地构造相划分数据库，包括断层、构造带以及构造单元划分等内容。

5 数据质量控制和评估

编图基础资料为 1999–2014 年华北地区完成的 34 幅 1：250 000 区域地质图及其数据库，224 幅 1：50 000 区域地质图及其数据库以及相关成果报告，包括华北地区大部分重要岩浆岩带。同时，汇总吸纳了晋冀成矿带、大兴安岭成矿 (南段) 带和豫西成矿带地质图 (1：500 000、1：1 000 000)、华北地区潜力评价–成矿背景基础研究编制的华北地区构造–地层区划图 (1：1 500 000)、华北地区各省地质志和地质图 (1：500 000) 等图件及相关成果资料，借鉴了区域性中小比例尺的编图经验。此外，充分收集了华北地区关于花岗岩研究的最新成果资料，包括中英文学术论文 330 余篇，区域地质调查报告 50 余份，收集筛选了研究区侵入岩高精度 (SHRIMP 及 LA–ICP–MS) 锆石年龄 730 余个，并将其中有明确坐标的 404 个数据进行投影作为编图参考，在此基础上还对兴蒙造山带以及华北克拉通北缘岩浆岩带进行了专题调查，对重点岩体进行了同位素定年和地球化学测试分析，补充了相关资料数据，保证了编图成果的真实可靠。

地质图数据库汇总成型之后，对全图进行了全面检查与修改，主要检查地质体接边属性、拓扑关系是否正确，针对地质体则检查属性及面元颜色、填充图案的完整性和准确性，以及属性和参数的匹配率，保证了数据库质量。在图面结构、构造–岩浆岩带划分等方面，进行了 2 轮专家审查，参照专家意见先后修改了数百处图面内容，对有争议的问题采用多数人接受的划分或表达方式，确保地质内容能够反映最新的主流认识。

6 数据库应用前景

在信息服务上，华北 1：2 500 000 侵入岩地质图可作为编制各种同比例尺专题图件的基础地质信息库，也可作为编制更小比例尺地质图的地质底图，从而为中国各种小比例尺地质图及相应专题图编制提供支持。在基础地质研究上，编图过程中根据构造–岩浆理论，对华北地区岩浆事件按时间和空间进行了划分，并详细总结了不同时期、不同分带中岩浆岩年代学测试结果、地球化学以及构造环境的差异，建立了华北地区岩浆岩时间、空间、物质成分及构造演化序列，相关结果按照元古宙、古生代、中生代分别汇总于图 2、图 3 和图 4，这些成果为该地区后续基础地质调查乃至资源勘查工作提供了科学支撑，提升了通过科技创新服务资源安全、经济社会发展和生态文明建设的能力。

图 2　华北地区元古宙岩浆岩时空分布、物质成分及构造环境

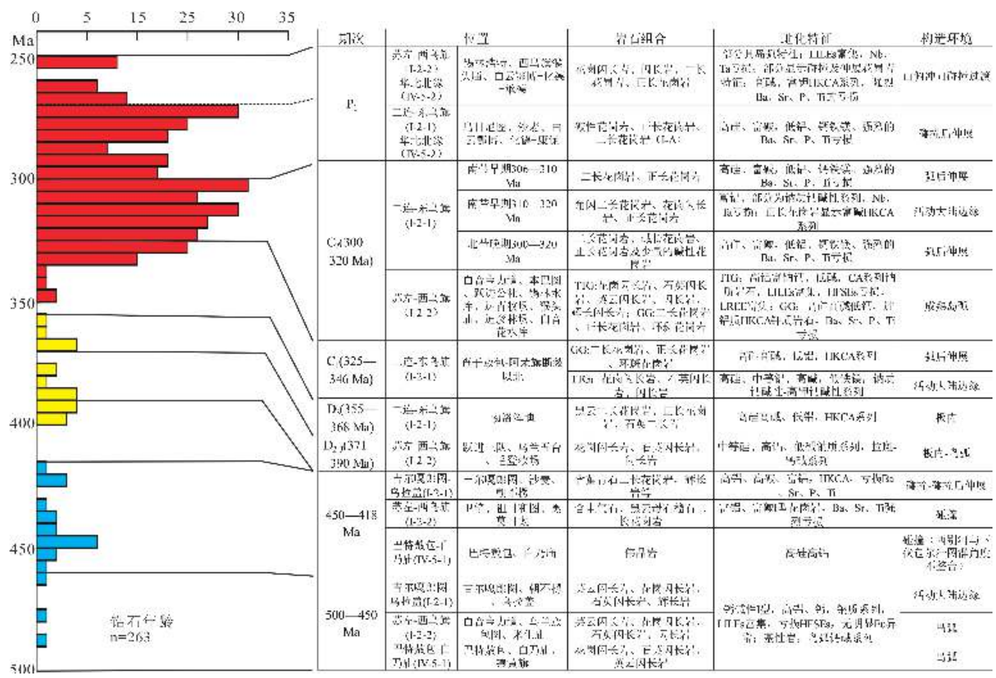

图 3　华北地区古生代岩浆岩时空分布、物质成分及构造环境

7　结论

华北 1∶2 500 000 侵入岩地质图是以板块构造及地球动力学理论等为指导，集成近年来华北地区区域地质调查、专题研究和科研文献的最新资料，应用数字制图等新技术新方法开展综合研究与地质图编制工作的成果。以侵入岩为主要对象，研究其时空分布及成因物源特征，系统性总结华北地区岩浆岩的时空演化、岩石组合、岩浆性质及构造背景，探讨岩浆作用与古亚洲洋演化、燕山期陆内造山以及华北克拉通破坏等构造事件的关系，初步建立了华北地区重大岩浆事件的空间格架，为基础地质问题解决提供翔实的地质资料。

(1) 突出了华北地区构造–岩浆岩带的表达。将华北自元古宙以来不同时代的侵入岩带及岩浆期次划分为 10 期岩浆作用，7 个岩浆岩带及 27 个岩浆岩亚带，同时总结了每

图 4　华北地区中生代岩浆岩时空分布、物质成分及构造环境

一期岩浆作用的时空分布、岩石组合、地球化学特征、可能的构造背景及动力学机制。

(2) 对兴蒙造山带等重点地区侵入岩空间分布、岩浆期次、岩石组合及成因构造背景进行了详细解剖。建立了两期三带的时空格架，新识别出部分具有重要构造意义的碱性花岗岩或蛇绿岩带，同时全面梳理了不同分带的岩浆活动特征及演化序列。

(3) 将燕山地区原划为早–中侏罗世的侵入岩大部分重新厘定为早白垩世，重新梳理了华北地区东部中生代侵入岩的时空分布规律和地球化学特征：三叠纪沿华北板块北部–东部周缘及兴蒙造山带分布，中侏罗世–早白垩世侵入岩沿太行山–大兴安岭向两侧逐渐变老；燕山地区中–晚侏罗世侵入岩具有类似埃达克岩特征，可能反映了加厚地壳背景，早白垩世侵入岩以高钾钙碱性和碱性花岗岩、碱性岩为主要岩石组合，指示了伸展的构造体制。

致谢：华北 1∶2 500 000 侵入岩地质图是一项集体成果，赵华雷、赵泽霖等技术人员为野外地质调查以及成果报告梳理提供了帮助，在空间数据库的建立过程中，得到谷永昌、刘永顺等多位专家的详细指导，在此致以最诚挚的感谢。

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Spatial Database of 1∶2 500 000 Geologic Map of the Intrusions in North China

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Abstract: The spatial database of 1∶2 500 000 geologic map of the intrusions in North China (also referred to as the Database) was established based on the data obtained from 1∶250 000– and 1∶50 000–scale basic geological surveys and special studies of North China conducted in recent years, as well as the latest literatures from China and abroad. Focusing on the intrusions in North China (also referred to as the study area), a geologic map was prepared and a database was built to express the spatial-temporal framework, material composition and spatial belt division of the intrusions in North China. The map was prepared with the MapGIS 6.7 software. The intrusions in the map were denoted by means of 'lithology + era'. The map, with a data size of about 218 MB, covers 1 743 graphic primitives of intrusions, 1 534 stratigraphic units and 404 pieces of isotopic age data. Meanwhile, corresponding attributes were assigned to the graphic primitives of the intrusions and the isotopic ages. The geological map highlights the division of magmatic rock belts in North China, with the data of different magmatic rock belts being collated in detail including spatial distribution, magma stages, rock association, geochemical characteristics, genesis and tectonic background. This Database fully reflects the new achievements obtained from geological survey and scientific research in recent years. Therefore, it will provide basic geological maps and data for future geological surveys, scientific research and production. In the meantime, to a certain extent, it can be used as a reference for resource exploration and economic and social development.

Key words: North China; intrusives; 1∶2 500 000 geologic map; spatial database; isotopic age; geological survey engineering

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

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1 Introduction

Multi-stage large-scale magmatic activities occurred in North China including the formation of the North China Craton in the Archean, the rifting of the continental margin in the Proterozoic, the evolution of the Central Asian Orogenic Belt in the Paleozoic, the subduction of the Pacific Plate and the destruction of the North China Craton in the Mesozoic (Gao S et al., 2004; Zhai MG and Peng P, 2006; Sun WD et al., 2008; Xiao WJ et al., 2009; Xu B et al., 2015; Liu CH and Liu FL, 2015). These events both directly and indirectly brought about the formation of multiple important metallogenic belts in North China (Mao JW et al., 2003; Xiao WJ et al., 2008; Zhang XH and Zhai MG, 2010; Zheng QB, et al., 2019). Therefore, major magmatic events in North China have long been hot topics of geological study. However, most of the previous studies on the important magmatism focused on a specific region or problem, causing a lack of a systematical division and summary of magmatic rock belts. Additionally, thorough understanding of the stages, spatial-temporal distribution and magma sequence of major magmatic events in North China is unavailable. All these have imposed limitations on solving basic geological problems in North China. Furthermore, previous results were mostly expressed in the form of papers, with few geological survey data being quoted. This made the results less comprehensive and intuitive, thus hindering the transformation and application of the results.

In recent years, a series of 1∶50 000– and 1∶250 000–scale regional geological surveys and special studies on different areas have been newly deployed in North China based on the implementation of the projects such as the *'Survey for Land and Resources'*, potential evaluation of mineral resources, comprehensive research on national geologic structure zoning and integration of regional geological surveys (Xiao KY et al., 2013). Meanwhile, the newest edition of the annals of geology have been synchronously compiled to systematically summarize the latest progress on basic geological research in various provinces in North China. These have all greatly deepened the understanding of the geological evolution of North China. Furthermore, geologic maps on various scales and basic databases were provided for these projects with the wide application of new technologies and methods such as the Geographic Information System (GIS) and digital geologic mapping. The maps include many small-scale thematic maps or provincial geologic maps in addition to the 1∶50 000 and 1∶250 000 standard maps that were prepared during regional geological surveys. These results, in combination with existing data obtained from regional geological surveys and scientific research, will greatly assist in deepening the understanding of the eras, features and tectonic genesis of the magma in North China.

The Database focuses on major magmatic events and tectonic background in North China. It was developed based on the freshly obtained basic geological data of North China, during which the digital geologic maps on different scales and the databases completed in recent years were fully utilized and the latest geological survey results and papers were referred to. A 1∶2 500 000 geologic map (Fig. 1) was prepared and a spatial database (Table 1, Yang ZL et al., 2020) was established in this study in order to investigate the major magmatic events

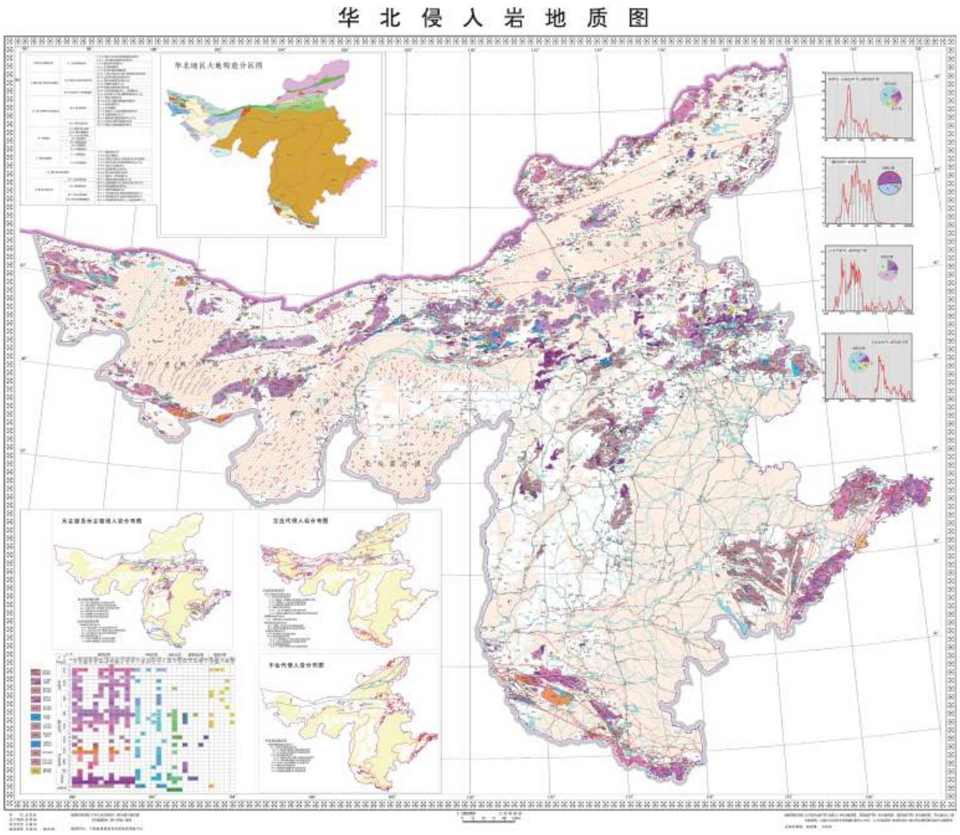


Fig. 1　1：2 500 000 geologic map of the intrusives in North China

Table 1　Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	Spatial Database of 1：2 500 000 Geologic Map of the Intrusions in North China
Database (dataset) authors	Yang Zeli, Tianjin Center, China Geological Survey Wang Shuqing, Tianjin Center, China Geological Survey Hu Xiaojia, Tianjin Center, China Geological Survey
Data acquisition time	2014–2015
Geographical area	North China except for Hinggan League, Jirem League, and Hulunbeier League in Inner Mongolia, with a latitude-longitude scope of 97°10'–122°20'E and 31°23'–46°45'N
Data format	MapGIS
Data size	218 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	The project titled *Comprehensive Research on Major Magma Events in North China and Their Mineralization and Tectonic Environment* initiated by China Geological Survey (No.: 12120144020401)
Language	Chinese
Database (dataset) composition	The Database consists of a system library, character library, and attribute library; sub-databases related to tectonic facies zoning, magmatic rock belts, geographic base map and ore occurrences; six thematic map layers of the intrusives of the Precambrian, early Paleozoic, late Paleozoic, Triassic and Jurassic – Cretaceous as well as the strata

represented by intrusions and the division of related magmatic rock belts in North China. On one hand, the spatial-temporal framework of the intrusions in North China was established in this study, which has helped to improve the understanding of the spatial-temporal evolution of magma, rock association characteristics and tectonic environment in North China. At the same time, this will provide further support to help solve major basic geological issues such as the evolution of the Paleo-Asian Ocean, Yanshanian intracontinental orogeny and the destruction of the North China Craton. On the other hand, the Database has filled the previous gap in spatial databases of thematic geologic maps of the intrusions in North China. In this way, relevant progress was reflected in a more intuitive and comprehensive approach and aided the realization of data sharing. Furthermore, this Database will provide basic geologic maps and data services for geological surveys, scientific research and production activities in North China.

2 Methods for Data Acquisition and Processing

2.1 Data Basis

According to the requirements of this study, the 1∶2 500 000 geologic map of the intrusions in North China was prepared by fully collecting the data from the regional geological surveys, comprehensive research conducted in North China in recent years and all relevant literature. The regional geological survey data include maps, a combination of reports and phased results of 13 regional geological survey projects on a scale of 1∶250 000 and 39 regional geological survey projects on a scale of 1∶50 000 that were completed before 2014. Meanwhile, the progress of 42 ongoing regional geological survey projects on the scale of 1∶50 000 and one on the scale of 1∶250 000 was closely tracked. The special study results included the spatial databases of basic maps and related results, such as the spatial databases of the 1∶500 000 geologic map of the Lüliang-Wutaishan region, 1∶500 000 geologic map of the northern margin of the North China Craton and 1∶1 000 000 geologic map of the metallogenic belt of the Da Hinggan Mountains (southern section). It further included the results of the potential evaluation and integration project of mineral resources in North China and the attached maps from the annals of geology of the various provinces in North China. In terms of the literature, about 330 published Chinese and English papers related to the intrusions in North China were collected. Meanwhile, the geochronologic and geochemical data of the intrusions were used as references for mapping. The geological data cited went up to the end of 2014 (with some as recent as the end of 2016). The aforementioned regional geological survey projects and relevant geologic maps, as well as scientific research results, laid the data foundations for the preparation of the geologic map in this study.

Related data showed that the geological records of crustal evolution in North China dated back to the Paleoarchean (Wan YS et al., 2005) with the following details:

① Early-middle Archean saw the growth of the continental nucleus in North China. Related rocks are mainly distributed in the Qixia area of the Jiaodong and Lushan regions in Henan Province, mainly including tonalite-trondhjemite. 2.8–2.5 Ga in the Neoarchean, which saw the accretion of continental crust. The magmatic rock association formed mainly includes island arc volcanics and large-scale TTG (tonalite + trondhjemite + granodiorite) and GMS (granite + monzogranite + syenogranite) intrusions (Zhai MG et al., 2005; Geng YS et al, 2006; Zhai MG, 2010).

② The early Proterozoic primarily saw the splicing of continental blocks, while the middle Proterozoic saw the development of rifts, large areas of alkaline granite, basic dike swarms and the occurrence of quartz syenite - rapakiwi granite (adamellite) associations. The Neoproterozoic was a stage of relatively stable sedimentation (Zhai MG and Peng P, 2006; Liu ZF et al., 2006; Liu CH and Liu FL, 2015).

③ In the early Paleozoic, the Xing'an-Mongolia orogenic series and Qinling-Qilian-Kunlun orogenic series, which lie on the northern and southern sides of North China respectively, experienced large-scale subduction. A large number of island arc intrusions were formed in the Erlianhot - East Ujimqin Banner, Sonid Left Banner - Xilinhot and Bao'erhantu - Bainaimiao areas on the northern side (Jian P et al., 2008; Xu B et al., 2015), while continental block subduction, island arcs and post-collision magmatism were recorded on the southern side (Guo CL and Chen DL, 2011; Wang XX et al., 2013; Wang JB et al., 2018). In the late Paleozoic, large-scale magmatic arcs consisting of island arc magmatic rocks and alkaline granite were formed in the Xing'an-Mongolia orogenic belt on the northern margin of the North China Craton; along with the disappearance of the Paleo-Asian ocean along the Soren Mountain - Xar Moron at the end of the Permian (Zhang SH et al., 2009; Jian P et al, 2010; Liu YJ et al., 2017).

④ In the Mesozoic, the North China Craton was integrated with the two orogenic series on the northern and southern sides and they were gradually controlled by the Pacific Tectonic Domain. The Qinling-Qilian-Kunlun orogenic series underwent deep intracontinental subduction in the Triassic. The magmatism in the middle Jurassic induced typical arc volcanic rock - TTG intrusion association with continental arc background. In the early Cretaceous, the compression background of the Jurassic was transformed into an extension. Meanwhile, lower crust delamination led to lithospheric thinning and massive magma activities during this period, resulting in the presence of post-collisional post-orogenic A-type granite (Tang JF et al., 2004; Gao S et al., 2004; Liu FL and Xue HM, 2007; Sun JF and Yang JH, 2013).

2.2 Data Processing

2.2.1 Data Preparation

The geologic map of the intrusions in North China covers the following provinces and regions including Inner Mongolia (excluding the Hinggan League, Jirem League, and Hulunbeier League), Hebei, Henan, Shandong, Shanxi, Beijing and Tianjin. It was prepared using the MapGIS 6.7 software, incorporating a scale of 1：2 500 000, a unit of millimeter, a datum of Beijing 1954 and a projection type of Lambert conformal conic projection. The first and second standard latitudes were set to 34° and 42°, respectively, the central meridian longitude was set to 110° and the latitude of the projection origin was set to 34°. Projection conversion was conducted for the maps collected at the early stages according to the above parameters, including the maps obtained from the 1∶50 000 – and 1∶250 000 – scale regional geological surveys, small-scale thematic maps and the geologic maps of various provinces in North China. Afterwards, these maps were overlapped with the 1∶2 500 000 geographical base maps of North China. Then various geologic maps were stitched together to form the geologic base map. Furthermore, the lithology, coordinates, geochemical data and age data of the rock masses in the regional geological survey reports and papers were sorted out by detail and summarized. Then the geologic point files in the format of.wt, with the same parameters, were generated through coordinate projection in order to guide follow-up mapping.

2.2.2 Preparation of the Map

(1) Determination of criteria: The numbers and codes of the intrusions were denoted by means of 'lithology + era' in accordance with *Geological Symbols Used for Regional Geological Maps* (GB 958−99). At the same time, the lithologic characteristics of the intrusions were highlighted. These were acquired from different materials and were reasonably grouped by their acidic, intermediate, basic, ultra-basic and alkaline natures as specified in the relative standards. To establish uniform rock codes, the types of rock masses were designated by referring to the '*Classification and Nomenclature Schemes of Rocks — Classification and Nomenclature Schemes of Igneous Rock'* (GB/T 17412.1−1998), i.e. the QAPF diagram. The strata were merged and simplified according to their eras and different strata were distinguished using various colors. The strata of several eras were finally determined after being grouped, which are as follows: Cenozoic strata (N–Q), Jurassic-Cretaceous strata (J–K), Triassic strata (T), upper Paleozoic strata (D–P), lower Paleozoic strata (Є–S), Proterzoic strata (Pt) and Archeozoic strata (Ar). In terms of mapping precision, the masses plotted in the geologic map include the polygonal ones with a size not less than 2mm x 2mm and linear ones with a width no less than 2mm. Special geologic blocks that are smaller, but can indicate the tectonic environment and genesis or special types of rocks, were expressed after being amplified according to the similarity principle.

(2) Topological mapping: The MapGIS 6.7 software was employed to conduct vectorization editing, topological area creation, color filling and decoration for the geologic base map. As a result, corresponding point files (.wt), line files (.wl) and polygon files (.wp) were generated. Meanwhile, relevant attribute structures were established according to standard requirements of this study. During the process of topological mapping, the geologic boundaries were drawn by mainly referring to the maps obtained from the 1∶250 000-scale regional geological surveys, thematic geologic maps and the annals of geology of various provinces in North China. Moreover, the boundaries, ages and lithology of geologic blocks were corrected by referring to the 1∶50 000 geologic maps and academic papers. Afterwards, the attributes of the intrusions were filled in according to the attribute structures and checked manually.

(3) Preparation of corner maps and decoration of the map face: ① The corner map of geotectonic zoning was prepared based on the latest research results and thematic reports of North China, with the tectonic belts being determined according to tectonic units and regional faults. ② The intrusions in North China were grouped into four stages and 27 magmatic rock sub-belts according to the eras and spatial distribution of magmatic rocks, tectonic evolution

stages (i.e., craton formation and reformation, peripheral orogeny and intracontinental orogeny) and evolution law of magmatic rocks. At the same time, corresponding corner maps were plotted. ③ A statistical figure of the eras and areas of the intrusions in North China was developed. ④ The geologic maps were decorated in accordance with the standard requirements. The positions and font sizes of legends were arranged according to the standard specifications and the intrusions were highlighted.

3 Description of Data Samples

3.1 Data Types

MapGIS 6.7 files include geologic polygon files (.wp), geologic line files (.wl) and geologic point files (.wt).

3.2 Contents in Map Layers

Geologic point entities: isotopic ages, labels of geologic blocks, geologic symbols, geologic patterns, ore occurrences, geographical features and city names.

Geologic line entities: geologic boundaries, faults, tectonic-magmatic rock belts, geographic features, etc.

Geologic polygon entities: strata, intrusive bodies of different eras, geographic features, etc.

3.3 Attribute Lists

The Database contains geologic entity features, geographical features and geologic map decoration features. The geologic entities mainly include the graphic primitives of intrusions and strata. The attribute structure of the former includes the fields of USERID, TYPE, ROCK_NAME, COLOR_NO, FILL_NO, FILL_COLOR, FILL_HEIGHT, LITHOLOGY, TIME, AGE and AGE_METHOD (Table 2). Specifically, the field USERID is the identification code consisting of 9 bytes. The first 4 bytes represent the number of the 1：500 000 map sheet in the 1：1 000 000 international map sheet, with the letters, which represent the line No. of the map sheet, being replaced with two figures and the figures, which represent the column No., remaining unchanged. The 5 byte represents the letter followed by the number of the 1:500 000 map sheet in the international map sheet, which was also replaced with a figure. The last 4 bytes represent the sequence number of the rock mass. AGE_METHOD denotes isotopic dating method, where, ‘1’ represents SHRIMP zircon U–Pb dating; ‘2’ represents SIMS zircon U–Pb dating; ‘3’ represents LA–ICPMS zircon U–Pb dating; ‘4’ represents evaporation zircon U–Pb dating; ‘5’ represents Ar–Ar laser dating; ‘6’ represents K–Ar isotopic dating; ‘7’ represents Rb–Sr or Sm-Nd isochron dating; and ‘8’ represents other methods. The attribute structure of strata is the same to the attribute structure of intrusions, except that the strata era and filling color are required to be filled into the fields ROCK_NAME and COLOR_NO, respectively. For the points wherein isotopic dating was conducted, the specific age and lithology of testing samples are required to be filled in the attribute list according to the description in the papers or reports.

Table 2 Attribute structure of graphic primitives of intrusions

Field name	Data type	Byte number	Decimal place	Description
USERID	Int	9		Identification code
TYPE	Int	8		Lithologic code of a rock mass
ROCK_NAME	Char	20		Rock name
COLOR_NO	Int	4		Filling color
FILL_NO	Int	4		Filling pattern No.
FILL_COLOR	Int	4		Color No. of filling pattern
FILL_HEIGHT	Float	6	2	Height of filling pattern
LITHOLOGY	Char	20		Lithology of the intrusive
TIME	Char	20		Era of the intrusive
AGE	Float	6	2	Isotopic age
AGE_METHOD	Int	2		Isotopic dating method

4 Composition of the Database

The Database was established in the format of MapGIS, with a data size of about 218 MB. The master map covers: (ⅰ) 1 743 mapping units of intrusions, which were classified as the five major rock types and expressed by means of 'lithology + era'; (ⅱ) 1 534 stratigraphic units that were formed by merging the lithostratigraphic units in the 1∶500 000 digital geologic maps; (ⅲ) 404 pieces of isotopic age data of typical rock masses.

Three sub-databases were also established besides the master map:

(1) The database of the geographic base map and the attributes of geographic contents, including administrative districts, boundaries of the administrative districts, habitations, roads, railways, rivers, lakes, marine features and landforms.

(2) The database of magmatic rock belts and their attributes, including overlying/underlying relationships and the division of intrusions and magmatic rock belts.

(3) The database of tectonic facies zoning, including the division of faults, tectonic belts and tectonic units.

5 Data Quality Control and Evaluation

The basic data used for the map preparation in this study include 34 regional geologic maps on a scale of 1∶250 000 and their databases, 224 regional geologic maps on a scale of 1∶50 000 and their databases and related results and reports completed in North China between 1999 and 2014. They cover the bulk of the major magmatic rock belts in North China. A great number of other maps and related results were also summarized and incorporated, including the geologic maps (1∶500 000 and 1∶1 000 000) of the Shanxi-Hebei metallogenic belt, metallogenic belt of Da Hinggan Mountains (southern section) and west Henan metallogenic belt; the tectonic-stratigraphic zoning map of North China (1∶1 500 000) that was prepared during the potential evaluation – metallogenic background basic research of North China and the annals of geology and geologic maps (1∶500 000) of various provinces in North China. The experience in preparing regional geologic maps on small - and medium -

scales was referenced.

In addition, the latest research results and data of granite in North China were fully collected, including more than 330 academic papers in both Chinese and English and over 50 regional geological survey reports. At least 730 high-quality (SHRIMP and LA–ICP–MS) zircon ages of the intrusions in North China were screened and collected, of which 404 pieces of data with identified coordinates were projected to provide reference. On this basis, special surveys were carried out in the Xing'an-Mongolia orogenic belt and the magmatic rock belts on the northern margin of the North China Craton, during which isotope dating and geochemical testing and analysis were conducted for key rock masses and relevant data were supplemented. In this way, the map prepared in this study is authentic and reliable.

After the Database was preliminarily established, comprehensive checks and modifications were conducted for the whole map. The checked items mainly include the accuracy of geologic body matching and topological relationships. For the geologic blocks themselves, the checked items mainly include the completeness and accuracy of attributes, the completeness and accuracy of the colors and filling patterns of graphic primitives and matching rate between attributes and parameters. In this way, the quality of the Database was ensured. Two rounds of expert reviews were conducted for the structure of the map face and the division of tectonic-magmatic rock belts. As a result, hundreds of revisions were made in accordance with the comments made by the experts. Meanwhile, the controversial issues were addressed by adopting the division or expression that was acceptable to the majority, thus ensuring that the geologic contents reflect the latest mainstream understanding.

6 Application Potentials of the Database

The Database has great application potential for information service and basic geological research. In terms of information service, the 1 ∶ 2 500 000 geologic map of the intrusions in North China can provide basic geologic information for the preparation of various thematic maps of the same scale. Meanwhile, it can also be used as a geological base map of the geologic maps on smaller scales, thus providing modernized support for the preparation of various geologic maps of smaller scales and corresponding thematic maps in China.

In terms of basic geological research, the magmatic events in North China were divided by time and space according to the tectonic-magmatic theory in this study. Meanwhile, the differences in the dating results, geochemical characteristics and tectonic environment of magmatic rocks in different periods and belts were summarized in detail, establishing the temporal and spatial distribution, material composition and tectonic evolution sequence of the magmatic rocks in North China. Relevant results were summarized according to the following periods: Proterozoic, Paleozoic and Mesozoic as shown in Figs. 2–4, respectively. All these achievements will provide scientific support for future basic geological surveys and even resource exploration in North China. It will also enhance the ability to serve as resource security, economic and social development and ecological construction through scientific and technological innovation.

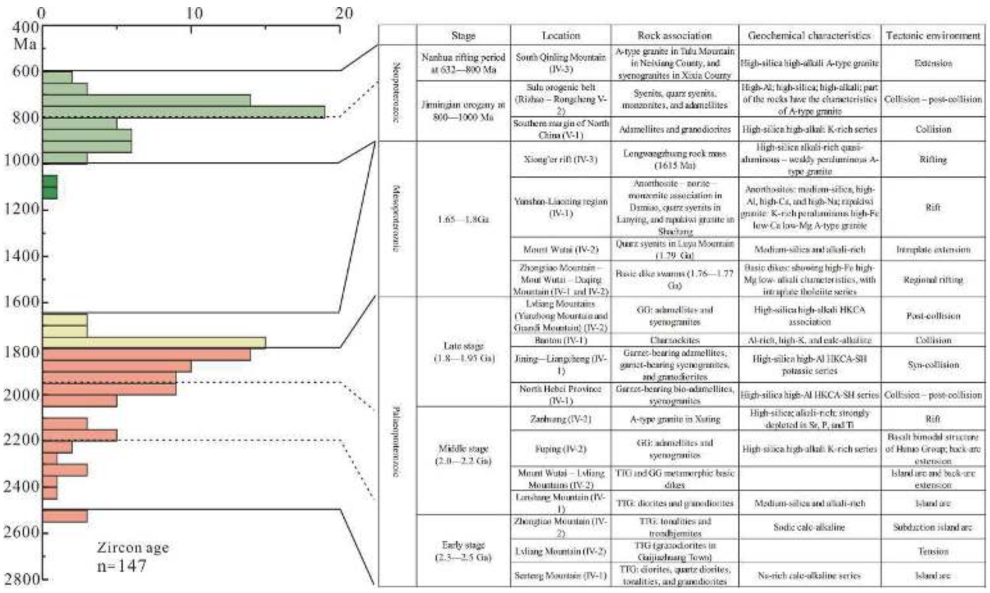


Fig. 2 Temporal-spatial distribution, material composition and tectonic environment of Proterozoic magmatic rocks in North China

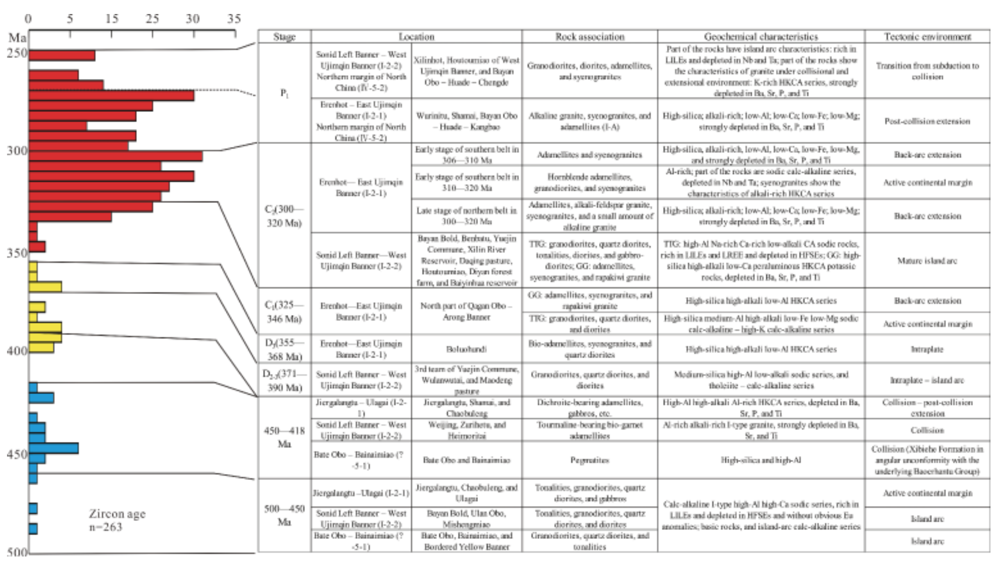
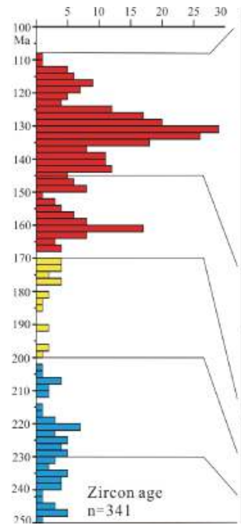


Fig. 3 Temporal-spatial distribution, material composition and tectonic environment of Paleozoic magmatic rocks in North China

7 Conclusion

The 1∶2 500 000 geologic map of the intrusions in North China was achieved through comprehensive research and geologic mapping using new technologies and methods (such as the digital mapping method) under the guidance of theories such as plate tectonics and geodynamics. Meanwhile, the latest data from regional geological surveys, special researches and scientific literatures of North China in recent years were integrated. The intrusions in North China were mainly studied in this paper as follows. The temporal and spatial distribution, genesis and provenance characteristics of intrusions were studied. The magmatic rocks in North China were systematically summarized, including their spatial-temporal evolution, rock association, magmatic properties and tectonic environment. The relationship



Stage	Location	Rock association	Geochemical characteristics	Tectonic environment
K_1(145—108 Ma)	Tongbai, Xinyang, Xinxian, and Shangcheng (VI-6)	ηγ, ξγ	High-silica high-alkali HKCA potassic series; part of the rocks show the characteristics of A-type granite	Extension
	Songxian, Luanchuan, and Nanzhao (VI-6)	ηγ, ξγ, γδ	High-silica high-alkali HKCA potassic rocks; part of the rocks have the characteristics of A-type granite	Extension
	Guojialing, Sanfo Mountain, and Laoshan Mountain (VI-5)	ηγ, ξγ, γδ, ηο	High-silica alkali-rich quasi-aluminous CA-HKCA series, showing high-Sr high-Ba low-Y characteristics	Melting of thickened crust under extensional background
	Southern section of Taihang Mountains: Pingshun and Wuan; northern section: Wang'an Town, Dahe Town, Mapeng, and Fangshan (VI-3)	Southern section: ν, δ, δη, ηο, δο, ξ; Northern section: ηγ, γδ, δο, νδ	Southern section: medium-silica; high-Al; high content of Fe, Mg and Ca; high-Sr; low-Y; Northern section: high-silica; high content of total alkali and Pb; high-Sr; high-Y	Melting of thickened crust under extensional background
	Yan Mountains: Badaling, Yunmeng Mountain, Wuling Mountain, Kulong Mountain, and Zhuizi Mountain (VI-4)	ξγ,ηγ, κγ,ξ	Alkali-rich parlkaline – quasi-aluminous HKCA-SH series, showing the characteristics of A-type granite	Extension
	Southern section of Da Hinggan Mountains (VI-2-2)	ηγ, ξγ, γδ	Alkali-rich quasi-aluminous – weakly peraluminous HKCA series, with part A-type granite	Extension
	Erenhot – East Ujimqin Banner (I-2-1): Dabimiao and Shamai (VI-1-2)	ηγ, ξγ	High-silica high-alkali HKCA weakly peraluminous series, depleted in Ba, Sr, P, and Ti	Post-orogenic extension
J_{2-3} (170—146 Ma)	Lingbao – Queshan area: Lushi and Luanchuan (VI-6)	ξγ, γδ, δο, ηο	High-silica high-alkali HKCA weakly peraluminous series, depleted in Ba, Nb, Ta, Sr, P, and Ti	Post-orogenic extension
	Duogu Mountain, Wendeng, Linglong, and Kunlun Mountain (VI-5)	ηγ, ξγ, γδ	High-silica high-alkali low-Al HKCA series, depleted in Nb, Ta, P, and Ti; high-Sr low-Y C-type adakites	Compression
	Yanshan area: Pingquan, Chengde County, Qinglong, Zhuizi Mountain of Weichang	δ, δηο, γδ, ηγ, ξγ	High-silica low-Al HKCA and CA series; part of the rocks show the characteristics of high-Sr low-Y C-type adakites	Compression
	Erenhot – East Ujimqin Banner: Dalaimiao, Shamai, Targan Obo, and Binbalechagan (VI-1-2)	ηγ, ξγ	High-silica high-alkali low-Al potassic HKCA series. They are strongly depleted in Ba, Sr, P, and Ti, with Eu negative anomalies and sea gull-shaped REE distribution curves. Part of the rocks have the characteristics of A-type granite	Post-orogenic extension
J_1(201—174 Ma)	Pingyi: Tongshi complex; East Hebei Province: Niuxin Mountain, Yuerya, Qingshankou, and Wangtufang (VI-4)	Tongshi complex: ξο, ψη, ηο, δηο; East Hebei Province: ηγ, γπ, δμ	Medium-silica high-Al high-alkali high-Ca HKCA or SH series, strongly depleted in Ta, P, and Ti	Post-orogenic extension
T_3 (230—220 Ma)	Diebusige, Urad Rear Banner, Bayan Obo, Chahar Right Middle Banner, Fengning, Longhua, and Pingquan (VI-2-1)	ξγ, ηγ, ξ, ξο	High-alkali low-Al HKCA and alkaline series, depleted in Ba, Sr, P, and Ti	Post-orogenic extension
T_1 (245—240 Ma)	Adunchulu in the north of West Ujimqin Banner (VI-1-1)	δο, γδ	High-Al high-Ca sodic CA series, rich in LILE and LREE and depleted in HFSE	Island arc

Fig. 4 Temporal-spatial distribution, material composition and tectonic environment of Mesozoic magmatic rocks in North China

between magmatism and tectonic events such as the evolution of Paleo-Asian Ocean, Yanshanian intracontinental orogeny and the destruction of the North China Craton was discussed. Furthermore, the spatial framework of major magmatic events in North China was preliminarily established. All of these will provide detailed geologic data for solving basic geological problems in North China.

(1) The geologic map highlights the expression of tectonic-magmatic belts in North China. In this study, the intrusion belts and magmatic stages of different eras since the Proterozoic in North China were divided into 10 stages of magmatism, 7 magmatic belts and 27 magmatic sub-belts. The spatial-temporal distribution, rock association, geochemical characteristics and possible tectonic environment and dynamic mechanism of each stage of magmatism were summarized.

(2) The spatial distribution, magmatic stages, rock association, genesis and tectonic environment of the intrusions in key areas such as the Xing'an–Mongolia orogenic belt were analyzed in detail in this study. A spatial-temporal framework consisting of two stages and three belts was established. Some alkaline granite or ophiolite belts of great tectonic significance were newly identified. Additionally, the characteristics of magmatic activities and the evolution sequences of different belts were comprehensively collated.

(3) In this study, most of the intrusions in the Yanshan region that were originally classified as early-middle Jurassic were re-determined as early Cretaceous. Meanwhile, the spatial-temporal distribution law and geochemical characteristics of Mesozoic intrusions in the eastern region of North China were re-collated as follows: Triassic intrusions are distributed along the northern and eastern margins of the North China Craton and Xing'an–Mongolia orogenic belt; the middle Jurassic–early Cretaceous intrusions gradually become older from the Taihang Mountains–Da Hinggan Mountains on both sides; the middle-late Jurassic intrusions in the Yanshan region shows the characteristics that are similar to those of adakites, which may reflect the thickened crust background; the early Cretaceous intrusions are mainly in the form

of the association consisting of high-K calc-alkaline rocks, alkaline granite and alkaline rocks, indicating the extensional tectonic system.

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