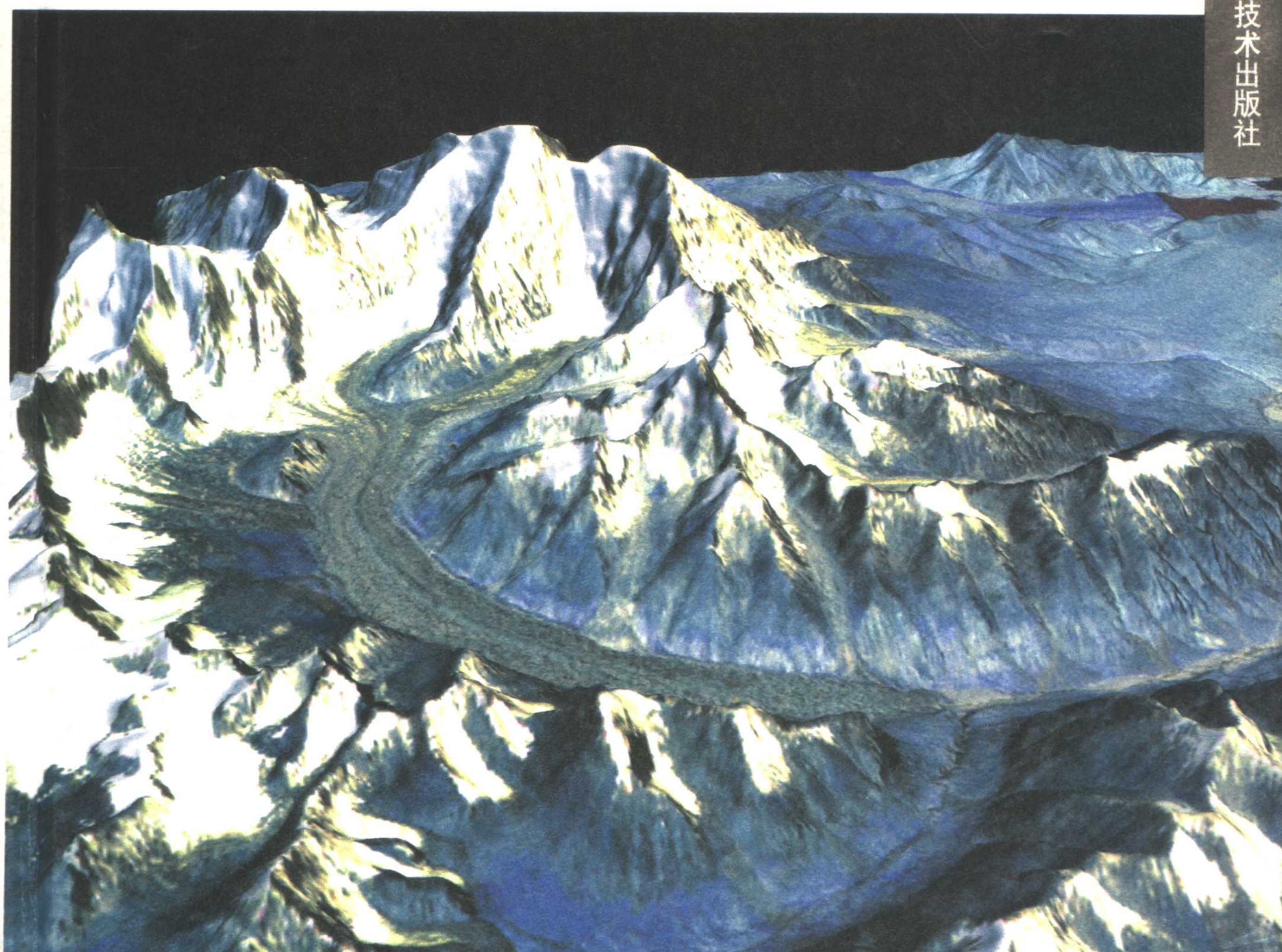
THE QUATERNARY

中国第四纪冰川与环境变化

GLACIATIONS AND ENVIRONMENTAL VARIATIONS IN CHINA

主编　施雅风　副主编　崔之久　苏　珍

河北科学技术出版社



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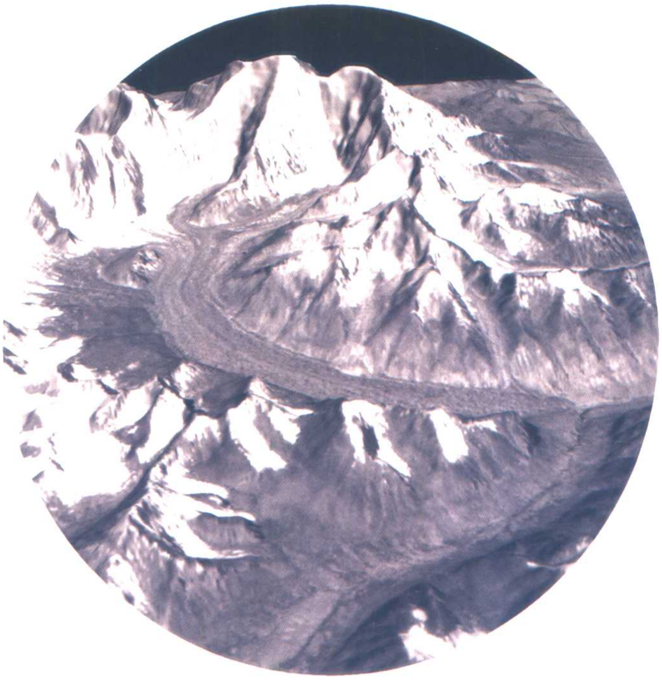

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THE QUATERNARY GLACIATIONS AND ENVIRONMENTAL VARIATIONS IN CHINA

Shi Yafeng（Editor-in-chief）

Cui Zhijiu　Su Zhen（Associate-Editors）

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内容介绍

本书是作者在对中国各山地多年考察研究、取得大量实地观测资料和实验资料的基础上，对中国第四纪冰川与环境变化研究的总结。本书系统地阐述了中国各地第四纪以来冰期、间冰期的气候变化和遗留下来的地貌、沉积物以及化石证据，藉以探索气候变化在不同时间尺度上所能达到的规模和幅度，探索第四纪冰川变化与环境变化的关系，据此提出了未来50年气候变化趋势预测及现代冰川变化趋势与水资源变化、环境变化的初步预测。全书共分19章，1~5章为综合论述部分，综述了中国第四纪冰川与环境变化的研究成果，论述了小冰期以来冰川变化及预测、冰芯研究进展与贡献、冰川沉积和测年评估、冰川的水资源变化趋势等。6~19章为分区论述部分，分别对喜马拉雅-青藏高原、喀喇昆仑山系、帕米尔高原、羌塘高原、唐古拉山系、昆仑山系、祁连山系、念青唐古拉山系、横断山系、天山山系、阿尔泰山系和中国东部高山区第四纪冰川进行了系统的论述和总结。

本书是目前惟一全面论述中国发育过第四纪冰川山地的专著，学术思想新颖，有许多新发现、新观点和结论，既有理论价值又有应用价值，对我国未来水资源变化、环境变化、区域经济规划乃至经济可持续发展都具有很强的指导作用。本书可供地质、地理、环境、气候、水文、区域规划等技术和研究人员参考，也可作为高等院校相关专业的教材。

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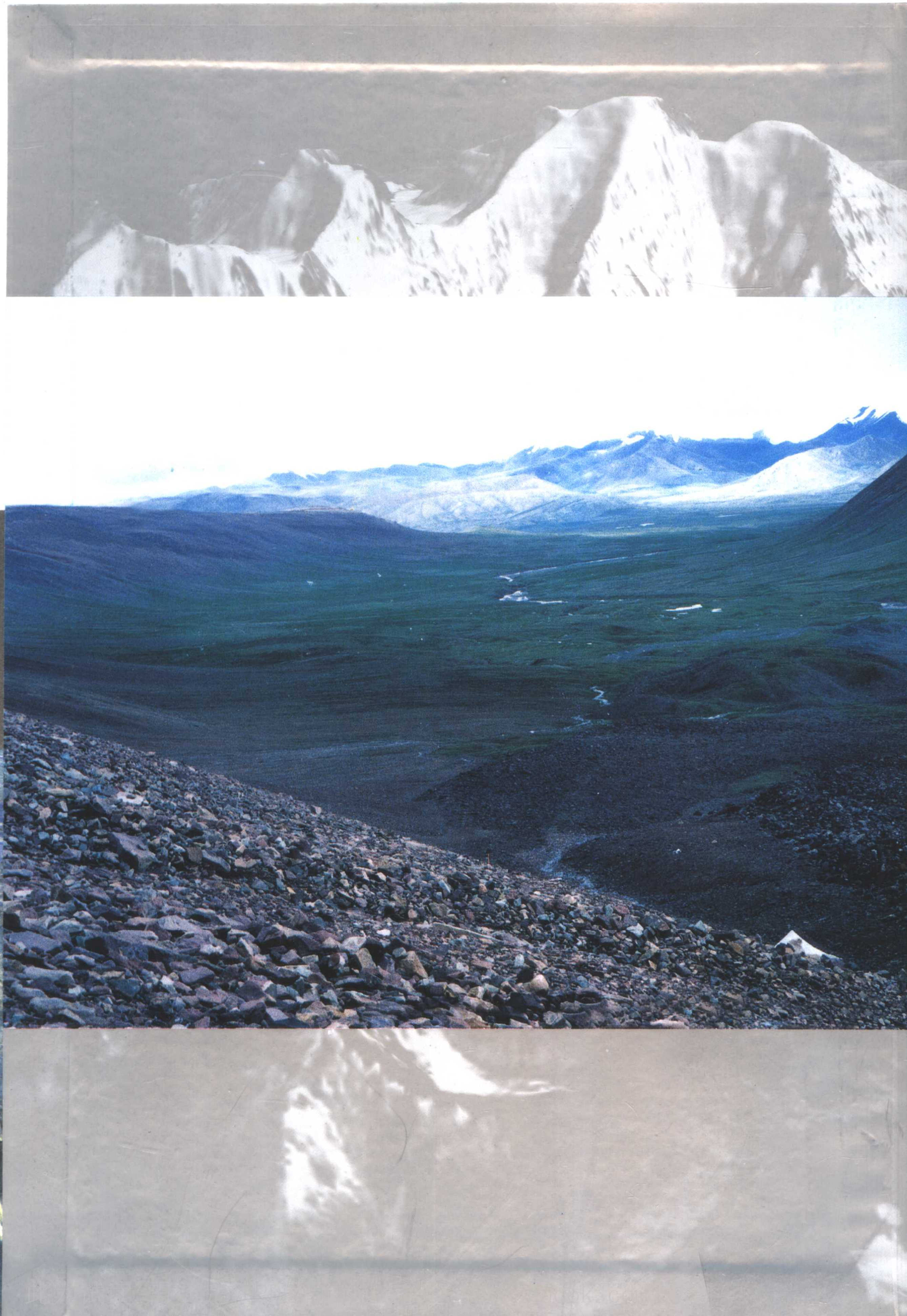

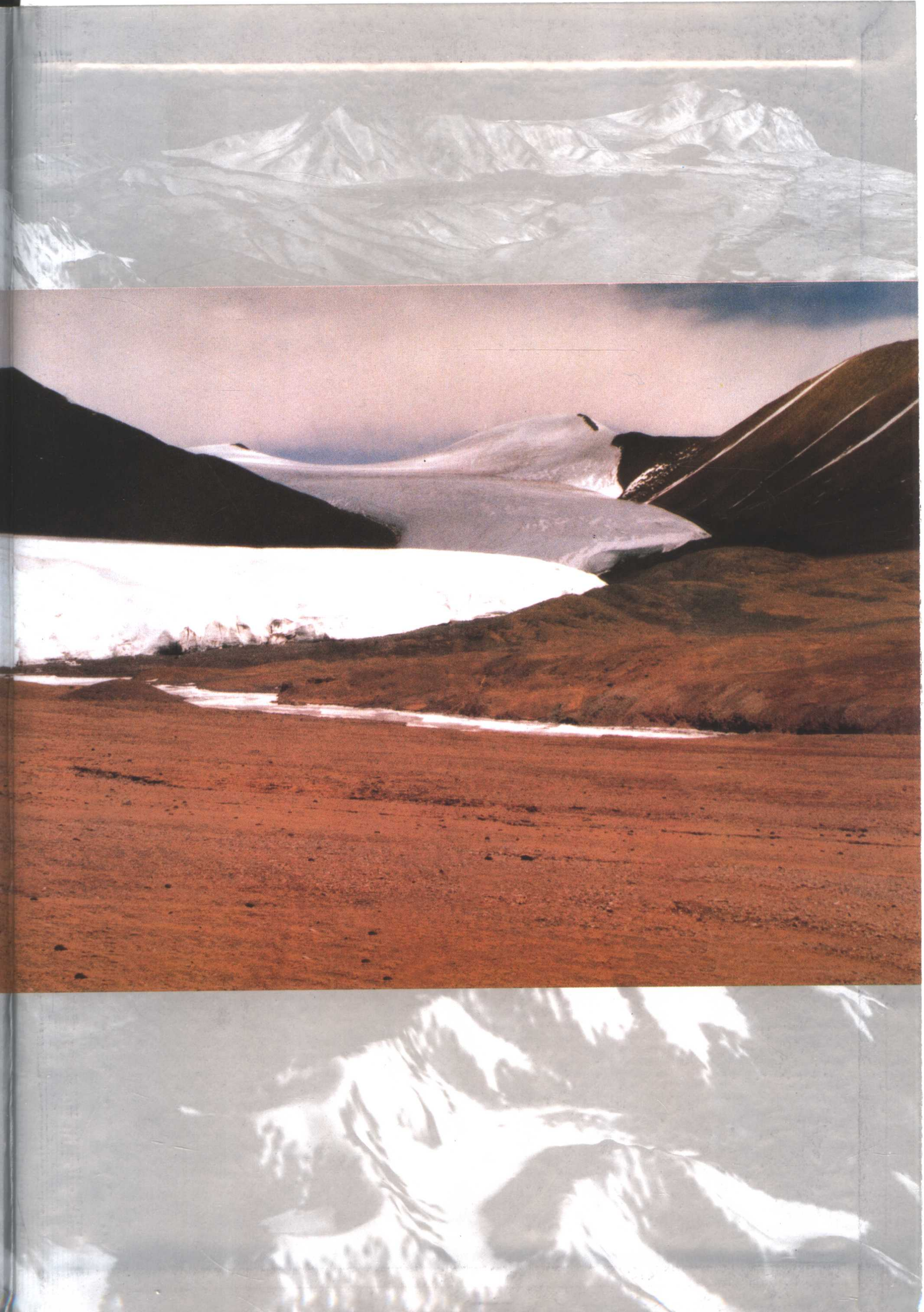

部分作者在安徽滁县考察夷平面（左起：李吉均、李世杰、施雅风、郑本兴、苏珍、焦克勤、崔之久、周尚哲）（郑本兴摄）

学者们畅谈考察收获（李世杰摄）

施雅风等在海螺沟冰川考察时的留影（左起：赵桂久、郑度、施雅风、杨逸畴）（苏珍摄）

作者简介

ZUOZHEJIANJIE

施雅风 1919年生，江苏海门人，中国科学院寒区旱区环境与工程研究所名誉所长、研究员，南京地理与湖泊研究所研究员，中国科学院资深院士。浙江大学研究院毕业，硕士（1944年），曾任中国科学院地理研究所副研究员，兰州冰川冻土研究所研究员兼所长，中国科学院地学会部副主任，中国地理学会理事长、名誉理事长，国际冻土协会理事，国际冰川学会理事，名誉会员，国际第四纪协会和皇家伦敦地质学会名誉会员。中国冰川学的主要开创者，曾多次组织领导祁连山、天山、喜马拉雅山和喀喇昆仑山冰川考察，组建了中国科学院兰州冰川冻土研究所。与同事们合作提出的将高亚洲冰川划分为海洋型温冰川、亚大陆型（或亚极地型）和极大陆型（或极地型）冷冰川三类，并被广泛接受和引用。由其提出的波动冰量平衡法用于预报喀喇昆仑山长59km的巴托拉冰川定量前进值，成功地解决了中巴（中国—巴基斯坦）公路通过该地区线路问题。领导编辑了完整的《中国冰川目录》。深入进行了第四纪冰川研究，提出了青藏高原最大冰期出现于60~80万年前，但没有形成统一冰盖，首创3~4万年前青藏高原与全中国都盛行暖湿气候，重建2万年前中国末次冰期与环境，明确了中国东部只有少数高山存在末次冰期遗迹。在多年冻土和泥石流研究、西北水资源、第四纪环境演变以及全球变暖对西北气候、水资源和海平面上升的影响等领域也有重要贡献。在国内外学术期刊发表论文200多篇，主编出版专著20余部，曾获国家自然科学一等奖（1987年）和三等奖（1982年），中国科学院自然科学一等奖（2000年）、二等奖，香港何梁何利科技进步奖（1997年），中国地理学会地理科学成就奖（2004年），甘肃省科技功臣奖（2006年）等。

崔之久 北京大学环境学院教授，博士生导师，国际地理联合会冰缘委员会委员，国际冻土协会冰缘与环境委员会委员，中国地理学会地貌与第四纪专业委员会主任，曾任《极地研究》编辑部副主编，北京大学地理研究所所长。长期从事冰川、冰川地貌与沉积、冰缘地貌和泥石流沉积、崩塌、滑坡地貌与沉积以及灾害地貌过程与防治等研究，卓有成就。多次深入青藏高原和天山地区野外考察，足迹遍及国内外名山大川、高山高纬地区及南

极，有丰富的野外科学考察工作经验。在国内外学术期刊发表论文200余篇，出版专著（合著）10余部。

苏　珍　中国科学院寒区旱区环境与工程研究所研究员，长期从事冰川学、第四纪冰川及环境变化研究。多次主持我国西部各大山区冰川资源、环境变化及冰雪灾害的考察研究，主持了中苏、中苏美联合青藏高原冰川考察等国际合作项目。在国内外学术期刊发表论文100余篇，出版了《天山托木尔峰地区的冰川与气象》、《横断山冰川》、《喀喇昆仑山—昆仑山地区的冰川与环境》等专著5部。获中国科学院科技成果二等奖、科学进步特等奖、国家自然科学一等奖、国家自然科学三等奖，享受国务院政府特殊津贴。

李吉均　中国科学院院士，兰州大学资源环境学院教授，地貌和冰川学家，长期致力于青藏高原隆升、中国大地貌格局和环境的形成演化研究。在高原隆起的时间和幅度、冰川发育、长江黄河演化、亚洲季风形成和西北干旱化、中国东部第四纪冰川等诸多方面的研究中卓有建树。提出"青藏运动"、"季风三角"等许多重要的学术思想和概念，发展了诸如"亚洲干极"、"黄河地文期"等一系列学术思想，获国家自然科学一等奖。

姚檀栋　中国科学院青藏高原研究所所长、研究员、博士生导师。在中国冰川、冰芯与全球变化研究中做出了重要贡献，发表论文、出版专著400多篇（部），研究成果先后获国家自然科学奖、中国科学院自然科学奖等奖项，2002年获香港何梁何利地球科学奖。

王宁练　中国科学院寒区旱区环境与工程研究所研究员，博士生导师，主要从事冰川与资源环境、冰芯气候环境记录与全球变化研究，中国科学院"百人计划"入选者。"中国科学院创新团队国际合作伙伴计划"项目"干旱区内陆河流域水问题基础研究"负责人，曾主持科技部"九七三"课题、国家自然科学基金课题以及中国科学院重大课题的研究工作，多次参与组织了青藏高原冰川与环境综合科学考察。已发表论文100余篇。曾获青藏高原青年科技奖、第八届全国青年地理科技奖和甘肃省科技进步一等奖。

徐柏青　中国科学院青藏高原研究所研究员，主要从事青藏高原雪冰—大气化学与气候环境变化研究。率先对中低纬度极高海拔冰芯包裹气体进行提取分析，并利用自行设计的仪器首次获得2000年来中低纬度大气甲烷记录。在国内外学术期刊发表论文30余篇，获得专利4项，2005年8月被中国青藏高原研究会授予"第五届青藏高原青年科技奖"。

段克勤　中国科学院寒区旱区环境与工程研究所副研究员，主要从事青藏高原雪冰—降水记录与气候环境变化研究。率先从喜马拉雅山冰芯中恢复了近400年的季风降水记录，同时从冰芯中恢复了青藏高原中部近600年的

降水记录。承担国家“九七三”项目、国家自然科学基金项目、中科院知识创新工程重大项目数项，在国内外学术期刊发表论文30余篇。

田立德 中国科学院青藏高原研究所研究员，主要从事青藏高原及周边现代降水及冰芯中稳定同位素研究。研究成果包括揭示了青藏高原降水中稳定同位素的空间变化特征，建立了不同地区的大气水线。在JGR等国内外著名刊物上发表论文20多篇。

郑本兴 中国科学院寒区旱区环境与工程研究所研究员，多年从事冰川、第四纪冰川与环境研究，多次对青藏高原和天山进行科学考察，在青藏高原各山地冰期次数、冰川规模与山地上升、气候变化的关系研究，冰川地貌制图等方面成绩显著。曾获竺可桢野外科学奖、中国科学院1986年科学技术特等奖。发表论文100多篇，出版专著4部。

易朝路 中国科学院青藏高原研究所研究员，博士生导师，从事第四纪冰川与环境、国土资源开发研究，入选中国科学院“百人计划”。在国内外学术期刊发表论文50余篇，合著出版学术著作6部。

熊黑钢 北京联合大学教授，博士生导师，从事环境资源方面的研究，主要侧重于气候地貌与环境变迁、自然灾害及其治理。主持和参加国家自然科学基金、国家重大基础项目等科研课题15项，《干旱区地理》副主编。在国内外学术期刊发表论文60余篇，合著出版学术著作3部。获国家教育委员会科技进步二等奖、三等奖。享受国务院政府特殊津贴，全国模范教师获得者。

李炳元 中国科学院地理科学与资源研究所研究员，主要从事地貌与第四纪环境研究。在对青藏高原湖泊水系演化、第四纪冰川、晚更新世以来环境、夷平面等地貌与环境、青藏高原和中国地貌分类与制图等研究方面有突出贡献。著有《西藏第四纪地质》、《西藏地貌》等专著5部，编绘《中国地貌图（1:400万）》、《青藏高原第四纪冰川遗迹分布图（1:300万）》等大型地貌图3幅。获国家自然科学一等奖、技术进步三等奖，院省级科技成果二等奖。

李世杰 中国科学院南京分院副院长，中国科学院南京地理与湖泊研究所研究员、博士生导师，长期从事沉积与第四纪环境变化研究，是国家“八五”攀登计划研究项目、国家“九五”攀登计划研究项目和国家重点基础研究发展规划项目研究骨干。在国内外学术期刊发表论文80余篇，参与编写出版专著7部。1995年获中国科学院方树泉青年科学家奖，同年获国务院政府特殊津贴；1997年获中国科学院野外工作先进个人奖；1998年获中国青藏高原研究会优秀青年科技工作者奖；1999年获中国科学院自然科学

二等奖；2000年获江苏省优秀青年科技工作者奖。

焦克勤 中国科学院寒区旱区环境与工程研究所副研究员，中国科学院天山冰川观测试验站副站长，长期从事冰川与气候环境变化的监测及研究工作，多次组织和参加青藏高原和天山等地区的冰川综合性考察。曾负责和参加的科研项目20余项，在国内外学术期刊发表论文80余篇，参与编写出版专著5部。获中国科学院自然科学一等奖，享受国务院政府特殊津贴，2002年获何梁何利地球科学奖。

沈永平 中国科学院寒区旱区环境与工程研究所研究员，中国地理学会冰川冻土分会秘书长，《冰川冻土》《气候变化研究进展》编辑部主任、专职副主编。主持和参加国家自然科学基金项目、“九七三”项目及国际合作项目等20多项。在国内外学术期刊发表论文80余篇，独立和参与编写专著10部。

周尚哲 华南师范大学地理科学学院教授，博士生导师，从事自然地理学地貌第四纪方向的研究和教学工作。在中国第四纪冰川与环境变化、青藏高原和干旱区地貌与环境、冰期天文理论等领域有较多成果。现致力于季风亚洲第四纪冰川系列年代学以及南岭地貌演化方面的研究。

张　威 辽宁师范大学资源环境学院副教授，从事环境与灾害地貌的研究工作。中国地理学会会员。主持国家自然科学基金项目1项，专著有《滇东北高山末次冰期冰川与环境》，参编出版专著5部。获辽宁省科技进步二等奖，辽宁省自然科学三等奖。

杨建强 中国科学院青藏高原研究所博士后，从事冰冻圈地貌与环境研究。曾先后考察了天山、昆仑山、巴颜喀拉山、喜马拉雅山、横断山的冰川地貌，并对大理冰期的命名地——云南点苍山进行了重点研究，在国内外学术期刊发表论文10余篇。

Main Conclusions of This Book

Editor-in-Chief: ShiYafeng

The progress in studies on the Quaternary Glaciations and environments during the past 50 years in China is summarized by 19 authors in this book; the main conclusions are as follows:

1. The late stage of Last Glaciation (or Last Glaciation Maximum, LGM) and the following glacial fluctuations

Based on the dispersed findings on reliable glacial remains in China, the real extension of glacial area in various mountains, including the Himalayas, Karakorum, Kunlun Mountains etc, and around the Tibetan Plateau, during the late stage of Last Glaciation, 16 ~ 30 kaBP, reached over 350 000 km^2. Reckoning up those in the Tianshan Mountains, Altay Mountains and several small glacial regions, such as Mount Taibai in Shaanxi, Mount Changbai in Jilin, Mount Xueshan in Taiwan, the total area was about 500 000 km^2, 8.4 times of the glacier area at present. At that time, temperature was 5 ~ 11℃ lower than that at present, precipitation was only 30% ~ 80% of that at present, and sea level was 130 ~ 150 m lower than that at present. The islands Taiwan and Hainan were connected with the mainland. On the same time, permafrost zone was also enlarged, with the south limit in eastern China moving from south part of Northeast China to North China, sand wedges and ice wedges appeared in the Inner Mongolia Region and Shanxi Province. After the time of 16 kaBP, with an unevenly increase of temperature, glaciers were retreating continuously. Around 11 kaBP, a Younger Dryas cooling event occurred and then entered the Holocene Interglacial. In the Holocene climate was warm with a fluctuation and reached the climax at 7 ~ 6 kaBP, when temperature was 2 ~ 3℃ higher than that at present, glaciers partly disappeared and inland lakes expanded, accompanied by sea transgression with the sea level 1 ~ 3 m higher than that at present. Later, the Neoglacial appeared, when glaciers advanced and many prominent moraine series appeared in many mountains. In the Neoglacial temperature decreased mainly in 3 ~ 4 kaBP. The glacial advance of Little Ice Age appeared during 15 ~ 19th century, when three end moraines formed in general.

2. The arguments on the extension of Quaternary glaciations in both eastern China and Tibetan Plateau are thoroughly examined by the authors and collaborators, including several foreign scientists

Researches of us reach a conclusion that Pleistocene Glaciations were limited in high mountains above 2 500 m a. s. l. in eastern China. Some other documents that argue there were Quaternary Glaciations on the lower and middle mountains, such as Mount Lushan and Mount Huangshan in lower reaches of the Yangtze River and Western Hills in Beijing, are all misinterpreted. In the Tibetan Plateau, the unified ice sheet hypothesis suggested either by M. Kuhle or by Han Tonglin are inconsistent with the reality and, therefore, has been abandoned by numerous scientists.

3. History of the late Pleistocene Glaciations and environmental evolution in the western China

The progress on ice core study together with other dating methods makes it possible to reconstruct the history in detail on the late Pleistocene glacial and environmental evolution in western China. The Guliya ice core record from West Kunlun Mountains provides evidence of climatic conditions over the last 130 000 years. In the last interglacial from 130 ka to 74 kaBP, there were three warm stages corresponding to MIS 5e, 5c, 5a and two cold stages corresponding to MIS 5d, 5b. Among them, the MIS 5e was the warmest and wettest stage, with temperature about 5℃ higher than that at present, when most of glaciers disappeared and the forest expanded greatly. There was a rapid change from MIS 5a (78 kaBP) to MIS 4 (75 kaBP), i. e., the early stage of Last Glaciation, in which the glacial extent was slightly larger than that in the late stage of Last Glaciation, 30 ~ 16 kaBP. MIS 3 appeared in 58 ~ 32 kaBP, containing a complete precession cycle with two warmer time, MIS 3c and MIS 3a, and one colder time, MIS 3b. Temperature of MIS 3b was about 5℃ lower than that at present. Low temperature and more precipitation at that time resulted in obvious glacial advance in some places, such as the Xueshan Mountain in Taiwan, and in the south slopes of the Hindu Kush, Karakorum Mountains and Himalayas. In MIS 3a, temperature was 4℃ higher and the precipitation was 40% ~ 100% more than those in the present day. As a result, many large glacial retreated and then many large fresh water lakes formed in the Tibetan Plateau and northwest China, together with pronounced sea transgression in the large delta area of eastern China.

4. The glacial and interglacial sequences during early and middle Pleistocene is not perfectly clear, because of shortage of date and detailed investigations

Since late Pliocene, the rapid uplifting of the Himalayas and Tibetan Plateau, accompanied by the global cooling, induced the first glaciation, of which the remains became the highest moraine caped mountains, for example, 6 200 m a. s. l. in the Mount Xixabangma. We named it as Xixabangma Glaciation, which can be dated back to the late early Pleistocene by our speculation. In morphological sequence, the second glaciation appeared in the northern slopes of Mount Xixabangma marked by a huge Nyanyaxungla moraine platform. Other evidence are the piedmont glacier till on the south slopes of the middle Kunlun Mountains with ESR date 710 kaBP, the base till of Guliya ice core in west Kunlun Mountains with ^{36}Cl date 760kaBP, the oldest Ningzhong moraine with ESR date 593 kaBP and 678 kaBP, the oldest Daocheng glacial deposit with ESR date 571 kaBP in the Hengduan Mountains and some area with very large valley glacier deposits. Thus, we named them as Kunlun Glaciation or Maximum Glaciation 0. 8 ~ 0. 6 Ma ago, correspondent with MIS 16 ~ 18, when the Tibetan Plateau uplifted over 3 500 m a. s. l. and entered the cryosphere. ESR dating of glacial deposits in highest river terraces, such as in the headwaters of the Bailang River in northern slopes of the Qilian Mountains and in the Gaowangfeng terrace at the upper reach of Urumqi River in Tianshan Mountains, indicates that there was a clear glaciation during 450 ~ 480 kaBP, corresponding with MIS 12, which was called as Zhonglianggan Glaciation. The distribution features of this glaciation are not very clear. From geomorphic sequence, the deposit of the latter glaciation appeared in the higher lateral moraine and some distant and partly destructed end moraine, such as Jilongsi moraine in Rongbuk Valley in the north of Mount Qomolangma, the Guxiang Glaciation in southeast Tibet, the glacial sand with TL date 206 kaBP in Bulakbashi glacial platform in the west Kunlun Mountains, the base loess covering on the longer valley glacial deposits with TL date 200 kaBP in Mount Nianbaoyuze on the east end of Kunlun Mountains, and so on. We estimate this evidence correspond mainly to the Penultimate Glaciation or MIS 6, partly extended to MIS 8 even 10. The extension of this glaciation was larger than that of the Last Glaciation, but much smaller than that of the Maximum Glaciation. A large interglacial with higher temperature was focused on the MIS 13, earlier than the Zhonglianggan Glaciation.

5. Climatic warming, glacial shrinkage and their impacts on water resources and disasters in the near future

The present interglacial just meets the anthropologic global warming, characterized by rising concentrations of CO_2 and other gases. From the middle Little Ice Age to mid 20^{th} century, temperature increased about 1 ~ 2℃ in the high mountains of west China and glaciers shrank about 20%. Especially in the early and mid 20^{th} century, climate was controlled by a warming and drying trend in West China in general. In the recent thirty years, enhanced water cycle under global warming results in climate change more complicated. Accompanied by the rapid global warming, glacier retreat is obvious in West China. Precipitation increased in major parts of Northwest China and Tibetan Plateau, however, in some parts of the periphery of the northern Tibetan Plateau and Xinjiang, it is still cooling, and in the northeast part of the Tibetan Plateau drying still continues. Comparison of the incomplete data from remote sensing images around 2 000 with the data in Glacier Inventory of China (total 46 377 in number, 59 425 km^2 in area and 5 600 km^3 in water resources) reveals that the glaciers retreated about 4% ~ 5% during the recent 20 ~ 30 years. On the assumption that temperature will further increase 1 ~ 2.4℃ by the year 2050, glacier area is likely decrease 20% ~ 40%. Thus, owing to glacier retreating and precipitation increasing, water resources from river runoff and some inland lakes will increase generally. These will bring benefits to economic development and people, especially those living in the Tarim Basin, where there are a great amount of glaciers. But in somewhere else, such as in the southeast part of the Tibetan Plateau and Hengduan Mountains with higher precipitation and monsoonal temperate glaciers, frequency of catastrophic floods and debris flow disasters may increase.