中国地质调查成果

中国崩塌滑坡泥石流易发程度图

（1∶5 000 000）

说　明　书

中国地质环境监测院
房　浩　主编

地质出版社

本图系由中国地质调查局“全国环境地质编图研究（1212011220127）（12120112200893）”项目、“典型地区资源环境承载力综合调查评价（1212011220089）”项目、“跨界含水层调查（1212011220941 ）”项目、“重要地区地质环境图件编制（12120112200894）”项目、“全国地质资源环境承载能力评价与监测预警”二级项目资助

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中国地质环境监测院

主编　房　浩

编制　李　媛　杨旭东　曲雪妍　尹春荣　佟　彬

地质出版社

· 北　京 ·

全国地质环境图系编制说明

一、编制背景及目的意义

20 世纪 80 年代末 90 年代初，在地质矿产部地质环境管理司组织下，老一辈环境地质工作者（段永侯等）根据当时的工作基础和需求，编制了由 11 张全国性图件组成的《中国环境地质图系（1∶600 万）》，于 1992 年出版。进入 21 世纪，我国大力加强地质灾害调查研究，中国地质调查局水文地质环境地质部（殷跃平等）主持编制了以地质灾害为主要内容的全国性图件 6 张（1∶400 万），于 2011—2013 年出版。

20 世纪 90 年代特别是 1999 年国土资源大调查以来，我国相继完成了全国分省 1∶50 万环境地质调查、县市地质灾害调查和重点地区 1∶5 万地质灾害调查、新一轮全国地下水资源评价、主要平原盆地地下水资源调查评价和全国地下水污染调查、全国地热资源评价等工作，持续开展了全国矿山环境地质调查、重点地区地面沉降调查监测、重要经济区和城市群环境地质调查、海岸带综合地质调查、主要活动断裂调查评价、分省重要地质遗迹调查、土地荒漠化调查、应对全球气候变化地质调查研究等工作，与此同时各省（自治区、直辖市）也部署开展了大量的水工环地质调查评价工作，这些都大大提升了我国地质环境调查研究程度，取得了许多新的认识，有的还填补了空白。

为系统总结多年调查研究成果，进一步完善和提升对我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与地质灾害防治，国土资源部办公厅于 2013 年 6 月 20 日印发了《全国地质环境图系编制工作方案》（国土资厅函〔2013〕556 号）的通知，启动了全国地质环境图系编制工作。

二、编制思路及总体构架

根据国土资厅函〔2013〕556 号文要求，国土资源部地质环境司、中国地质调查局在中国地质环境监测院设立了全国地质环境图系编制办公室，经过多次研讨、咨询、修改，于 2013 年 11 月完成了《全国地质环境图系编制实施方案》，形成了按“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”等五个专业领域，“全国和分省”“全域和局域”

两个层次编制图系的总体构想；搭建了按“地质环境分区图”“地质灾害分布图”“地质灾害易发程度图”“地下水资源图”“地下水环境图”“矿山地质环境问题图”“矿山地质环境治理区划图”和“地面沉降现状图”“地质遗迹资源分布图”的“7+2 模式”编制分省图系的主体框架；确定了在“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“三统一技术框架”下编制图系的总体要求，从而实现了“1+31 套图系”编制工作的同步推进，并为实现多尺度表达和动态更新奠定了技术基础。

之后，全国地质环境图系编制办公室以 1∶100 万分幅地理信息数据为基本数据基础，统一建立了全国 1∶500 万地理信息底图库、跨省域重要地区地理信息底图库和分省（自治区、直辖市）地理信息底图库，并按专业领域组织编制了《全国地质环境图系编制技术要求》《全国地质环境图系建库技术要求》《全国地质环境图系专业术语汇编》，通过对分省编图人员的技术培训和研讨，不断完善各项技术要求，实现编图思想的统一、地质认识的提升、图面表达的科学性和艺术化，并逐步建立起全国地质环境图系数据库系统。

三、图系构成及分工

根据国土资厅函〔2013〕556 号文要求，中国地质调查局负责编制全国和跨省区域的地质环境图件，完成《中国地质环境图系》编制工作；各省（自治区、直辖市）国土资源主管部门组织相关单位，编制本省（自治区、直辖市）及省内区域的地质环境图件，完成《××省（自治区、直辖市）地质环境图系》编制工作。

《中国地质环境图系》（以下简称《图系》），历经初步编制阶段、研讨评审阶段、完善出版阶段，是由十余家局属单位、数百名专业技术人员共同编制完成的。《图系》系统集成了我国多年来地质环境调查监测成果资料，共编制或修编全国和区域地质环境图件 36 张（表 00-1），包括地质环境条件类 19 张、地质灾害类 5 张、地下水类 8 张、矿山地质环境类 2 张、地质遗迹类 2 张；其中全国图件 20 张、区域图件 16 张。

《图系》主持机构：国土资源部地质环境司

《图系》组织实施机构：中国地质调查局水文地质环境地质部

《图系》技术负责单位：中国地质环境监测院

《图系》主编：郝爱兵、李瑞敏

《图系》副主编：石菊松、徐慧珍、李明路

《图系》编委会：李媛、孙继朝、张进德、董颖、曾青石、罗跃初、李铁锋、乐琪浪、林良俊、张二勇、王祎萍、荆继红、程国明、吴中海、郭建强、时坚、马震、朱桦、赵海卿、姜月华、黄长生、郑万模、孙永军

《图系》编辑：李小磊、殷铭、高萌萌、尹春荣、任鹰、黄卓、王轶、刘琼、曹峰、张像源、陈文杰

《图系》专家咨询组（以姓氏笔画为序）：王明德、文冬光、石建省、卢耀如、成杭新、孙晓明、李文鹏、李京森、李烈荣、岑嘉法、邱心飞、沈照理、张作辰、张岳桥、武强、林学钰、赵运昌、侯金武、秦毅苏、袁道先、殷跃平、陶庆法、黄学斌、蒋忠诚

表 00-1 《中国地质环境图系》构成一览表

类别	编号	图件名称	主要编制单位
地质环境条件类	00-1-01	中国地质环境分区图（1∶500 万）	中国地质环境监测院
	00-1-02	中国地质环境安全程度图（1∶500 万）	中国地质环境监测院
	00-1-03	中国岩溶环境地质图（1∶500 万）	中国地质科学院岩溶地质研究所
	00-1-04	中国荒漠化土地分布图（1∶500 万）	中国国土资源航空物探遥感中心
	00-1-05	中国及毗邻海区活动断裂分布图（1∶500 万）	中国地质科学院地质力学研究所
	00-1-06	中国工程地质图（1∶400 万）	中国地质科学院水文地质工程地质研究所
	00-1-07	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（1∶500 万）	中国地质调查局水文地质环境地质调查中心
	00-1-08	中华人民共和国及其毗邻海区第四纪地质图（1∶250 万）	中国地质科学院水文地质工程地质研究所
	00-1-09	中国沿海地区环境地质图（1∶305 万）	中国地质调查局天津地质调查中心
	00-1-10	环渤海重点经济区环境地质图（1∶120 万）	中国地质调查局天津地质调查中心
	00-1-11	长江三角洲经济区环境地质图（1∶75 万）	中国地质调查局南京地质调查中心
	00-1-12	海峡西岸经济区（核心区）环境地质图（1∶60 万）	中国地质调查局南京地质调查中心
	00-1-13	长江中游城市群环境地质图（1∶90 万）	中国地质调查局武汉地质调查中心
	00-1-14	珠江三角洲经济区环境地质图（1∶50 万）	中国地质调查局武汉地质调查中心
	00-1-15	北部湾经济区环境地质图（1∶45 万）	中国地质调查局武汉地质调查中心
	00-1-16	成渝经济区环境地质图（1∶100 万）	中国地质调查局成都地质调查中心
	00-1-17	长吉图经济区环境地质图（1∶60 万）	中国地质调查局沈阳地质调查中心
	00-1-18	关中盆地城市群环境地质图（1∶35 万）	中国地质调查局西安地质调查中心
	00-1-19	黄淮海平原土壤硒环境图（1∶115 万）	中国地质环境监测院
地质灾害类	00-2-01	中国崩塌滑坡泥石流分布图（1∶500 万）	中国地质环境监测院
	00-2-02	中国崩塌滑坡泥石流易发程度图（1∶500 万）	中国地质环境监测院
	00-2-03	中国地面沉降现状图（1∶500 万）	中国地质环境监测院
	00-2-04	三峡库区崩塌滑坡泥石流分布图（1∶65 万）	中国地质环境监测院、 中国地质调查局武汉地质调查中心
	00-2-05	长江三角洲地区地面沉降现状图（1∶75 万）	上海地质调查研究院

续表

类别	编号	图件名称	主要编制单位
地下水类	00-3-01	中国地下水资源图（1：500 万）	中国地质科学院水文地质环境地质研究所
	00-3-02	中国地下水环境图（1：500 万）	中国地质科学院水文地质环境地质研究所
	00-3-03	中国水文地质图（1：500 万）	中国地质科学院水文地质环境地质研究所
	00-3-04	中国地热资源分布图（1：500 万）	中国地质科学院水文地质环境地质研究所
	00-3-05	黄淮海平原水文地质图（1：115 万）	中国地质科学院水文地质环境地质研究所
	00-3-06	鄂尔多斯盆地水文地质图（1：110 万）	中国地质调查局西安地质调查中心
	00-3-07	松嫩平原水文地质图（1：75 万）	中国地质调查局沈阳地质调查中心
	00-3-08	江汉洞庭平原水文地质图（1：45 万）	中国地质调查局武汉地质调查中心
矿山地质环境类	00-4-01	中国矿山地质环境问题图（1：500 万）	中国地质环境监测院
	00-4-02	中国矿山地质环境保护与治理区划图（1：500 万）	中国地质环境监测院
地质遗迹类	00-5-01	中国重要地质遗迹资源分布图（1：500 万）	中国地质环境监测院
	00-5-02	中国重要古生物化石产地分布图（1：500 万）	中国地质环境监测院

注：《中国工程地质图（1：400 万）》《中华人民共和国及其毗邻海区第四纪地质图（1：250 万）》均已于 1990 年出版，此次仅补充完成了图件数字化、规范化和建库工作，不出版。

分省（自治区、直辖市）地质环境图系（以下简称“分省图系”）由各省（区、市）国土资源管理部门组织相关单位（共约 50 多家单位、上千名专业技术人员），按照全国地质环境图系编制办公室的统一技术要求分别完成编制、出版等工作。“分省图系”共 31 套、图件 271 张（表 00-2），包括地质环境条件类 44 张、地质灾害类 71 张、地下水类 78 张、矿山地质环境类 61 张、地质遗迹类 17 张；其中全省域图件 266 张、省内区域图件 5 张。为了保证全国地质环境图系的系统性，“分省图系”亦应按“图系序号 - 图件类别 - 图件序号”分别对本省（自治区、直辖市）地质环境图件编号，例如《北京市地面沉降现状图》，图件编号应为“01-02-03”。

表 00-2　分省（自治区、直辖市）地质环境图系构成一览表

序号	省（自治区、直辖市）	图件数量（张）	编制牵头单位
01	北京	9	北京市地质研究所
02	天津	10	天津市地质环境监测总站
03	河北	8	河北省地质环境监测总站
04	山西	8	山西省地质环境监测中心
05	内蒙古	10	内蒙古自治区地质环境监测院
06	辽宁	8	辽宁省地质环境监测总站
07	吉林	9	吉林省地质环境监测总站
08	黑龙江	11	黑龙江省水文地质工程地质勘察院

续表

序号	省（自治区、直辖市）	图件数量（张）	编制牵头单位
09	上海	4	上海市地质调查研究院
10	江苏	8	江苏省地质调查研究院
11	浙江	8	浙江省地质环境监测院
12	安徽	7	安徽省地质调查与环境监测中心
13	福建	7	福建省地质环境监测中心
14	江西	22	江西省地质灾害应急中心
15	山东	9	山东省地质环境监测总站
16	河南	11	河南省地质环境监测院
17	湖北	7	湖北省地质环境总站
18	湖南	7	湖南省地质环境监测总站
19	广东	7	广东省地质环境监测总站
20	广西	7	广西壮族自治区地质环境监测总站
21	海南	13	海南省地质调查院
22	重庆	8	重庆市地勘局南江水文地质工程地质队
23	四川	8	四川省地质环境监测总站
24	贵州	13	贵州省地质环境监测院
25	云南	8	云南省地质环境监测院
26	西藏	2	中国地质环境监测院
27	陕西	8	陕西省地质环境监测总站
28	青海	7	青海省水文地质工程地质环境地质调查院
29	甘肃	13	甘肃省地质环境监测院
30	宁夏	7	宁夏回族自治区国土资源调查监测院
31	新疆	7	新疆维吾尔自治区地质环境监测院
合计		271	

成果引用格式：如引用《中国及毗邻海区活动断裂分布图》，应标注“吴中海，周春景主编，2017，中国及毗邻海区活动断裂分布图（1∶500 万）。见：郝爱兵，李瑞敏主编，《中国地质环境图系》（图件编号：00-01-05），北京：地质出版社。”

在全国地质环境图系编制过程中，得到了国土资源部、中国地质调查局、中国地质环境监测院、各省（自治区、直辖市）国土资源厅（局）及有关单位领导和专家的大力支持，在此一并表示衷心感谢！

全国地质环境图系编制办公室

2017 年 6 月

前　言

《中国崩塌滑坡泥石流易发程度图》是《图系》中地质灾害类图件之一。

地质灾害是自然、人为作用导致地质环境或地质体发生变化，给人类和社会造成的一种危害，其可细分为崩塌、滑坡、泥石流、地面沉降、地面塌陷、地裂缝、岩土胀缩、砂土液化、土地冻融、土壤沙化、沼泽化和土壤盐渍化等类型。在各类型地质灾害中，崩塌、滑坡和泥石流造成的危害最为严重。

我国地形地质条件复杂，山地丘陵面积约占国土面积的三分之二，区域气候多变，局地暴雨多发频发，地震多发，加之密集的人口分布和人类工程活动的剧烈影响，导致地质灾害频繁发生。据统计，近 50 年来，崩塌、滑坡、泥石流灾害共造成 20000 多人死亡，每年死亡几百到一千多人，在众多自然灾害中，死亡人数仅次于地震、洪水灾害。崩塌、滑坡、泥石流灾害的频繁发生，给人民群众生命财产造成了严重损失，已成为制约国民经济发展的因素之一。

为全面总结地质环境背景特征和发育演化规律，进一步推进调查、监测成果的转化应用，有效地支撑我国地质环境保护管理工作，原国土资源部决定启动《中国地质环境图系》编制工作。《中国崩塌滑坡泥石流易发程度图》的编制目的是服务我国地质灾害防灾减灾工作，为国家及地区制订地质灾害防治规划、开展地质灾害工作部署，以及为社会经济建设提供技术支撑。

本图是在《中国地质环境图系》的统一要求，在《中国地质环境图系》专家委员会的指导下，由中国地质环境监测院编制完成。主编房浩，编图指导李媛，编图组成员有：杨旭东、曲雪妍、尹春荣、佟彬。图件编制过程中，得到了原国土资源部地质环境司、中国地质调查局、中国地质环境监测院及部分省份的领导和相关专业技术人员的大力支持和指导。在此一并表示衷心感谢！

目　录

一、编图原则、内容及方法

（一）编图原则

1. 反映自然诱发因素条件下的易发程度空间差异

在构建崩塌、滑坡、泥石流易发程度评价指标体系时，只考虑自然诱发因素，指标体系不包括与人类活动相关的因素。最终的评价结果只反映长时期内，在自然因素影响下的崩塌、滑坡、泥石流易发程度的空间差异。

2. 为宏观规划服务

本图是为国家及地区编制地质灾害防治规划、制定地质灾害防治工作部署、为社会经济建设提供技术支撑，服务于地质灾害防灾减灾工作。

3. 利用最新成果，与省级易发程度图、《中国崩塌滑坡泥石流分布图》衔接对应

本图编制过程中，尽量选取最新的、正式出版的研究成果。评价结果充分考虑各省级行政区的地质灾害易发程度综合研究成果，对于每个省级行政区的易发程度划分，其高低等级次序不得颠倒。此外，本图与已出版的《中国崩塌滑坡泥石流分布图》同属于《中国地质环境图系》中地质灾害专题图，因此，易发程度评价结果充分考虑与《中国崩塌滑坡泥石流分布图》的衔接对应。

4. 确保图件的简洁性和易读性

本图的表现形式力求简明、易懂、重点突出，注意摒弃过于专业化的术语、冗长的文字论述和复杂的图面。

5. 依据标准规范编制

本图的内容和表现形式，均按照《全国地质环境图系编制技术要求》及相关国家标准、行业标准进行编制。

（二）编图内容

《中国崩塌滑坡泥石流易发程度图》结合了地貌、地形、岩土体类型、地质构造、地震、降水、植被、水系等影响因素，反映在自然因素影响下，长时期内崩塌、滑坡、泥石流易发程度的空间差异，划分出崩塌滑坡泥石流的高易发区、中易发区、低易发区、非易发区，并分区说明崩塌、滑坡、泥石流的发育分布特征和危害。

因为目前全国地质灾害数据库中没有记录香港、澳门和台湾的崩塌、滑坡、泥石流灾害数据，所以，上述三个地区在图中的易发程度评价结果为地质环境条件经量化计算后所得。

（三）编图方法

中国崩塌滑坡泥石流易发程度评价采用定量计算的方法，根据区域崩塌、滑坡、泥石流发育现状，结合地形、地貌、岩土体类型、地质构造、地震、降水、植被、水系等自然影响因素，采用确定性系数法和灰色关联分析法对崩塌滑坡泥石流易发程度进行评价。在易发程度评价的基础上，根据地貌、地形、岩土体类型等主要自然影响因素和崩塌、滑坡、泥石流发育特征，采用“自下而上”的方法，进行崩塌滑坡泥石流易发程度划分。

《中国崩塌滑坡泥石流易发程度图》以行政区划为地理底图，地质灾害专业图层信息用面普染色表达，采用不同色系的颜色区分地质灾害高易发、中易发、低易发和非易发四个等级。

二、地质灾害影响因素分析

在自然条件下，我国发育的崩塌、滑坡、泥石流主要受地形、地貌、岩土体类型、地质构造、地震、降水、植被、水系等因素的影响。

（一）地形地貌

地形地貌是崩塌、滑坡、泥石流发育的主要因素之一。中国的陆地地形划分为三级阶梯，第一级阶梯是青藏高原，平均海拔在 4500m 以上，由高山、极高山和镶嵌在其间的起伏和缓的高海拔丘陵、台地、平原构成的高原面组成；第二级阶梯位于青藏高原的外缘与大兴安岭—太行山—伏牛山—巫山—雪峰山一线之间，平均海拔为 1000~2000m，由塔里木盆地、准噶尔盆地、黄土高原、内蒙古高原、四川盆地和云贵高原，以及天山山脉、阴山山脉、秦岭、大巴山、大娄山等盆地高原和山脉组成；第三级阶梯位于大兴安岭—太行山—伏牛山—巫山—雪峰山一线以东，平均海拔在 500m 以下，由东北平原、黄淮海平原、长江中下游平原和长白山脉、山东低山丘陵及江南丘陵组成。

在各级阶梯过渡的斜坡地带和大山系及其边缘地带，岭谷高差达 2000m 以上，地形坡度较大，发育众多的临空面，松散的堆积物比较多，十分容易发生崩塌、滑坡、泥石流。其中，崩塌、滑坡主要发育在第二级地势阶梯及其周边起伏山地，在中起伏山地中最为发育，占发育总数的 34.2%；泥石流主要发育在第一级与第二级阶梯的过渡地带，在大起伏山地中最为发育，占发育总数的 33.4%（表 1）。

表 1　不同地形崩塌、滑坡、泥石流发育数量百分比

灾害类型	极大起伏山地（ > 2500m ）	大起伏山地（1000~2500m ）	中起伏山地 (500~1000m)	小起伏山地 (200~500m)	丘陵（ < 200m ）
崩塌、滑坡	0.5%	28.0%	34.2%	22.8%	14.5%
泥石流	2.6%	33.4%	29.9%	16.6%	17.5%

（二）地质构造

活动断裂是区域性崩塌、滑坡、泥石流的直接控制因素。我国各地的活动性断裂在规模、活动方式、活动历史和活动强度等方面具有一定的差异性。综合分析活动性断裂的特点，我国按地域可划分为华北地区、东北地区、华南地区、西南地区、西北地区及台湾地区活动性断裂。其中，华北地区的活动性断裂大多数是中新生代以来的继承性断裂，特别是走向北北东和北东方向的活动性断裂，规模较大，垂直差异性活动较强烈；东北地区的北东—北北东方向主要断裂活动性在逐渐减弱，但北西向活动性断裂生成时代较新，活动性强；华南地区的北西向和东西向断裂亦具有一定的活动性，与北东—北北东方向断裂的交会部位，常常是现今地壳稳定性较差的地区；西南地区的活动性断裂带走向多呈近东西—北西—北北西弧形和南北向，大部分为大型活动性断裂，活动强烈；西北地区的活动性断裂非常发育，主要走向为近东西向和北西向，少数为北东走向，性质以压扭性为主。

在活动构造断裂带，通常比较容易发生区域性的崩塌、滑坡、泥石流。其原因在于一方面在活动断裂带，岩石破碎，有利于风化，降低了岩体的完整性，带来了丰富的松散物质，另一方面，构造结构面，如层面、断层面、节理面、片理面或地层的不整合面等，控制着滑动面的空间位置和滑坡、崩塌的边界。因此，活动构造控制着崩塌、滑坡、泥石流发育地带的延伸方向、发育规模及分布密度。

（三）地震

地震是崩塌、滑坡、泥石流的重要诱发因素之一。我国是一个多地震国家，地震活动主要分布在：①东部的台湾、渤海－鲁中及华北平原地区；②北部的祁连山、吕梁山、贺兰山区；③西南的云南、西藏及四川西部地区；④西北的天山及阿尔泰山地区。从震中分布看，大部分集中在晚近地质时期形成的构造带或断裂带上。

地震会使斜坡土石结构松动，在地震力的反复震动冲击之下，岩土体沿原有或新产生的软弱结构面发生错动，同时也为诱发泥石流提供了丰富的松散物质。地震产生裂缝和断层，有助于降雨和融雪的渗透，因此地震以后常因降雨、融雪而发生滑坡或崩塌。一般说来，在雨季或

暴雨、融雪时发生的地震，同发型（与地震同时发生）滑坡较多；旱季时斜坡干燥，稳定性较高，同发型滑坡较少，后发型（在地震以后很长时间才发生）滑坡较多（表 2）。

表 2　不同地震动峰值加速度崩塌、滑坡、泥石流发育数量百分比

地震动峰值加速度 /g	灾害类型	
	崩塌、滑坡	泥石流
≥ 0.4	0.5%	2.6%
0.3~0.4	28%	33.4%
0.2~0.3	34.2%	29.9%
0.15~0.2	22.8%	16.6%
0.1~0.15	14.5%	17.5%

（四）岩土体类型

岩土体类型是崩塌、滑坡、泥石流发育的物质基础因素。我国幅员辽阔，工程地质条件复杂，大体上，可将岩土体分为岩体和土体两大类。其中，岩体按照岩石的成因类型、强度特征及岩体结构类型又可细分为：岩浆岩建造、碎屑岩建造、碳酸盐岩建造和变质岩建造四个建造类型。土体按照粒度成分及土的特殊工程地质性质可细分为：粗粒土、砂质土、细粒土、软弱黏性土、胀缩土、盐渍土、多年冻土、黄土。

一般情况下，易形成崩塌、滑坡的岩石，大都是碎屑岩、软弱的片状变质岩，岩性多为泥岩、页岩、板岩、含碳酸盐岩类软弱岩层、泥化层、构造破碎岩层。这些软弱岩层经水的软化作用后，抗剪强度降低，形成软弱滑动面，容易发生崩塌、滑坡。季节性冻土，在冰雪消融季节，土中融化产生的水也会影响岩土边坡的稳定性，从而诱发崩塌、滑坡。崩塌、滑坡产生的松散堆积物，以及山坡上的残坡积物、沟床内的冲洪积物又形成了泥石流的固体物质来源，在一定的降雨条件下，容易发生泥石流（表 3）。

表 3　不同类型岩土体崩塌、滑坡、泥石流发育数量百分比

灾害类型	岩体				土体	
	岩浆岩建造	碎屑岩建造	碳酸盐岩建造	变质岩建造	黄土	其他土类
崩塌、滑坡	21.4%	34.7%	19%	21.7%	1.5%	1.7%
泥石流	21.3%	27.5%	19%	26.3%	2.2%	3.8%

（五）降水

降水是诱发崩塌、滑坡、泥石流的重要外部因素之一。由于自然地理环境的影响，我国降

水量的分布，总趋势是从东南向西北逐渐减少，局地性暴雨多集中在西部山地。从我国年均降水量等值线来看，秦岭—淮河一线以南，年平均降水量约在 800mm 以上，雨量丰富，为湿润区；秦岭—淮河一线以北，降水较少，为半干旱、干旱区。台湾、华南沿海山丘区及云南西北和西藏东南的部分边界地区年平均降水量超过 2000mm，而在西部地区，如新疆托克逊，年平均降水量仅 7.1mm。我国降水季节性变化明显。我国东部地区的主要雨带每年都有一个先北进后南退的过程，形成了降水季节变化的趋势。一般情况下，每年 2 ～ 5 月主雨带位于华南沿海地区，6 月中旬随着副热带高压北跳，雨带移到长江流域，形成 20 多天的梅雨；7 月中旬副热带高压第二次北跳，雨带到达黄河流域；7 月、8 月交界雨带到达华北和东北，8 月中旬雨带达到最北位置。8 月、9 月间，随着副热带高压的南退，半个月内主雨带到达长江流域，在冷空气南下时，川黔一带形成秋雨，10 月中旬雨带退到华南沿海。

降水量多寡决定了水动力作用的强弱。对于崩塌、滑坡灾害来说，一是降水渗透进入土体孔隙或岩石裂缝，软化、泥化和润滑裂隙面，降低岩土的抗剪强度，导致岩土体容易发生错动；二是降水渗透补给地下水，使地下水位或地下水压增加，对岩土体产生浮托作用，土体软化、饱和，这样也会造成岩土抗剪强度的降低，降低岩土体的稳定性，从而容易产生崩塌、滑坡。对于泥石流来说，水既是泥石流的重要组成部分，又是泥石流的激发条件和搬运介质，在具备一定坡度的沟谷地区，如果存在丰富的松散物质，则短时间强降水极易引发泥石流。此外，在西藏东南部的念青唐古拉山（东段）、喜马拉雅山（中东段）、横断山（中段）、唐古拉山（东段）、昆仑山、天山和祁连山地等地，季节性融水所产生的水动力也常常会引发泥石流（表 4）。

表 4　不同降水量崩塌、滑坡、泥石流发育数量百分比

降水量 /mm	灾害类型		降水量 /mm	灾害类型	
	崩塌、滑坡	泥石流		崩塌、滑坡	泥石流
＜ 75	0.2%	0.8%	500~600	3.2%	9.2%
75~100	0.7%	1.5%	600~800	6.3%	20.5%
100~150	1.4%	2.9%	800~1000	16.9%	13.9%
150~200	2.2%	3.3%	1000~1200	14.8%	9.3%
200~300	0.3%	2.5%	1200~1400	17%	5.4%
300~400	1.6%	8%	1400~1600	19.2%	3.8%
400~500	3.4%	17.5%	≥ 1600	12.7%	1.4%

（六）水系

河流水系是崩塌、滑坡产生的外动力因素之一。在气候和地貌的制约下，我国水系的地域分布很不平衡，总体来说具有四个方面的特点：

1. 数量众多

我国流域面积在 100km^2 以上的河流有 5 万余条；1000km^2 以上的河流有 1580 条；大于 10000km^2 的尚有 79 条。

2. 水量充沛，随季节变化

据统计，全国河川年平均径流总量约为 26000 × 10^{8}m^3，占世界河川总径流量的 6.6%。我国河流水量虽然丰沛，但季节分配很不均匀，夏季径流占优势，冬季很少。

3. 地区径流差异大

我国因受季风气候影响，占全国耕地面积 50% 的华北和西北地区，径流量只占全国的 10%，其中淮河、海河、辽河三流域占全国耕地 28%，径流量仅占 4%。

4. 河网密度地区差异大

我国东部地区河网密度一般在 0.1km/km^2 以上，其中南方更高，超过 0.5km/km^2。而西北内陆地区河网密度较低，不少地区接近于 0 或等于 0。

河流对崩塌滑坡的影响主要表现为河流在流动过程中，由于水动力作用，会对山坡坡脚产生水力侵蚀，从而降低岸坡的稳定性，导致滑坡、崩塌的发生。对于远离河流的边坡，由于不会受到河流的水动力侵蚀，因此河流水系对其的影响较小或没有。

（七）植被

植被是影响崩塌、滑坡、泥石流发育的外部因素之一。我国植被覆盖类型划分为自然植被、农业植被和无植被地段三大类。其中，自然植被又划分为针叶林、阔叶林、灌丛和萌生矮林、荒漠、草原和稀树灌木草原、草甸和草本沼泽；农业植被划分为：一年一熟粮食作物和耐寒经济作物；一年两熟或两年三熟旱作（局部水稻）和暖温带落叶果树园经济林；一年水旱两熟粮食作物和亚热带常绿、落叶经济林及果树园；单（双）季稻连作喜凉旱作或一年三熟旱作和亚热带常绿经济林、果树园；双季稻或双季稻连作喜温旱作和热作常绿经济林、果树园。

通常情况下，在植被覆盖率高的地区，因为树木根系具有稳固水土、防止水土流失的作用，所以植被在一定程度上能够加强岩土体边坡的稳定性。但是，因不同类型的植被生长的环境不同，所以植被类型在一定程度上对崩塌、滑坡、泥石流的发育也能起到一定的指示作用。

三、崩塌滑坡泥石流易发程度划分

根据全国崩塌滑坡泥石流易发程度评价结果，可将全国划分为崩塌滑坡泥石流高易发区、中易发区、低易发区和非易发区。

崩塌滑坡泥石流高易发区面积约 131 × 10^{4}km^2，占全国总面积的 13.6%，主要有：滇西南

藏东滑坡崩塌泥石流高易发区、川西南滇中泥石流滑坡崩塌高易发区、云贵高原滑坡崩塌高易发区、秦巴山区滑坡崩塌泥石流高易发区、陇中陇东黄土高原滑坡崩塌泥石流高易发区、吕梁山太行山滑坡崩塌泥石流高易发区等。

崩塌滑坡泥石流中易发区面积约 $278 \times 10^4 km^2$，占全国总面积的 29.0%，主要有：青藏高原东南部滑坡崩塌泥石流中易发区、粤桂湘赣滑坡崩塌泥石流中易发区、琼南滑坡崩塌泥石流中易发区、鄂东湘东滑坡崩塌泥石流中易发区、浙闽赣滑坡崩塌中易发区、伊犁河谷中高山滑坡崩塌泥石流中易发区、燕山辽东辽西泥石流滑坡崩塌中易发区、长白山泥石流崩塌滑坡中易发区等。

崩塌滑坡泥石流低易发区面积约 $329 \times 10^4 km^2$，占全国总面积的 34.3%，主要有：青藏高原中西部崩塌滑坡泥石流低易发区、贺兰山中东部崩塌滑坡泥石流低易发区、阴山山地崩塌滑坡泥石流低易发区、大小兴安岭山地台原崩塌滑坡泥石流低易发区等。

崩塌滑坡泥石流非易发区面积约 $222 \times 10^4 km^2$，占全国总面积的 23.1%，主要分布在除上述区域以外的地区。

（一）崩塌滑坡泥石流高易发区

1. 滇西南藏东滑坡崩塌泥石流高易发区

本区位于横断山南端，丽江、大理、个旧以西的高中山地区和西藏东部地区。本区北部属横断山高山峡谷区，在高黎贡山、怒山、雪盘山、云岭、雪山、玉龙山、点苍山等大山之间夹有怒江、澜沧江、金沙江和独龙江，河流切割强烈，造成深邃的峡谷和陡峭的山坡，是滑坡、崩塌、泥石流集中的发育区。

2. 川西南滇中泥石流滑坡崩塌高易发区

本区位于四川西南部的雅安、攀枝花，向南延伸至云南中部的丽江、大理、楚雄和个旧，全区海拔在 1500 ~ 2000m 之间，自北而南逐渐降低，金沙江横贯本区的中部。该区地质构造复杂，地震频发，地形陡峭，松散碎屑物质丰富，降雨充沛，泥石流沿金沙江干支流和元江密集发育，威胁区内的水利水电工程区。

3. 云贵高原滑坡崩塌高易发区

本区位于四川东南部、重庆东南部、云南东北部和贵州西部，呈东北—西南方向的长带，是我国西部高山到东部低山间的一个过渡地区。由许多平行的山脉组成，主要有武陵山、大娄山等，碳酸盐岩分布广泛，岩溶发育。区内滑坡、崩塌普遍发育，大娄山、武陵山地区滑坡、崩塌集中发育。

4. 秦巴山区滑坡崩塌泥石流高易发区

本区位于甘肃陇南，四川广元、巴中、达州，陕西安康、汉中（不含汉中盆地）、商洛和湖北十堰一带，由秦岭、大巴山和米仓山组成，南为大巴山，北为秦岭，海拔多在 1000 ~ 3000m，区内峰峦重叠，山岭陡峻，河谷深切。第四系坡残积层在区内广泛分布，东南部丹江、汉江沿岸和西南部的嘉陵江沿岸以片岩、板岩、千枚岩等易滑岩组为主。区内滑坡、崩塌、泥石流发育，其中滑坡最为发育，在全区广泛分布；泥石流主要集中发育在陇南白龙江中下游和嘉陵江支流西汉水流域，是我国泥石流最为发育的地区；受“5 · 12”汶川地震影响，龙门山断裂带上滑坡、崩塌、泥石流集中发育。

5. 陇中陇东黄土高原滑坡崩塌泥石流高易发区

本区位于甘肃天水、平凉、庆阳以北和宁夏固原一带，该区是我国黄土滑坡最为发育的地区。区内洮河中游、渭河上游及泾河上游黄土覆盖厚，地下水丰富，软弱面发育，同时新构造运动强烈，地震频繁。渭河中游北岸及泾河支流蒲河、洪河流域滑坡密集，新老叠置。泥石流主要分布于渭河河谷天水段、宝天铁路沿线和泾河河谷以北马莲河以西的地区。

6. 吕梁山太行山滑坡崩塌泥石流高易发区

本区位于吕梁山和太行山地区，其中吕梁山高易发区位于山西西部，介于黄河谷地与汾河谷地之间，大体呈北北东走向，吕梁山麓均有黄土分布；太行山在晋冀边界呈南北走向，至晋豫边界转为向东南凸出的弧形。区内滑坡、崩塌、泥石流普遍发育。

（二）崩塌滑坡泥石流中易发区

1. 青藏高原东南部滑坡崩塌泥石流中易发区

本区位于青海西宁市、果洛藏族自治州，西藏那曲—昌都和日喀则—拉萨—林芝—墨脱地区，区内泥石流沿黄河上游，雅砻江、金沙江、澜沧江、怒江和雅鲁藏布江等干支流呈条带状密集发育；滑坡、崩塌沿道路呈线状分布。

2. 粤桂湘赣滑坡崩塌泥石流中易发区

本区位于湖南南部低山、广西中东部、广东东部低山丘陵区，地貌单元上属云贵高原至东南沿海过渡的山地丘陵地带。本区东部多花岗岩丘陵，外形浑圆、沟谷纵横，地表切割得十分破碎；西部主要是石灰岩丘陵，峰林广布，地形崎岖；主要山脉有十万大山、云开大山、莲花山等。区内地质灾害密集，类型以滑坡、崩塌为主，泥石流较少。滑坡以小型坡残积松散层土质为主；崩塌多为小型，类型上土质与岩质各占一半。

3. 琼中南滑坡崩塌泥石流中易发区

本区位于海南岛中部及南部，为中等山地区，是由花岗岩侵入穹窿断裂构造所形成的块状

山地，主要的山脉有五指山、黎母岭、鹦哥岭、雅加大岭。区内崩塌发育，滑坡、泥石流较少。

4. 鄂东湘东滑坡崩塌泥石流中易发区

本区位于湖北东部、湖南东部、江西西部，罗霄山脉矗立中心，是湘江、赣江及北江部分水系的分水岭和发源地。地貌上表现为层峦叠嶂，山岭高大，山势陡峻，沟谷深切。滑坡、崩塌、泥石流沿罗霄山脉密集发育。

5. 浙闽赣滑坡崩塌中易发区

本区位于武夷山、仙霞岭、会稽山一线以东的东南部地区，包括浙江、福建和江西丘陵地区。地形上山岭连绵，丘陵广布，气候受海洋影响很深，年降水量 1400 ~ 1900mm。区内以构造侵蚀中低山为主，山高坡陡，地形地貌复杂，是滑坡碎屑流中易发区。台风暴雨为本区滑坡、崩塌的最直接诱发因素。

6. 伊犁河谷中高山滑坡崩塌泥石流中易发区

本区位于新疆西部的伊犁地区，伊犁河谷北、东、南三面环山，北面有西北—东南走向的科古琴山、博罗科努山；南有北东东—南西西走向的哈尔克他乌山和那拉提山；中部还有乌孙山、阿吾拉勒山等横亘，构成“三山夹两谷”的地貌轮廓。三列山系向东辐合于东部的依连哈比尔尕山，使伊犁河谷形成向西开敞的喇叭形谷地，来自大西洋的湿润水汽易形成山地降雨，为滑坡、崩塌、泥石流的发生提供条件。区内中高山地区滑坡、崩塌密集发育，泥石流发育数量较少。

7. 燕山辽东辽西泥石流滑坡崩塌中易发区

本区东至辽河平原和渤海湾，西至内蒙古高原，南至华北平原，北至西辽河南岸。区内山脉主要有努鲁儿虎山、大青山、松岭、七老图山、燕山等，水系主要有老哈河、青龙河、大凌河、辽河和滦河等。区内泥石流普遍发育；冀北燕山地区地形起伏大，地面非常破碎，河谷狭窄，泥石流、崩塌集中发育。

8. 长白山泥石流崩塌滑坡中易发区

本区泥石流和崩塌发育，滑坡相对较少。长白山南段地质灾害较北段密集，泥石流、滑坡集中分布于此，崩塌在区内各处均有分布。泥石流规模多为中、小型，按物质组成划分多为泥石流，少数为水石流和泥流；崩塌以小型岩质崩塌为主；滑坡规模以小型为主。

（三）崩塌滑坡泥石流低易发区

1. 青藏高原中西部崩塌滑坡泥石流低易发区

本区位于昆仑山、阿尔金山、祁连山以南，冈底斯山、念青唐古拉山以北，除高原湖盆外的广大地区，区内滑坡、崩塌、泥石流沿昆仑山、祁连山和河流、道路发育。

2. 贺兰山中东部崩塌滑坡泥石流低易发区

本区位于贺兰山中段，总体地势比较高陡，加之附近地震活动频繁，崩塌、泥石流相对集中发育。

3. 阴山山地崩塌滑坡泥石流低易发区

本区主要位于沽源、康保、商都一线，与狼山、大青山，以及河套平原与张家口、大同一带盆地北缘组成的区域，区内崩塌、泥石流相对比较发育。

4. 大小兴安岭山地台原崩塌滑坡泥石流低易发区

大兴安岭地貌形态由中山、低山、丘陵、熔岩台地和山间沟谷组成，地形总趋势为南高北低，主要在南段东坡发育泥石流、崩塌灾害;北段不发育地质灾害。小兴安岭南坡山势浑圆平缓，北坡陡峭，发育崩塌灾害，主要分布在小兴安岭南段。

（四）崩塌滑坡泥石流非易发区

崩塌滑坡泥石流非易发区分布在除上述崩塌滑坡泥石流高、中、低易发区以外的区域，主要为成都平原、准噶尔盆地、塔里木盆地、南阳盆地、鄱阳湖平原、洞庭湖平原、黄淮平原、胶莱平原、华北平原、河套平原、三江平原、松辽平原等，区内地势平坦，崩塌、滑坡、泥石流不发育。

四、结语

我国是世界上地质灾害最严重、受威胁人口最多的国家之一，地质条件复杂，山地、丘陵约占国土面积的65%，构造活动频繁，崩塌、滑坡、泥石流等地质灾害隐患多、分布广，防范难度大。截至2015年，全国已登记各类地质灾害隐患点288525处，威胁1891万人和4431亿元财产的安全。其中，在山地丘陵区，发育有崩塌、滑坡、泥石流灾害及隐患点247379处。降雨和地震等自然诱发的滑坡、崩塌、泥石流等地质灾害尽管数量和因灾人员伤亡有所减少，但财产损失增加明显，灾情形势复杂。未来一段时间内，我国极端天气增多趋势明显，中高强度地震仍将处于频发、多发时期，暴雨、地震等导致地质灾害的突发性、异常性和不可预见性增加，崩塌、滑坡、泥石流等地质灾害仍将呈高发、频发态势，地质灾害防治工作面临的形势依然严峻。

《中国崩塌滑坡泥石流易发程度图》的编制，旨在帮助读者理解和认识影响崩塌、滑坡、泥石流发育的不同自然因素，了解自然条件下我国不同地区崩塌、滑坡、泥石流灾害的易发程度，并且为政府部门制订地质灾害防治规划、开展地质灾害防治工作部署等提供技术支撑，服务于我国的地质灾害防灾减灾及社会经济建设。

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China Geological Survey Achievements

Explanation of Susceptibility Map of Collapse, Landslide and Debris Flow in China

(1：5,000,000)

China Institute of Geo-Environment Monitoring

Chief Compiler: Fang Hao

Compilers: Li Yuan, Yang Xudong, Qu Xueyan,
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Geological Publishing House

BEIJING

Compiling Explanation for Atlas Sets of Geological Environment of China

1. Background and Purpose

At the late 1980s and the early 1990s, under the organization of the Department of Geological Environment of the Geology and Mineral Resources, based on the available data and requirements some veteran environmental geological professionals (Duan Yonghou et al.) accomplished *Series of Environment Geology Map of China (1:6,000,000)* consisting of 11 national maps published in 1992. In the early 21st century, with the development of society, more and more attention has been paid to the research on geological disasters with financial support of Chinese government. The Hydrogeology and Environmental Geology Department of China Geological Survey (Yin Yueping et al.) led the compilation of 6 national geological environmental maps (1:4,000,000), which focused on the geo-hazards in China and were published in 2011 to 2013 successively.

Since the 1990s, especially the national land resource survey starting from 1999, a large amount of geological surveys at the national level have been completed, including the province-based 1:500,000 environmental geological surveys, the county-and-city-based geological disaster surveys and the 1:50,000 geological disaster investigation in the key areas, the new round of national evaluation of groundwater resources, the groundwater resource surveys and evaluations in the major basins and plains, the national groundwater pollution survey, the national geothermal resource evaluation and etc. Further geological surveys have also been carried out recently, such as the national mining environmental geological survey, the land subsidence investigations in the key areas, the environmental geological surveys in the important economic zones and urban agglomerations, the integrated geological survey in the coastal areas, the investigation and evaluation of the major active faults, the province-based investigations on the important geo-heritage resources, the land desertification survey, and the geological survey in response to global climate change. At the province level, plenty of work on geological investigations and evaluations in all provinces, autonomous regions and municipalities is accomplished or in progress. In general, the level of geological environmental survey in China is enhanced greatly. A deal of regular patterns of geo-environment are summarized, some of which are even breakthroughs in the world.

With the aims of summarizing investigation and research results, further improving and enhancing the understanding of the characteristics of the regional geological environment and the development distribution of geological disasters in China, promoting the theoretical innovation of hydrogeology, engineering geology and environmental geology and the development of disciplines and the application of the results, and providing better service to geological environment protection management and geological disaster, the General Office of the Ministry of Land and Resources (MLR) issued *Compilation Program of Atlas Sets of Geological Environment of China* on June 20, 2013 (No. 556 Office Letter of the MLR, 2013), and officially launched the project to compile *Atlas Sets of Geological Environment of China*.

2. A train of Thoughts and General Framework

According to the letter mentioned above, the Geological Environment Department of the MLR and the China Geological Survey (CGS) set up an office for compiling *Atlas Sets of Geological Environment of China* in the China Institute of Geo-Environment Monitoring. After several times of discussion and consultation, *Implementation Plan of Atlas Sets of Geological Environment of China* was finally settled in Nov. 2013. The framework of the compilation is built on the five-professional-fields ("category of geological environmental condition", "category of geological hazard", "category of groundwater", "category of mine geological environment" and "category of geo-heritage") and two-geographical-dimensions ("national and provincial" and "global and local"). In addition, the provincial atlas consists of "7 compulsory + 2 elective maps", which are "geo-environment zonation map", "distribution map of geological hazards", "susceptibility map of geological hazards", "map of groundwater resources", "map of groundwater environment", "map of mine geo-environmental problems", "zoning map of protection and restoration of mining geo-environmental instructions" and "status quo map of land subsidence", "distribution map of important geo-heritage resources". The general requirement of compilation is namely "three unified framework", including "unified geographic data base", "unified mapping requirements" and "unified database building requirements". All disciplines mentioned above lead to a synchronized progress of "1 (national) + 31 (provincial, autonomous region's or municipal) atlas sets", and also lay a technical foundation for realization of multi-scale expression and dynamic update.

Using the geographic information data (1:1,000,000) as foundation, the Office established a unified national geographic information base map (1:5,000,000), inter-provincial important area geographic information base maps and province (autonomous region, or municipality) geographic information base maps. Meanwhile, "mapping requirements", "database building requirements" and "glossary of professional terms" in five-professional-fields were issued to standardize the compilation. Through the trainings to provincial mapping staff and back and forth discussions, the technical standards were constantly improved, which realized the unity of graphic thinking, the promotion of geological understanding, the scientific and artistic expression of mapping, and gradually established the national geological environment map database system.

3. Atlas Composition and Task Assignment

According to the letter mentioned above, the China Geological Survey is responsible for *Atlas of Geological Environment of China*, which is the series of the national geological environment maps and interprovincial regional geological environment maps. The counterparts of local government organize relevant institutions to compile their own *Atlas of Geological Environment of* ×× *Province (Autonomous Region, or Municipality)* respectively.

Atlas of Geological Environment of China (hereinafter referred to as *Atlas*), whose compilation goes through three stages from technical preparation, compilation and evaluation, to perfection and publication, is completed by hundreds of geological professionals from more than ten institutions affiliated to the CGS. The *Atlas* systematically integrates the data of geological environment investigation and monitoring in China for many years, which has 36 maps compiled or revised with national and regional geological environmental interests (see Table 00-1). The 36 maps include 19 geological environmental condition maps, 5 geological disaster maps, 8 groundwater maps, 2 mine geological environment maps and 2 geo-heritage maps, among which 20 maps are in national interests and the rest of them are in regional interests.

The *Atlas* organized by: Geological Environment Department of the Ministry of Land and Resources.

The *Atlas* deployed by: Hydrogeology and Environmental Geology Department of China Geological Survey.

The *Atlas* technically guided by: China Institute of Geo-Environment Monitoring.

Atlas Chief Editors: Hao Aibing, Li Ruimin.

Atlas Associate Editors: Shi Jusong, Xu Huizhen, Li Minglu.

Atlas Editorial Committee: Li Yuan, Sun Jichao, Zhang Jinde, Dong Ying, Zeng Qingshi, Luo Yuechu, Li Tiefeng, Le Qilang, Lin Liangjun, Zhang Eryong, Wang Yiping, Jing Jihong, Cheng Guoming, Wu Zhonghai, Guo Jianqiang, Shi Jian, Ma Zhen, Zhu Hua, Zhao Haiqing, Jiang Yuehua, Huang Changsheng, Zheng Wanmo, Sun Yongjun.

Atlas Compilers: Li Xiaolei, Yin Ming, Gao Mengmeng, Yin Chunrong, Ren Ying, Huang Zhuo, Wang Yi, Liu Qiong, Cao Feng, Zhang Xiangyuan, Chen Wenjie.

Atlas Advisory Group: Wang Mingde, Wen Dongguang, Shi Jiansheng, Lu Yaoru, Cheng Hangxin, Sun Xiaoming, Li Wenpeng, Li Jingsen, Li Lierong, Cen Jiafa, Qiu Xinfei, Shen Zhaoli, Zhang Zuochen, Zhang Yueqiao, Wu Qiang, Lin Xueyu, Zhao Yunchang, Hou Jinwu, Qin Yisu, Yuan Daoxian, Yin Yueping, Tao Qingfa, Huang Xuebin, Jiang Zhongcheng.

Table 00-1 List of *Atlas of Geological Environment of China*

Professional Category	Serial Number	Name	Compiled by
Category of Geological Environmental Condition	00-1-01	Geo-Environmental Zonation Map of China (1:5,000,000)	China Institute of Geo-Environment Monitoring
	00-1-02	Geo-Environment Safety Degree Map of China (1:5,000,000)	China Institute of Geo-Environment Monitoring
	00-1-03	Environmental Geological Map of Karst in China (1:5,000,000)	Institute of Karst Geology, CAGS
	00-1-04	Distribution Map of Desertification Land in China (1:5,000,000)	China Aero Geophysical Survey & Remote Sensing Center for Land and Resources
	00-1-05	Distribution Map of Active Faults in China and Its Adjacent Sea Area(1:5,000,000)	Institute of Geomechanics, CAGS
	00-1-06	Engineering Geologic Map of China (1:4,000,000)	Institute of Hydrogeology and Engineering Geology, CAGS
	00-1-07	Suitability Evaluation Map of CO_2 Geological Storage in Main Sedimentary Basins in China and Its Adjacent Sea Area (1:5,000,000)	Center for Hydrogeology and Environmental Geology Survey, CGS
	00-1-08	Quaternary Geologic Map of the People's Republic of China and Adjacent Sea Area (1:2,500,000)	Institute of Hydrogeology and Engineering Geology, CAGS
	00-1-09	Environmental Geological Map of the Coastal Areas in China (1:3,050,000)	Tianjin Geological Survey Center, CGS
	00-1-10	Environmental Geological Map of the Important Economic Zone in the Circum-Bohai-Sea Region (1:1,200,000)	Tianjin Geological Survey Center, CGS
	00-1-11	Environmental Geological Map of the Economic Zone in the Yangtze River Delta (1:750,000)	Nanjing Geological Survey Center, CGS
	00-1-12	Environmental Geological Map of the Economic Zone (Core Area) on the West Side of the Straits (1:600,000)	Nanjing Geological Survey Center, CGS
	00-1-13	Environmental Geological Map of the Urban Agglomerations in the Middle Reaches of the Yangtze River (1:900,000)	Wuhan Geological Survey Center, CGS
	00-1-14	Environmental Geological Map of the Pearl River Delta Economic Zone (1:500,000)	Wuhan Geological Survey Center, CGS
	00-1-15	Environmental Geological Map of the Beibu Gulf Economic Zone (1:450,000)	Wuhan Geological Survey Center, CGS
	00-1-16	Environmental Geological Map of the Chengdu-Chongqing Economic Zone (1:1,000,000)	Chengdu Geological Survey Center, CGS
	00-1-17	Environmental Geological Map of the Changchun-Jilin-Tumen Economic Zone (1:600,000)	Shenyang Geological Survey Center, CGS

Continue

Professional Category	Serial Number	Name	Compiled by
	00-1-18	Environmental Geological Map of the Guanzhong Basin Urban Agglomeration (1:350,000)	Xi'an Geological Survey Center, CGS
	00-1-19	Map of Soil Selenium Environment in the Huang-Huai-Hai Plain (1:1,150,000)	China Institute of Geo-Environment Monitoring
Category of Geological Hazard	00-2-01	Distribution Map of Collapse, Landslide and Debris Flow in China (1:5,000,000)	China Institute of Geo-Environment Monitoring
	00-2-02	Susceptibility Map of Collapse, Landslide and Debris Flow in China (1:5,000,000)	China Institute of Geo-Environment Monitoring
	00-2-03	Status Quo Map of Land Subsidence in China (1:5,000,000)	China Institute of Geo-Environment Monitoring
	00-2-04	Distribution Map of Collapse, Landslide and Debris Flow in the Three Gorges Reservoir Area (1:650,000)	China Institute of Geo-Environment Monitoring Wuhan Geological Survey Center, CGS
	00-2-05	Status Quo Map of Land Subsidence in the Yangtze River Delta (1:750,000)	Shanghai Institute of Geological Survey and Research
Category of Groundwater	00-3-01	Map of Groundwater Resources in China (1:5,000,000)	Institute of Hydrogeology and Environmental Geology, CAGS
	00-3-02	Map of Groundwater Environment in China (1:5,000,000)	Institute of Hydrogeology and Environmental Geology, CAGS
	00-3-03	Hydrogeological Map of China (1:5,000,000)	Institute of Hydrogeology and Environmental Geology, CAGS
	00-3-04	Distribution Map of Geothermal Resources in China (1:5,000,000)	Institute of Hydrogeology and Environmental Geology, CAGS
	00-3-05	Hydrogeological Map of the Huang-Huai-Hai Plain (1:1,150,000)	Institute of Hydrogeology and Environmental Geology, CAGS
	00-3-06	Hydrogeological Map of the Ordos Basin (1:1,100,000)	Xi'an Geological Survey Center, CGS
	00-3-07	Hydrogeological Map of the Songnen Plain (1:750,000)	Shenyang Geological Survey Center, CGS
	00-3-08	Hydrogeological Map of the Jianghan-Dongting Plain (1:450,000)	Wuhan Geological Survey Center, CGS
Category of Mine Geological Environment	00-4-01	Map of Mine Geo-Environmental Problems in China (1:5,000,000)	China Institute of Geo-Environment Monitoring
	00-4-02	Zoning Map of Protection and Restoration of Mining Geo-Environment in China (1:5,000,000)	China Institute of Geo-Environment Monitoring
Category of Geo-heritage	00-5-01	Distribution Map of Important Geo-Heritage Resources in China (1:5,000,000)	China Institute of Geo-Environment Monitoring
	00-5-02	Distribution Map of Important Fossil Localities in China (1:5,000,000)	China Institute of Geo-Environment Monitoring

Note：*Engineering Geologic Map of China* (1:4,000,000) and *Quaternary Geologic Map of the People's Republic of China and Adjacent Sea Area* (1:2,500,000) were published in 1990, which are only digitized, standardized and constructed to database this time.

The atlas of geological environment in provinces (autonomous regions or municipalities) (hereinafter referred to as “provincial atlas”) are accomplished by more than a thousand of geological professionals from over fifty institutions under the leadership of provincial (autonomous region’s or municipal) land and resources management departments. “Provincial atlas” are compiled and published according to “mapping requirements”, “database building requirements”, “standardized geographic information base map” and “glossary of professional terms”. 271 maps of 31 provincial atlas (see Table 00-2) include 44 geological environmental condition maps, 71 geological disaster maps, 78 groundwater maps, 61 mining geological environment maps, and 17 geo-heritage maps, among which 266 maps are in provincial interests and 5 maps are in inner-province regional interests. To ensure the systematic nature of *Atlas Sets of Geological Environment of China*, it is suggested that the geological environment maps of provinces (autonomous regions or municipalities) should be numbered in the format as “atlas serial number - category - map serial number”. For example, *Status Quo Map of Land Subsidence in Beijing* is numbered as 01-02-03.

Table 00-2 List of “Provincial Atlas”

Atlas Serial Number	Provinces (Autonomous Regions or Municipalities)	Number of Maps	Compiled by
01	Beijing	9	Beijing Institute of Geology
02	Tianjin	10	Tianjin Institute of Geo-Environment Monitoring
03	Hebei	8	Hebei Institute of Geo-Environment Monitoring
04	Shanxi	8	Shanxi Center of Geo-Environment Monitoring
05	Inner Mongolia	10	Inner Mongolia Institute of Geo-Environment Monitoring
06	Liaoning	8	Liaoning Institute of Geo-Environment Monitoring
07	Jilin	9	Jilin Institute of Geo-Environment Monitoring
08	Heilongjiang	11	Hydrogeology and Engineering Geology Exploration Institute of Heilongjiang Province
09	Shanghai	4	Shanghai Institute of Geological Survey
10	Jiangsu	8	Jiangsu Institute of Geological Survey
11	Zhejiang	8	Zhejiang Institute of Geo-Environment Monitoring
12	Anhui	7	Anhui Center of Geological Survey and Environmental Monitoring
13	Fujian	7	Fujian Center of Geological Environment Monitoring
14	Jiangxi	22	Jiangxi Center of Geological Hazard Emergency
15	Shandong	9	Shandong Institute of Geo-Environment Monitoring
16	Henan	11	Henan Province Geological Environment Monitoring Station
17	Hubei	7	Hubei Province of Geological Environment Terminus

Continue

Atlas Serial Number	Provinces (Autonomous Regions or Municipalities)	Number of Maps	Compiled by
18	Hunan	7	Hunan Institute of Geo-Environment Monitoring
19	Guangdong	7	Guangdong Institute of Geo-Environment Monitoring
20	Guangxi	7	Guangxi Institute of Geo-Environment Monitoring
21	Hainan	13	Hainan Institute of Geological Survey
22	Chongqing	8	Nanjiang Hydrogeological Engineering Geological team, Chongqing Bureau of Geology and Minerals Exploration
23	Sichuan	8	Sichuan Institute of Geo-Environment Monitoring
24	Guizhou	13	Guizhou Institute of Geo-Environment Monitoring
25	Yunnan	8	Yunnan Institute of Geo-Environment Monitoring
26	Tibet	2	China Institute of Geo-Environment Monitoring
27	Shaanxi	8	Shaanxi Institute of Geo-Environment Monitoring
28	Qinghai	7	Qinghai Institute of Hydrogeology and Engineering Geology and Environmental Geology
29	Gansu	13	Gansu Institute of Geo-Environment Monitoring
30	Ningxia	7	Ningxia Institute of Land Resources Survey and Monitoring
31	Xinjiang	7	Xinjiang Institute of Geo-Environment Monitoring
Total		271	

Citation format: if *Distribution Map of Active Faults in China and Its Adjacent Sea Area* is quoted, it should be cited as "Wu Zhonghai, Zhou Chunjing, 2017, *Distribution Map of Active Faults in China and Its Adjacent Sea Area (1:5,000,000)* Refer to: Hao Aibing, Li Ruimin, *Atlas Sets of Geological Environment of China*, Beijing: Geological Publishing House, Map Number: 00-01-05".

In the process of compilation of *Atlas Sets of Geological Environment of China*, we have always got strong support and guidance from Ministry of Land and Resources, China Geological Survey, China Institute of Geo-Environment Monitoring, Bureaus (Departments) of Land and Resources of Provinces (Autonomous Regions or Municipalities), and also leaders and professional personnel of relevant institutions. Here, we would like to express our heartfelt thanks to all of them who accompany us through the arduous but amazing journey!

Office for Compiling
Atlas Sets of Geological Environment of China
June, 2017

Foreword

Susceptibility Map of Collapse, Landslide and Debris Flow in China is one of the production maps in the category of geological hazards and belongs to the *Atlas of Geological Environment of China* (hereinafter referred to as the *Atlas*).

Geological hazards are trigged by variations in the geological environments or bodies caused by natural and human factors, and they are harmful to human beings and the society. These hazards can be divided into collapse, landslide, debris flow, ground subsidence, geofracture, rock/soil shrinkage and swelling, sand liquefaction, land freezing and thawing, soil desertification, swamping and soil salinization. Among these hazards, collapse, landslide and debris flow cause the most severe damages.

In China, topographical and geological conditions are complicated, and mountains and hills account for 2/3 of the national territory area; the regional climate varies, rainstorm occurs frequently in local areas, and earthquakes hit frequently. Geological hazards occur frequently due to the intense impacts of dense population and human engineering activities. Statistics show that collapse, landslide and debris flow hazards have caused more than 20,000 deaths over the past 50 years; that is, several hundreds to more than ten thousand people are killed every year. Among the numerous natural geological hazards, the resulting number of deaths is second to that in earthquake and flooding hazards. The frequent occurrences of collapses, landslides, and debris flows have caused heavy losses in people's lives and properties and become one of the factors constraining the national economic development.

The former Ministry of Land and Resources initiated a compilation of the *Atlas* to comprehensively summarize the background features and development evolution laws of the geological environment, further promote efficient transformation and application of the results from the field survey and monitoring of geological hazards, and effectively support the conservation management of the geological environment in China. The compilation of the *Susceptibility Map of Collapse, Landslide and Debris Flow in China* (hereinafter referred to as the Map) can be used to prevent and reduce geological hazards, perform geological hazard work deployment, and provide technical support for national social and economic construction.

The Map is compiled by the China Institute of Geo- Environment Monitoring under the uniform requirements of the *Atlas* and the guidance of the Expert Committee of the *Atlas*. The chief compiler is Fang Hao, the map compilation director is Li Yuan, and the map compilers are Yang Xudong, Qu Xueyan, Yin Chunrong, and Tong Bin. We express our sincere gratitude to the Geological Environment

Department of the former Ministry of Land and Resources, China Geological Survey, China Institute of Geo-Environment Monitoring, and leaders and relevant professional technicians from some provinces for their great support and guidance.

Contents

1 Compilation Principles, Contents and Methods

1.1 Compilation Principles

1.1.1 To reflect spatial differences in susceptibility under natural induction factors

During the construction of the susceptibility evaluation index system of collapse, landslide and debris flow, only natural induction factors are considered and human activity-related factors are excluded. The final evaluation results merely reflect the spatial differences in the susceptibility of collapse, landslide and debris flow under the impacts of natural factors in long term.

1.1.2 To serve macroscopic planning

This map aims to compile planning of geological hazard prevention and control, formulate deployment of geological hazard prevention and control, provide technical support for social and economical construction and serve geological hazard prevention and reduction for the country and local areas.

1.1.3 To correlate with and make correspondence to the provincial-level susceptibility maps and the Distribution Map of Collapse, Landslide and Debris Flow in China

During the Map compilation, updated and formally published research results should be selected. The comprehensive research results of the susceptibility of the geological hazards of various provincial-level administrative regions are considered; with respect to the division of the susceptibility of the geological hazards of each provincial-level administrative region, the high-to-low order sequence of susceptibility cannot be reversed. In addition, the Map and the *Distribution Map of Collapse, Landslide and Debris Flow in China* are thematic maps of the *Atlas of Geological Environment of China*; therefore, the susceptibility evaluation results consider the correlation with and correspondence to the *Distribution Map of Collapse, Landslide and Debris Flow in China*.

1.1.4 To ensure the simplicity and readability of the map

The representation of the Map should be simple and clear, understandable, and focused. Professionalized terminologies, redundant text discussion and complex drawing should be rejected.

1.1.5 To compile according to standards and regulations

The contents and manifestation patterns of the Map are based on the *Technical Requirements for the Atlas of Geological Environment of China* and relevant national and industrial standards.

1.2 Compilation Contents

The *Susceptibility Map of Collapse, Landslide and Debris Flow in China* combines the natural factors of topography, landform, rock and soil mass type, geological structure, earthquake, rainfall, vegetation, river system, etc., which reflect the spatial differences in the susceptibility of collapse, landslide and debris flow. This map also differentiates areas with high, middle, low, and no susceptible zones to collapse, landslide and debris flow and explains the development and distribution characteristics and risks of these hazards by zoning.

Given the lack of data recording collapses, landslides and debris flows in Hong Kong, Macao, and Taiwan in the current National Geo-hazard Database, the evaluation results of the susceptibility of the aforementioned areas in the Map are obtained by quantum mechanical calculation of geological environment conditions.

1.3 Compilation Methods

Quantitative calculation is applied to evaluate the susceptibility of collapse, landslide and debris flow in China. According to the development status quo of regional collapse, landslide and debris flow and combining with landform, topography, rock and soil mass type, geological structure, earthquake, rainfall, vegetation, river system and other natural factors, the certainty coefficient and gray correlation analysis methods are applied to evaluate the susceptibility of collapse, landslide and debris flow. According to the susceptibility evaluation and main natural influencing factors of topography, landform, rock and soil mass type and the development characteristics of collapse, landslide and debris flow, the “bottom-up” method is adopted to divide these hazards by susceptibility.

The *Susceptibility Map of Collapse, Landslide and Debris Flow in China* is based on administration division. Information of its geological hazard profession layer is expressed in a surface solid color, and different color systems are applied to differentiate geological hazards into high-, middle-, low-, and no susceptible levels.

2 Analysis of Influencing Factors of Geological Hazards

Under natural conditions, collapse, landslide and debris flow in China are mainly affected by landform, topography, rock and soil mass type, geological structure, earthquake, rainfall, vegetation, river system and other factors.

2.1 Topography

Topography is one of the main factors that influence the development of collapse, landslide and debris flow. The continental topography of China is divided into three-level terraces: the first level refers to the Qinghai-Tibet Plateau at an average elevation of >4,500 m above sea level and consists of high mountains, extremely high mountains, and fluctuating and gentle plateau surfaces constituted by high-elevation hills, platforms, and plains running among them; the second level is located between the outer margin of the Qinghai-Tibet Plateau and the Da Hinggan ling–Taihang–Funiu–Wushan–Xuefeng Mountains, and it has an average elevation of 1,000–2,000 m, and consists of the Tarim Basin, Junggar Basin, the Loess Plateau, the Inner Mongolia Plateau, the Sichuan Basin and the Yunnan-Guizhou Plateau as well as Tianshan, Yinshan, Qinling, Daba and Dalou Mountains, etc.; and the third level lies east of the Da Hinggan ling–Taihang–Funiu–Wushan–Xuefeng Mountains, has an average elevation of <500 m, and consists of the Northeast China Plain, the Huang-Huai-Hai Plain, the Middle–Lower Yangtze River Plain, the Changbai Mountains, the Shandong low-mountain hill and the hilly areas south of the Yangtze River .

In transitional slope zones, mountain series, and their margins among various levels of terraces, the height differences of valleys and ridges are up to 2,000 m, the terrain slopes are relatively high, numerous free faces are developed, and a high amount of loose accumulated deposits are formed, leading to collapse, landslide and debris flow. Collapse and landslide are principally developed in the second level terrace and its peripheral fluctuating mountain areas; they are the most developed in moderately fluctuating mountain areas, accounting for 34.2% of the total area. Debris flow are mainly developed in the transition from the first level to the second level terraces and the most developed in highly fluctuating mountain areas, accounting for 33.4% of the total area(Table 1).

Table 1 Amount Percents of Collapse, Landslide and Debris Flow in Different Terrains

Hazard type	Ultra-highly fluctuating mountain area (>2,500 m)	Highly fluctuating mountain area (1,000-2,500 m)	Moderately fluctuating mountain area (500-1,000 m)	Weakly fluctuating mountain area (200-500 m)	Hill (<200 m)
Collapse,Landslide	0.5%	28.%	34.2%	22.8%	14.5%
Debris flow	2.6%	33.4%	29.9%	16.6%	17.5%

2.2 Geological Structure

Active faults are factors that directly control regional collapse, landslide and debris flow. Active faults in various regions in China show differences in scale, activity mode, activity, and intensity. A synthetic analysis of the characteristics of active faults divides China by territory into North China, Northeast China, South China, Southwest China, Northwest China, and Taiwan regions. Active faults in North China are mostly inherited since the Mesozoic–Cenozoic time; in particular, NNE- and NE-trending active faults are large-scaled and intense in terms of vertical differentiated activity. Major NE–NNE trending faults in Northeast China gradually weaken in activity; however, NW-trending active faults are of young age and activate intensely. NW- and EW- trending faults in South China also show certain activity, and the intersections with NE–NNE trending faults usually become areas that are poorly stable in crust at present. Active fault belts in Southwest China mostly occur as nearly EW–NW–NNW arcs and strike NS, and most of which are large-sized active faults. Active faults in Northwest China are extremely developed and dominated by nearly EW and NW strikings with minor NE striking and are dominated by compressoshear properties.

Regional collapse, landslide and debris flow easily develop in active structural fault belts. On the one hand, the location is in active fault belts, where rocks are broken, favoring weathering, decreasing the rock mass integrity, and bringing abundant loose materials. On the other hand, structural surfaces/planes, such as bedding surfaces, fault planes, joint surfaces, schistosity planes, or stratigraphic unconformities, control the spatial locations of the sliding surfaces and boundaries of landslide and collapse. Therefore, active structures control the extension directions, development scales, and distribution densities of collapse, landslide and debris flow belt.

2.3 Earthquake

Earthquake is among the significant factors that trigger collapse, landslide and debris flow. China is often hit by earthquakes, which mainly occur in 1) Taiwan, Bohai–central Shandong, and the North China Plain in the east; 2) Qilian Mountain, Lüliang Mountain and Helan Mountain in the north; 3) Yunnan Province, Xizang(Tibet) Autonomous Region and western Sichuan Province in the southwest; 4) Tianshan and Altay Mountains in the northwest. According to the epicenter distribution, most earthquakes are concentrated in tectonic or fault belts formed in the late geological time.

An earthquake loosens slope soil and rock structures. Under the repeated vibration shock by the earthquake, rock and soil masses are dislocated along the original or new soft structural planes and provide abundant loose materials for debris flow. The earthquake produces fractures and faults, which favor seepage of rainfall and melted snow. Thus, after the earthquake, landslides or collapses often occur due to rainfall and snow melt. Generally, earthquakes and simultaneous (co-developing with earthquake) landslides usually occur in rainy season or during rainstorm or snow melting. In dry season, slopes are dry and have high stability; as such, simultaneous landslides have been rarely developed, whereas post-developing (occurring in a very long time after an earthquake occurs) landslides are often developed.

Table 2 Amount Percents of Collapse, Landslide and Debris Flow at Different Ground Motion Peak Accelerations

Ground motion peak acceleration/g	Hazard types	
	Collapse, Landslide	Debris flow
≥0.4	0.5%	2.6%
0.3-0.4	28%	33.4%
0.2-0.3	34.2%	29.9%
0.15-0.2	22.8%	16.6%
0.1-0.15	14.5%	17.5%

2.4 Rock and Soil Mass Type

Rock and soil mass type is a material basis factor for the development of collapse, landslide and debris flow. China is vast in territory and has complex engineering geological conditions. Generally, rock and soil mass can be divided into rock and soil mass types. Rock mass can be subdivided based on genesis type, intensity characteristics, and structure into magmatic, clastic, carbonate, and metamorphic forms. Meanwhile, soil mass can be subdivided based on grain composition and soil special engineering geological properties into coarse-grained soil, sandy soil, fine-grained soil, soft cohesive soil, swelling soil, salinized soil, permafrost, and loess.

Generally, clastic rocks and soft flaky metamorphic rocks mainly cause collapse and landslide, and are lithologically dominated by mudstone, shale, slate, soft rock beds containing carbonatites, argillization beds, and structural fractured beds. After water softening, these soft beds feature low shearing strength, form soft sliding surfaces, and easily cause collapse and landslide. In snow and ice melting seasons, seasonal frozen ground brings water, which impacts the stability of rock and soil slopes and triggers collapse and landslide. Loose accumulation deposits produced from collapse and landslide, slope residues on mountains slopes, and pluvial alluvial sediments within valley beds are the sources of solid materials of debris flow. Debris flow easily occur under certain rainfall conditions(Table 3).

Table 3 Amount Percents of Collapses, Landslides and Debris Flows in Different Types of Rock and Soil Mass

Hazard type	Rock mass				Soil mass	
	Magmatic rock	Clastic rock	Carbonate rock	Metamorphic rock	Loess	Others
Collapse, landslide	21.4%	34.7%	19%	21.7%	1.5%	1.7%
Debris flow	21.3%	27.5%	19%	26.3%	2.2%	3.8%

2.5 Rainfall

Rainfall is one of the significant external factors that trigger collapse, landslide and debris flow. As affected by physico-geographical environment, rainfall in China generally tends to gradually decrease from SE to NW, and local rainstorm concentrates in western mountains. According to the rainfall contour of China, south of the Qinling mountains–Huaihe River Line, the annual average rainfall is above 800 mm, rainfall is abundant, and the region is humid. To the north of the line, rainfall is rare and the region is semi-arid and arid. Taiwan, the hilly area of the coastal region of South China, and some boundary areas of northwestern Yunnan Province and southeastern Xizang(Tibet) Autonomous Region have average annual rainfall of above 2,000 mm. In the west, such as in Toksun in Xinjiang Uygur Autonomous Region, the average annual rainfall is merely 7.1 mm. Rainfall in China varies greatly with season. In Eastern China, the main rainfall belt experiences a northward-starting to recession-southward process every year, forming a rain seasonal change tendency. Generally, the main rain belt is located in the coastal area of south china from February to May every year. In middle June, with the Subtropical High jumping northwards, the rain belt migrates to the Yangtze River basin, producing more than 20 days of plum rains. In middle July, the Subtropical High jumps northwards in a second time and the rainy belt arrives in the Yellow River basin. During the transition from July to August, the rain belt reaches North China and Northeast China. In middle August, the rainy belt lies to the northernmost part. In August and September, with the retreating southwards of the Subtropical High, the rainy belt arrives in the Yangtze River basin within a half of month. When cold air runs southwards, autumn rains hit Sichuan–Guizhou Provinces. In middle October, the rainy belt retreats to the coastal region of South China.

The amount of precipitation determines the intensity of hydrodynamism. On the one hand, with respect to collapse and landslide hazards, rainfall permeates into pores in soil mass or rock fissures to soften, argillize, and lubricate fissure surfaces and thus decrease the rock shearing strength and easily dislocate rock and soil mass. On the other hand, rainfall permeates into and supplies ground water, increasing the ground water level or pressure and posing floating effects on rock and soil masses. Soil masses are softened and saturated, thereby decreasing the shearing intensity and stability of rock/soil masses and easily causing collapse and landslide. Water is not only an important constituent of debris flow but also a triggering condition and transportation medium. In valleys with certain slope, if abundant loose materials are available, heavy rainfall easily causes debris flow within a short period. In addition, in places such as Nyainqentanggula Mountains (eastern segment) in the southeastern Xizang, Himalayas Mountains (central eastern segment), Hengduan Mountains (central segment), Tanggula Mountains (eastern segment), Kunlun Mountains, Tianshan Mountains, and Qilian Mountains, hydrodynamic force produced from seasonal melt water usually gives rise to debris flow (Table 4).

Table 4 Amount Percents of Collapse, Landslide and Debris Flow at Different Precipitation Amounts

Amount of precipitation /mm	Hazard types		Amount of precipitation /mm	Hazard types	
	Collapse, landslide	Debris flow		Collapse, landslide	Debris flow
< 75	0.2%	0.8%	500-600	3.2%	9.2%
75-100	0.7%	1.5%	600-800	6.3%	20.5%
100-150	1.4%	2.9%	800-1000	16.9%	13.9%
150-200	2.2%	3.3%	1000-1200	14.8%	9.3%
200-300	0.3%	2.5%	1200-1400	17%	5.4%
300-400	1.6%	8%	1400-1600	19.2%	3.8%
400-500	3.4%	17.5%	⩾ 1600	12.7%	1.4%

2.6 River System

River system is one of the external dynamic factors for the occurrence of collapse and landslide. Under climate and topography constraints, river systems are very unevenly distributed in China and generally show four characteristics.

2.6.1 Large in number

there are above 50,000 rivers with a drainage area of above 100 km^2, 1580 rivers with a drainage area of above 1,000 km^2, and 79 rivers with a drainage area of above 10,000 km^2.

2.6.2 Abundant water varying with season

Statistics show that the average annual runoff volume of rivers in China is about $26{,}000\times10^8$ m^3, accounting for 6.6% of the world's total runoff volume. Although rivers in China have abundant water, their distribution is extremely uneven with season and runoff is predominated in summer and weakens in winter.

2.6.3 High runoff difference in different regions

Given that China is affected by monsoon climate, in North China and Southwest China, which account for 50% of the national agricultural acreage, the runoff volume only accounts for 10% of China's total volume. Among them, the Huaihe River, Haihe River, and Liaohe River basins account for 28% of the total agricultural acreage and only 4% of the runoff.

2.6.4 High river density in various regions

The river density in Eastern China is generally over 0.1 km/km^2, especially in Southtern China which is more than 0.5km/km^2. The river density which is located in the inland of Northwest China is low, close to or equal to zero in some areas.

The impacts of rivers on collapse and landslide are mainly expressed as follows: in the flowing process of rivers, hydrodynamism produces water erosion to mountain slope foots, thereby decreasing the stability of bank slopes and giving rise to collapse and landslide. In side slopes far from rivers, river systems pose weak or no impacts since they are not affected by hydrodynamic erosion of rivers.

2.7 Vegetation

Vegetation is among the external factors that affect the development of collapse, landslide and debris flow. Vegetation cover types in China are divided into natural vegetation, agricultural vegetation, and non-vegetation sections. Natural vegetation is subdivided into coniferous forest, broad-leaved forest, bushwood and short coppice, desert, prairie, meadow, and herbaceous swamp. Agriculture vegetation is subdivided into: grain crops with one harvest a year and cold-resistant commercial crops; rainfed crops (local rice) with two harvests a year or three harvests for two years and deciduous fruit tree garden economic forest of warm temperate zone; dry and humid grain crops with two harvests a year and subtropical evergreen; deciduous economic forest and fruit tree garden, shadow-loving, irrigated single (double, continuous) cropping rice or rainfed rice with three harvests a year and subtropical evergreen economic forest and fruit garden; and double-cropping rice or warm-loving double continuous cropping or warm-loving rainfed rice and tropical evergreen economic forest and fruit garden.

Under normal conditions, vegetation in high vegetation coverage areas can enhance the stability of side slopes of rock and soil mass at a certain degree because tree roots play a role in stabilizing water and soil and preventing the loss of water and soil. Given that different types of vegetation grow in different environments, vegetation types play a certain indication role in the development of collapse, landslide and debris flow at a certain degree.

3 Division of Collapse, Landslide and Debris Flows by Susceptibility

According to the susceptibility evaluation of collapse, landslide and debris flow in China, the entire country can be divided into high, middle, low, or no susceptible zones to collapse, landslide and debris flow.

High susceptible collapse, landslide and debris flow zone covers an area of about 131×10^4 km^2, accounting for 13.6% of the total territory area, and mainly include southwestern Yunnan-eastern Xizang, southwestern Sichuan-central Yunnan, Yunnan-Guizhou Plateau, Qingling-Daba Mountains, central Gansu–eastern Gansu Loess Plateau, Lüliang Mountain-Taihang Mountains, etc.

Middle susceptibility collapse, landslide and debris flow zone covers an area of about 278×10^4 km^2, accounting for 29.0% of the total territory area, and mainly include southeastern Qinghai-Tibet Plateau, Guangdong–Guangxi–Hu'nan–Jiangxi, southern Hainan, eastern Hubei- eastern Hu'nan, Zhejiang–Fujian–Jiangxi, Ili River Valley Meddle-High Mountain, Yanshan Mountain–Eastern Liaoning–Western Liaoning and Changbai Mountains, etc.

Low susceptible collapse, landslide and debris flow zone covers an area of about 329×10^4 km^2, accounting for 34.3% of the total territory area, and mainly include central western Qinghai- Tibet Plateau, central eastern Helan Mountains, Yinshan Mountains, Da Hinggan ling–Xiao Hinggan ling, etc.

No susceptible collapse, landslide and debris flow zone covers an area of about 222×10^4 km^2, accounting for 23.1% of the total territory area, and are mainly distributed in the areas except for the aforementioned areas.

3.1 High Susceptible Collapse, Landslide and Debris Flow Zone

3.1.1 Southwestern Yunnan–eastern Xizang high susceptible landslide, collapse and debris flow zone

This zone lies in the southern end of Hengduan Mountains and covers the high-medium mountainous area to west of Lijiang, Dali and Gejiu and eastern Xizang. The northern part of the area is within the Hengduan Mountains valley area. The Nujiang River, Lancang River, Jinsha River, and Dulong River are bounded among high mountains, such as Gaoligong, Nushan, Xuepan, Yunling, Xueshan, Yulong and Diancang Mountains. The rivers are incised deeply, giving rise to deeply separated middle and high mountains, constituting an area with concentrated landslide, collapse and debris flow.

3.1.2 Southwestern Sichuan-central Yunnan high susceptible debris flow , landslide and collapse zone

This zone is located in Ya'an and Panzhihua in southwestern Sichuan and southwards extends into Lijiang, Dali, Chuxiong and Gejiu in central Yunnan. The elevations vary between 1,500 m and 2,000 m above sea level and decreases gradually from north to south. Jinsha River traverses the central area, which features complicated geological structures, frequent earthquakes, steep terrain, abundant loose clastic materials, and abundant rainfall. Thus, debris flows are densely developed along the mainstream and tributaries of Jinsha River and Yuanjiang River. This hazard threatens water conservancy and hydropower projects within the area.

3.1.3 Yunnan-Guizhou Plateau high susceptible landslide and collapse zone

This zone is distributed in southeastern Sichuan, southeastern Chongqing, northeastern Yunnan, and western Guizhou, forming an elongated NE–SW trending band. This area is a transition zone from high mountains to low mountains in western China. Comprises many parallel mountains, including Wuling and Dalou Mountains. Carbonatites are widely distributed, and karsts are developed in the area. Landslides and collapses are widely developed within the area, particularly in the Dalou Mountain and Wuling Mountain.

3.1.4 Qingling-Daba Mountain high susceptible landslide, collapse and debris flow zone

This zone is distributed in Longnan of Gansu Province, Guangyuan, Bazhong and Dazhou in Sichuan Province, Ankang, Hanzhong (excluding Hanzhong Basin) and Shangluo in Shaanxi Province, Shiyan in Hubei Province and consists of Qinling, Daba and Micang Mountain. Daba Mountain is located in the south, and Qinling Mountain is located in the north, with elevations mostly of 1,000–3,000 m. Within the area, ridges and peaks rise one after another, mountain ridges are steep, and river valleys are deeply incised. The Quaternary slope-residual layer is widely distributed within the area. The coasts of Danjiang and Hanjiang Rivers in the southeast and the coast of Jialing River in the southwest are lithologically dominated by schist, slate, phyllite, and other easily sliding rocks. Landslides, collapses and debris flows are also developed within the area, in which landslides are the most developed and widespread. Debris flows are concentrated in the middle and lower reaches of Bailong River in Longnan of Gansu Province and the western Hanjiang River basin in Jialing River Branch. As affected by May 12th Wenchuan Earthquake, landslides, collapses and debris flows became concentrated along the Longmenshan fault belt.

3.1.5 Central and eastern Gansu Loess Plateau high susceptible landslide, collapse and debris flow zone

This zone is located in north of Tianshui, Pingliang, Qingyang in Gansu Province and Guyuan in Ningxia Hui Autonomous Region. The loess landslides of this area are the most developed in China. The Middle Reaches of Taohe River, the Upper Reaches of Weihe River, and the Upper Reaches of Jinghe River are covered with thick loess, have abundant ground water and developed soft surfaces, and had experienced intense Neotectonic movement and frequent earthquakes. In the northern bank of the central reaches of Weihe River and the Puhe and Honghe Branches of Jinghe River, landslides are densely developed and superimposed in old and young ages. Debris flows are mainly distributed in the Tianshui segment of Weihe River Valley along Baoji–Tianshui Railway as well as in areas north of Jinghe River Valley and west of Mailian River.

3.1.6 Lüliang-Taihang Mountains high susceptible landslide, collapse and debris flow zone

This zone is located in Lüliang and Taihang Mountains. The Lüliang Mountains high susceptible area is located in western Shanxi Province between Yellow River Valley and Fenhe River Valley and generally extends NNE. Loess is distributed across the foot of Lüliang Mountains. Taihang Mountains extends NS along the Shanxi Province–Hebei Province boundary and turns to be convexsoutheastwards along Shanxi Province–Henan Province Boundary, occurring as an arch. Landslides, collapses and debris flows are widely distributed within the area.

3.2 Middle Susceptible Collapse, Landslide and Debris Flow Zone

3.2.1 Southeastern Qinghai-Tibet Plateau middle susceptible landslide, collapse and debris flow zone

This zone is located in Xining City and Tibetan Autonomous Prefecture of Golog in Qinghai Province, and Nagqu–Qamdo, Xigaze–Lhasa–Nyingchi–Medog of Xizang. Within the area, debris flows are densely developed as bands along the Upper Reaches of Yellow River, Yalong River, Jinsha River, Lancang River, Nujiang River, and Yarlung Zangbo River; landslides and collapses are distributed linearly along the roads.

3.2.2 Guangdong–Guangxi–Hu'nan–Jiangxi middle susceptible landslide, collapse and debris flow zone

This zone is located in low mountains of southern Hu'nan Province and low mountains and hills of central eastern Guangxi Zhuang Autonomous Region and eastern Guangdong Province. With respect to landform unit, this area is a mountain hill area transitioning from the Yunnan-Guizhou Plateau to the southeastern coastal areas. The eastern area contains many round-shaped granite hills, where valleys crosscut and the surface is cut into fractured. The western area mainly consists of limestone hills, widespread peak forests, and steep terrain. The main mountains include Shiwandashan, Yunkaidashan and Lianhua Mountains. Within the area, geological hazards are densely developed, and their types mainly include landslide, collapse and minor debris flow. Landslide is mainly developed in small-sized slope residue loose soil layers. Collapse mainly occurs in small-sized areas with a half of earthy type and a half of rock type.

3.2.3 Central southern Hainan middle susceptible landslide, collapse and debris flow

This zone is located in the central and southern parts of Hainan Dao and a medium mountainous block area formed by granite intrusive dome–fault structures. The main mountains include Wuzhishan, Limuling, Yinggeling and Yajiadaling Mountains. Collapse, landslide and debris flow are relatively rare within the area.

3.2.4 Eastern Hubei–eastern Hu'nan middle susceptible landslide, collapse and debris flow zone

This zone is located in eastern Hubei Province, eastern Hu'nan Province and western Jiangxi Province. Luoxiao Mountain stands in the center and is a watershed and source area of some water systems of Xiangjiang, Ganjiang, and Beijiang Rivers. With respect to topography, peaks rise one after another, mountain ridges are tall, mountains are steep, and valleys are deeply incised. Landslides, collapses and debris flows are densely developed along Luoxiao Mountain.

3.2.5 Zhejiang–Fujian–Jiangxi middle susceptible landslide and collapse zone

This zone is located in the southeast area east of Wuyi Mountain, Xianxia Ridge and Huiji

Mountain and includes hills of Zhejiang, Fujian and Jiangxi provinces. The terrain consists of successive mountain ridges and widespread hills, the climate is deeply affected by ocean, and the annual rainfall varies from 1,400 mm to 1,900 mm. Within the area, structures mainly erode medium and low mountains, and the terrain is complex. The area is a middle susceptible landslide and debris area. Storms and rainstorms are the most direct factors that trigger landslide and collapse in the area.

3.2.6 Ili River Valley medium–high mountainous middle susceptible landslide and collapse zone

This zone is located in Ili of western Xinjiang Uygur Autonomous Region. The Iili River Valley is surrounded by mountains to the north, east and south. Kokirqin and Borohoro Mountains extend NW–SE to the north. Haerketawu and Nalati Mountains extend NEE–SWW to the south. The center consists of Wusun and Awulale Mountains, constituting a topographic outline of "two valleys being constrained by three mountains." The three mountain systems converge eastwards to Eren Habirga Mountains, shaping the Ili River Valley into a westward-open trumpe valley. Humid water vapor from the Atlantic Ocean forms mountain rainfall and provides conditions for the formation of collapse, landslide and debris flow. In the medium and high mountain areas, landslides and collapses are densely developed, and minor debris flows are developed.

3.2.7 Yanshan Mountains–eastern Liaoning–western Liaoning middle susceptible debris flow, landslide and collapse zone

This zone extends eastwards to the Liaohe Plain and Bohai Bay, westwards to Inner Mongolia Plateau, southwards to the North China Plain, and northwards to the southern bank of Xiliaohe River. Within the area, the mountains mainly include Nulu'erhu, Daqing, Songling, Qilaotu and Yanshan Mountains. The river systems mainly include Laoha, Qinglong, Daling, Liaohe and Luanhe Rivers. Debris flows within the area are widespread. The terrain of Yanshan Mountains in northern Hebei Province fluctuates greatly, the ground is extremely fragmented, river valleys are narrow, and debris flows and collapses are concentrated.

3.2.8 Changbai Mountains middle susceptible debris flow, collapse and landslide zone

In this zone, debris flow and collapse are developed, and landslide is relatively occasional. In the southern segment of Changbai Mountains, geological hazards are more concentrated relative to the northern segment; debris flows and landslides are concentrated across the southern segment. Collapses are widely distributed in the area. Debris flows are mostly medium- and small scaled. By material composition, debris flow types are mostly debris flows, with minor water and mud flows. Collapse is dominated by small-sized rock collapse, and landslide is principally small-sized.

3.3 Low Susceptible Collapse, Landslide and Debris Flow Zone

3.3.1 Central western Qinghai-Tibet Plateau low susceptible collapse, landslide and debris flow zone

This zone is confined to the south of Kunlun, Altun, and Qilian Mountains and to the north of

Gangdise and Nyainqentanggulaa Mountains, excluding plateaus and lake basins. Within the area, landslides, collapses and debris flows are developed along Kunlun and Qilian Mountains as well as rivers and roads.

3.3.2 Central eastern Helan Mountains low susceptible collapse, landslide and debris flow zone

This zone is located in the central segment of Helan Mountains, where the general terrain is relatively steep. Earthquakes are active frequently nearby, and collapses, landslides and debris flows are concentrated.

3.3.3 Yinshan Mountains low susceptible collapse, landslide and debris flow zone

This zone is distributed along Guyuan, Kangbao, and Shangdu and consists of the Hetao Plain and the northern basin margin of Zhangjiakou and Datong. In this area, collapses, landslides, and debris flows are relatively developed.

3.3.4 Da Hinggan ling–Xiao Hinggan ling tableland low susceptible collapse, landslide and debris flow zone

With respect to terrain, the Da Hinggan ling consist of moderate mountains, low mountains, hills, lava platforms, and intermountane valleys. The terrain is generally high in the south and low in the north. Debris flows and collapses are principally developed in the eastern slope of the southern segment. Geological hazards are not developed in the northern segment. The terrain in the southern slope of Xiao Hinggan ling is round-shaped, flat and gentle, while the northern slope is steep,resulting in the development of collapse. Collapse hazards are developed mainly in the southern segment of Xiao Hinggan ling.

3.4 No Susceptible Collapse, Landslide and Debris Flow Zone

This zone covers areas that are excluded in the high-, medium- and low susceptible areas and includes the Chengdu Plain, the Junggar Basin, the Tarim Basin, the Nanyang Basin, the Poyanghu Plain, the Dongtinghu Plain, the Huanghe-huaihe Plain, the Jiaolai Plain, the North China Plain, the Hetao Plain, the Sanjiang Plain, and the Songliao Plain. Within the area, the terrain is flat and collapse, landslide, and debris flow are not developed.

4 Conclusions

China is among the countries that face the most serious geological hazards and the largest threat caused by population worldwide. China possesses complex geological conditions and has mountains and hills accounting for 65% of the national territorial area. As of the end of 2015, 288,525 occurrences of various geological hazards had been registered across the country, thereby threatening the safety of 18,910,000 people and 443.1 billion CNY of property. In the mountainous and hilly regions of China, 247,379 collapses, landslides and debris flows hazards potentially occur. Although geological hazards, such as collapses, landslides and debris flows, which are triggered by natural factors including earthquakes and rainfall, decrease, the number of loss of life, personal injury, and loss of properties increases and the situation of the hazards is complex. In the future, days of extreme weather obviously tend to increase in China. Medium-high intensity earthquakes are still in a frequent and concentrated occurrence period; abruptness, abnormity, and unpredictability of geological hazards that are aroused by rainstorms, earthquakes, etc. increase. Collapse, landslide, debris flow and other geological hazards will still face a frequent and concentrate occurrence situation. As such, geological hazard prevention and control is important.

The compilation of the *Susceptibility Map of Collapse, landslide and debris flow in China* aims to help readers understand and recognize different factors that affect the development of collapse, landslide and debris flow. The compilation also aims to understand the susceptibility of collapse, landslide and debri flow in different areas of China and provide technical support for government sectors in formulating geological hazard prevention and control planning and performing geological hazard prevention and control deployment. Overall, the compilation serves as a tool for geological hazard prevention and reduction and national social economic construction in China.

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