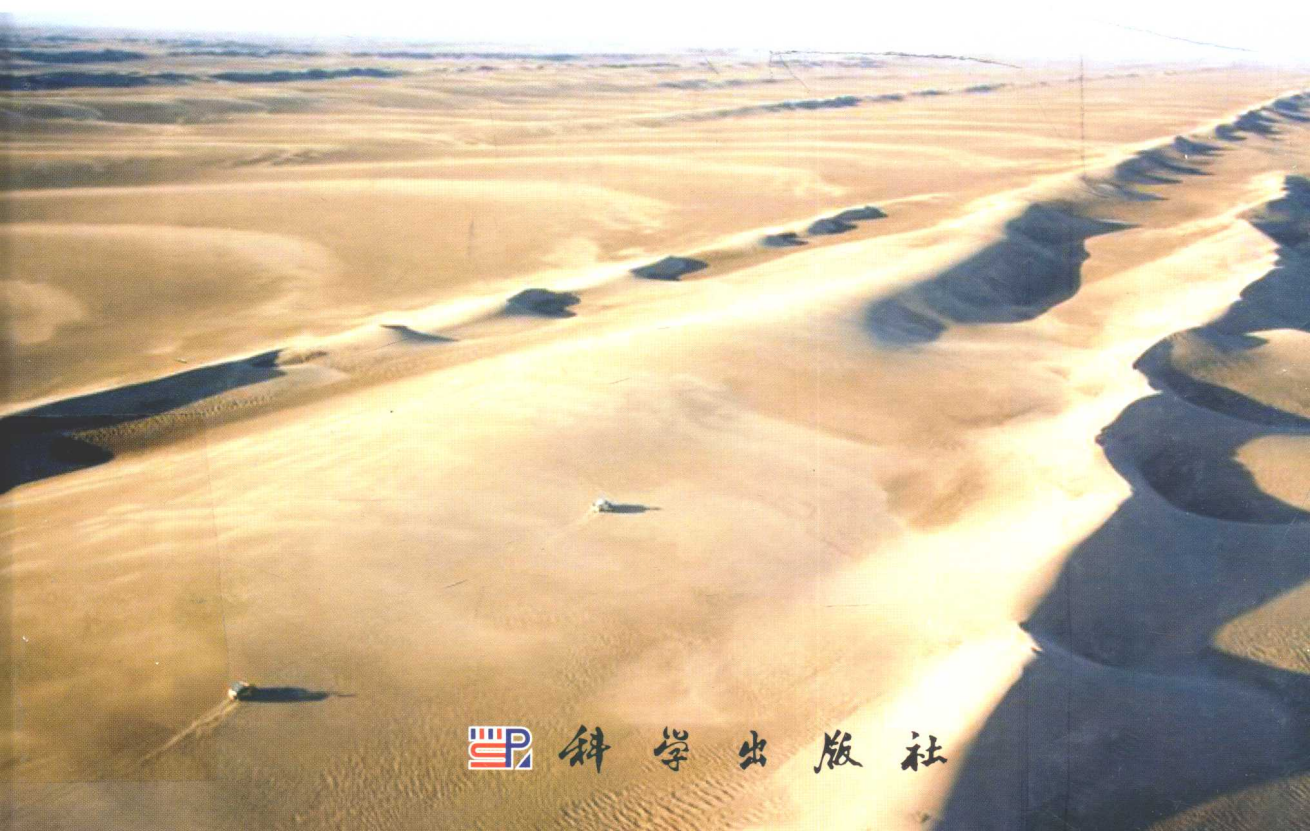
库姆塔格沙漠研究

A STUDY OF THE KUMTAG DESERT

库姆塔格沙漠综合科学考察队　著



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内 容 简 介

本书是对库姆塔格沙漠开展跨部门、多学科综合科学考察研究成果的系统总结，揭示了库姆塔格沙漠的形成时代及演化历程，阐明了风沙地貌的类型、分布及羽毛状沙丘的形成发育过程，阐述了研究区的基本气候要素、气候变化特征、水文过程及水资源利用，论述了动植物区系与生物多样性保护；并以遥感数据为基础，分析了沙漠动态与区域景观格局。书中对库姆塔格沙漠地区的生态保护与区域可持续发展提出了积极的对策和建议。

本书内容丰富，资料翔实，体系严谨，论理有据，图文并茂；可供从事干旱地区及沙漠研究的科研工作者和高等院校相关专业师生参考。

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序

中国沙漠面积位居世界第三，是受风沙和沙漠化严重危害的国家之一。为了调查和了解我国各主要沙漠的基本情况、编制防治规划并探索治理沙害的途径与措施，1959 年中国科学院组建了治沙队，对我国各大沙漠和沙地开展了长达 3 年的综合科学考察和研究工作。

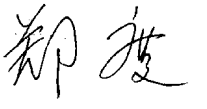
库姆塔格(维吾尔语即“沙山”之意)沙漠分布于新疆维吾尔自治区若羌县与甘肃省敦煌市和阿克塞哈萨克族自治县(下称阿克塞县)接壤的地区。它南依阿尔金山，西北毗邻罗布泊洼地，北达阿奇克谷地，东抵敦煌鸣沙山，面积约 2.28 万 km^2，列我国沙漠的第六位。但受各种条件的限制，库姆塔格沙漠成为我国唯一未曾被综合科学考察的沙漠。

在国家科技基础性工作专项的资助下，由中国林业科学研究院牵头组建，由来自全国 18 家科研机构、高校和国家级自然保护区的中青年专家为主体组成的综合科学考察队，于 2007～2009 年对库姆塔格沙漠开展了两次大规模、全方位的综合科学考察及 20 多次分学科专业调查取样，累计野外工作时间 150 多天，车辆行程超过 15 万 km。通过野外考察、样地调查、定位观测、标本采集、遥感数据与影像图片解析和实验分析等各种手段，在诸多领域取得了重要的研究进展。例如，初步探明了库姆塔格沙漠羽毛状沙丘的形成机理；编制完成了反映该沙漠全貌的自然地理图件；揭示了沙漠地表沉积物矿物组成及其来源；认识了晚新生代沉积物的特点及地层序列；编绘了新的沙漠地区地质图；建立了全方位、全天候的沙漠气象观测场；对双峰野骆驼种群及其适宜生境开展了系统调查；发现了沙生柽柳等 6 个植物种的新分布区；初步划定了沙漠及其周边区域的生态经济功能分区，并提出治理方向和对策建议。

《库姆塔格沙漠研究》专著是对库姆塔格沙漠开展跨部门、多学科综合科学考察研究成果的系统总结。结合宏观科学设想，项目组经过认真探索求证和广泛学术交流，逐步达成了学术共识。这一专著概述了库姆塔格沙漠考

察的重要意义和以往的研究工作积累；分析了沙漠地区地质背景与晚新生代干旱环境演化过程，揭示了库姆塔格沙漠的形成时代及演化历史；阐明了风沙地貌的类型、分布及羽毛状沙丘的形成发育过程；阐述了研究区的基本气候要素和气候变化特征、水系分布及水文特性；论述了植物区系与植物群落类型、动物区系和典型动物分布以及生物多样性保护；基于遥感数据分析了沙漠动态与区域景观格局；最后综述了库姆塔格地区的生态保护与区域可持续发展战略构想。

《库姆塔格沙漠研究》专著的编撰出版，在科学上揭示了该沙漠的形成演化过程和风沙运动规律，有助于科学合理防沙治沙方略的制订；拟订了生态经济分区方案，为资源的合理开发利用、自然与文化保护以及区域可持续发展提供了积极的对策与建议，对保护敦煌绿洲和莫高窟文化有重要的价值。这一成果体现了新一代沙漠科学人勇往直前、不畏艰辛、通力协作探索大自然奥秘的科学精神。我相信，这一专著的出版将有助于人们对库姆塔格沙漠的全面了解。希望新一代沙漠科学人进一步加强学科间的渗透与综合集成，在沙漠科学研究、沙漠化防治、自然保护与生态建设工作中取得更加突出的成就，为区域可持续发展作出积极的贡献。



2010年4月27日

Foreword

With a vast distribution of desert and Gobi in the Northwest, China is the third largest country in the world and is one of the countries seriously affected by dust and sandstorm disasters and desertification issues. In consideration of state needs to comprehend the basic condition of main deserts in the arid zone of China, and to develop a regional strategic plan to control dust and sandstorm and combat desertification and to explore sound measures and solutions to mitigate desertification and control dust and sandstorm in the region, the Chinese Academy of Sciences estabtished the China Desert Control Team in 1959. A 3-year-long integrated scientific expedition, with ground observations and field investigations, to each of seven desert and four sandy-lands of China has been conducted.

The Kumtag Desert (referring to "Megadunes" in Uygur language) is widely located at the broad boundary area among Ruoqiang County of Xingjiang Uygur Autonomous Region, Dunhuang City and Aksay Kazak Autonomous County of Gansu Province. The Kumtag Desert borders the Altun Mountains to the south, the Lop Nur in the northwest, the Akeqi Valley in the north and the Mingsha Mountain (Whispering Megadunes) of Dunhuang in the east. The total area of the Kumtag Desert is 2.28×10^4 km^2, which is the sixth largest desert among the eight deserts in China. The Kumtag Desert had not been explored in a scientific manner with systematic ground observation and field investigation until the beginning of the 21st century.

Financed by the China National Science & Technology Basic Research Programme, the Chinese Academy of Forestry sponsored the scientific expedition and organized an expedition team composed of national scientists and experts, both senior and junior, from 18 academies, institutes, universities and national nature reserves. The expedition team carried out two large-scale complex scientific expeditions from 2007 to 2009 to the Kumtag Desert and collected more than 20 sets of field samples and ground observations. The total work days in the field are more than 150 days with the vehicles travelling more than 150 000 km. Important research results in many subjects have been obtained by conducting field investigation, study site surveys, positioned observation, sample collection, remote sensing data and image interpretation and laboratory analysis. The expedition has resulted in the first-time discovery of the occurrence mechanism of feather-like longitudinal dunes of the Kumtag Desert and the compilation of a physical geography map showing the general landscape of the desert. These results show the mineral composition of surface sediments of the desert and their origin and recognize the characteristics of sediments and their stratum chronology in the Later Cenozoic Era. Meanwhile, omnidirectional and all-weather desert meteorological stations have been built. A systematic survey of wild Bactrian Camel and its suitable habitat was conducted. New distribution areas of *Tamarix taklamakan* and other two plant varieties

were found. The sub-divisions of ecological services and economic functions of the Kumtag Desert and its neighbouring regions were initially classified and strategic recommendations were provided accordingly.

The book provides a systematic summary and conclusions of the study accomplishments and findings of the cross-sectoral, multidisciplinary and integrated scientific expedition to the Kumtag Desert. Members of the expedition team members, with their macroscopic scientific hypothesis, conscientious exploration and careful technical verifications and extensive academic exchanges reached overall academic consensus.

This monograph summarizes the significance of the expedition to the Kumtag Desert and integrates the research results made previously. It analyzes the geological background and the arid environment evolution processes of the Later Cenozoic Era and shows the age and evolution history of the formation of the Kumtag Desert. It illustrates both the patterns and distribution of aeolian landforms, and the formation and development processes of feather-like longitudinal dunes. It describes briefly primary climate regime, climate change characteristics as well as hydrological process and water resource use of the Kumtag Desert. The book also discusses the flora and the types of botanical community, the fauna, typical animal distribution as well as biodiversity protection. Based on remote sensing data, this monograph analyzes desert development dynamics and regional landscape patterns. As a conclusion, it presents strategies on ecological preservation, sustainable development and management of the Kumtag Desert.

The study of the Kumtag Desert reveals for the first time the formation and evolution processes and enunciates the movement principles of wind-sand of the Kumtag Desert. Research results are useful and helpful for developing a scientifically-oriented strategy to combat desertification and prevent dust-sand disasters. Consequently, the ecological and economic sub-plans were worked out to promote sustainable development and rational utilization of natural resources and to protect natural and ancient cultural heritage. Positive approaches and suggestions on regional sustainable development were formulated in the context of the conclusive recommendations of the book, which are of great value in protecting the Dunhuang Oasis and the Mogao Grottoes Buddhism Cultural Heritage. These accomplishments embody the conscientiousness, fearlessness and the high level of teamwork of the new generation of desert scientists in exploring the profound mysteries of nature. It is believed that this publication will acknowledge all of the Kumtag Desert, and it is hoped that the new generation of desert scientists will further strengthen interdisiciplinary research and a more integrated approach, and, as a result, greater advances, will be made in desert research, desertification combating, nature preservation and ecological improvement to contribute significantly to regional sustainable development.

Zheng Du, Academician, Chinese Academy of Sciences

April 27, 2010

前　言

库姆塔格沙漠位于塔里木盆地东端，地跨中国西北部的甘肃省与新疆维吾尔自治区。它东止敦煌市鸣沙山，西隔罗布泊洼地与塔克拉玛干沙漠相望，南依阿尔金山，北抵阿奇克谷地和北山。东西最长约 280 km，南北最宽约 120 km，总面积 2.28 万 km^2。境内自然条件恶劣，气候极端干旱，地貌类型复杂，沙丘类型多样，尤以独特的羽毛状沙丘著称。20 世纪 50 年代以来，中国虽曾组织了多次大规模的沙漠科学考察，但由于各种原因，这片被列为中国第四大流动沙漠的广袤区域却成了沙漠科考的最后空白。

2006 年 12 月，科学技术部正式批准“库姆塔格沙漠综合科学考察”作为首批国家科技基础性工作专项九个重点项目之一，由中国林业科学研究院牵头，会同中国科学院、教育部、中国气象局和甘肃省所属的 18 家科研、教学机构共同参与实施，集地质、地貌、水文、气象、动物、植物、土壤、测绘（制图）、综合（区划）等 9 个学科 21 个专业方向的 150 多人（次）组成的科考和创新团队，自 2007 年 6 月～2009 年 12 月，先后组织了两次大规模、综合性、全方位沙漠科考，20 多次学科组专业调查取样，累计野外工作 150 多天、行程超过 15 万 km。

通过野外综合科学考察、定位观测、样地调查、标本采集和系统实验分析，不仅完成了对库姆塔格沙漠地区系统性、综合性的科学考察，填补了中国沙漠科考的最后空白，而且在诸多领域取得了阶段性研究成果。

（1）在全面认识库姆塔格沙漠风沙地貌形成与发育规律的基础上，初步查明了“羽毛状”沙丘的形态学特征及形成过程。根据野外实地考察，结合遥感影像资料分析，提出了适用于库姆塔格沙漠的沙丘分类系统，并据此编制完成了反映库姆塔格沙漠地区全貌的地貌图；首次确认并命名了库姆塔格沙漠发育的一种独特风成地貌单元——“沙砾碛”，并详细考察了其与相邻沙丘、沙垄分布的特殊地貌体系。通过野外观测、遥感影像分析、模拟实验和实验室分析等手段，从形态学、风场特征、沉积构造、粒度和矿物组成、光谱特征，及颗粒形貌等多层次、多视角探讨了“羽毛状”风沙地貌。所谓“羽毛状”沙丘实际上是一种复合或复杂线形沙丘，由新月形沙丘演变而来。其形成条件是：①高风能环境和总体上有利于线形沙丘形成的锐双峰型风场；②沉积物供应量相对有限；③沉积物中含有较多的不可蚀粗沙；④下伏地形平坦。关于库姆塔格风沙地貌独特性的多篇研究论文发表在国际地貌学权威刊物 *Geomorphology* 上，并被《自然》杂志（2008 年 2 月 6 日在线出版）作为最新研究亮点转载介绍，认为其研究结论可能有助于对火星表面沙丘形态的判断。

（2）初步探明了库姆塔格沙漠地表沉积物的矿物组成及物源，揭示了晚新生代沉积物特征和地层序列，绘制了沙漠地区地质图。通过对库姆塔格沙漠地表沉积物样品进行重矿物和主量元素分析，首次获得了其矿物和元素组成特征：重矿物种类多、以绿帘石和角闪石为主；化学组成以 Si、Al 为主，与上陆壳平均化学组成相比，除 Si、Ca 外都

有一定的亏损，Fe、Mg、Ca、P、Ti、Mn等元素的变异系数较高。库姆塔格沙漠地表物质组成特征与阿尔金山北麓出露的岩石及冲（洪）积扇物质组成基本一致，反映了地表沙物质主要来源于阿尔金山。沙漠北区强烈的东北风将阿奇克谷地和疏勒河下游的河湖相沉积物搬运至沙漠腹地，是另一个重要的沙物质来源。库姆塔格沙漠晚新生代沉积物以河湖相、风成沙和粉沙堆积为主，地层序列表现为多旋回和较大的相变变化。根据实际考察和资料总结，绘制了库姆塔格沙漠地质图。另外，首次在沙漠南部发现了晚第四纪的冻融和冰缘沉积，反映了当时冷湿的气候环境。

（3）基本确定了库姆塔格沙漠地区古风成砂的形成时代，揭示了沙漠的成因和演化过程。对晚新生代以来的含古风成砂地层沉积相分析、区域地层对比以及对地层中古风成砂的光释光(OSL)和电子自旋共振(ESR)年代测定，表明库姆塔格沙漠至少形成于晚中新世到上新世。根据地层年代测定和区域新构造运动证据，库姆塔格沙漠北部大面积的风蚀雅丹地貌主要形成于中更新世晚期至晚更新世初期。库姆塔格沙漠的形成是青藏高原不断隆升的新构造运动和长期气候变化相互作用的结果。

（4）初步查清了库姆塔格沙漠水系分布及水文、水化学特性，绘制了库姆塔格沙漠水系演变图。库姆塔格沙漠水系的格局与演变是在新生代以来青藏高原隆升特别是第四纪构造运动的基础上，在全球气候变化和人类活动的影响下，河流水文过程与地表蚀积过程相互作用的结果。库姆塔格沙漠现代水系由发源于阿尔金山、祁连山和北山山地并沿南北向沟谷下泄的多条河流（沟）以及泉、沼泽和湖泊等组成，分属河西走廊-阿拉善内流区（疏勒河水系）和塔里木内流区（罗布泊），并据此绘制了现代水系分布图；同时，应用相关的地质和历史资料，绘制了自中更新世晚期以来的库姆塔格沙漠地区及疏勒河水系演变图。库姆塔格沙漠地区气候干旱，泉涌水量和河流流量普遍较小，径流出山前，沿程流量逐渐增加，泥沙含量较小，流经补给区后，流量逐渐减少，水中泥沙含量增加。水化学组成主要受蒸发浓缩作用的影响，矿化度较高，以微咸水和咸水为主，水化学类型总体上为氯化物-硫酸盐/钠质-钙质水。

（5）对库姆塔格沙漠地区土壤形成过程、类型、分布特征进行了全面深入研究。根据中国土壤发生分类系统及研究区域特点，将库姆塔格沙漠地区的土壤类型分为17个土类，34个亚类，分别归属于9个土纲和14个亚纲。在土壤类型和分布特征方面，库姆塔格沙漠地区地带性土壤类型为棕漠土，分布面积最大的土壤类型为非地带性的风沙土类型；土壤分布垂直地带性显著，存在多种地带与非地带性土壤类型中微域组合。在土壤形成发育和演变方面，风蚀、沙化严重，常使许多土壤类型处于复幼过程；土壤盐分表聚明显；土壤形成发育和演变过程由水文过程主导；区域土壤普遍肥力低下。

（6）建立了全方位、全天候、全覆盖的沙漠气象观测场，初步揭示了库姆塔格沙漠及其周边气候变化特征和趋势。观测场由布设在库姆塔格沙漠南北的2台基于卫星自动传输的多要素标准气象站和4个地面测风站、4个临时气象站构成，首次实现了气象数据卫星传输的实时采集，获取了沙漠内部第一手气象观测资料。通过对沙漠及其周边近50年常规气象观测资料的分析，显示在全球气候变暖的大背景下，沙漠及周边地区气温表现出明显的上升趋势，降水量变化趋势不明显，风速则以减小的趋势为主，沙尘暴发生日数呈现明显的减少趋势。影响库姆塔格沙漠及周边地区沙尘天气的主要天气型有冷空气翻山型、冷空气东灌型、局地对流型和锋前热低压发展型等4种。库姆塔格沙漠

及其干旱气候的形成与演化受其周围复杂地形及其对水汽输送的影响较大。

（7）初步查明了双峰野骆驼等野生动物种类、种群、数量和分布区。通过野外线路踏勘和观测，架设多台远红外自动监测设备、野生动物排泄物采集取样检测等方法和手段，基本摸清了库姆塔格沙漠双峰野骆驼的分布范围和活动规律，并对双峰野骆驼种群及其适生环境开展了系统调查和研究。结果表明，分布于库姆塔格沙漠地区的双峰野骆驼有 400 余峰，主要活动于阿尔金山北边的荒漠区域、阿奇克谷地以及敦煌西湖地区，以柽柳、芨芨草、芦苇、骆驼刺、白刺、梭梭等的枝叶为食。利用粪便 DNA 分析技术进行个体识别和种群遗传结构研究发现，罗布泊—嘎顺戈壁和阿尔金山北麓分布区的双峰野骆驼种群具有较高的杂合度，分别为 0.7 和 0.73，从该基因角度说明研究种群具有丰富的遗传多样性。近年来，受矿产资源开发等人类活动及气候变化的影响，库姆塔格沙漠地区植被不断退化、萎缩，水源地缩减，严重威胁着双峰野骆驼的生存。

（8）首次对库姆塔格沙漠区域自然植被进行实地调查，发现沙生柽柳、白花柽柳、侧花沙蓬等 6 个植物种新的分布区。通过对库姆塔格沙漠区域自然植被进行实地调查、植物标本采集和分类鉴定，基本查清了沙漠及周边区域植物数量、类型及分布特征，编制了详细的植物名录和库姆塔格沙漠区域植被分布图。据初步统计，库姆塔格沙漠区域共有种子植物 26 科 76 属 120 种、亚种和变种，裸子植物仅 1 科 1 属 2 种，被子植物 25 科 75 属 118 种。库姆塔格沙漠区域植被受周围环境条件的影响，形成了独特的植被分布特征。自然植被以暖温带灌木和半灌木荒漠为主，群落结构简单；植被组成随地貌分布变化，呈现出由山前洪积扇到沙漠腹地逐渐过渡的特征。植被主要分布在沙漠北部边缘阿奇克谷地一线、阿奇克谷地与北山之间的山前洪积扇、沙漠东部、东北部的沙漠与湿地过渡带，沙漠南部沟谷、山前洪积扇与沙漠过渡带，而沙漠的核心区域植被分布极为稀少。在沙漠腹地甘肃和新疆交界处、阿奇克谷地边缘，沙漠南缘由东到西的崔木土沟、多坝沟、梭梭沟、小泉沟、红柳沟等多条沟谷发现沙生柽柳、白花柽柳、侧花沙蓬等 6 个物种新的分布区，其中 3 种为中国特有种。

（9）首次提出了库姆塔格沙漠及其周边地区的生态经济功能分区。通过对以敦煌绿洲为核心的库姆塔格沙漠及其周边区域历史人文与经济发展模式的系统考察发现：库姆塔格沙漠及其周边区域是一个历史文化遗产与自然文化遗产相对富集的区域，是一个旅游资源相对集中的区域，具有广阔的开发前景。该区域存在的主要问题是：疏勒河、党河中下游断流，区域来水量减少，灌溉农业大量用水等引起的瓜州、敦煌绿洲地下水位快速降低，导致西湖湿地和月牙泉萎缩，库姆塔格沙漠日渐东扩，严重威胁敦煌绿洲；绝大多数历史文化遗迹和自然景观受损严重或将要消失；产业结构急需调整等。这些使得以敦煌为中心的周边地区经济社会的全面、协调、可持续发展面临前所未有的严峻挑战。从生态环境保护、社会经济发展和资源管理的角度出发，结合该区域经济发展特征、生态保护和区域生态功能，将库姆塔格沙漠周边区域划分为沙漠戈壁生态保护区、疏勒河下游流域生态保护与绿洲农业区、疏勒河水源涵养区和阿尔金山荒漠生态区等 4 个一级生态经济区；在一级分区的基础上，依据生态系统特点和生态功能差异，进一步将该区域划分为 6 个生态亚区 15 个生态经济小区，并对建立大敦煌生态经济特区进行了可行性分析。为保护文化遗产、拯救绿洲提供了科学依据和智力支持。

（10）基本构建完成了库姆塔格沙漠基础科学数据库(群)。包括标本、样品、图片、

影像、分析数据、社会经济等海量数据；编辑出版《库姆塔格沙漠地貌图》、《库姆塔格沙漠研究》、《库姆塔格沙漠地理图集》、《库姆塔格不再遥远》等专著和图件。截至目前，共发表研究论文 41 篇，其中 11 篇为 SCI 论文；完成学位论文和研究报告 10 篇。

上述成果对揭示西北干旱区气候与环境形成演变及其与青藏高原隆升和全球变化的联系，探讨库姆塔格沙漠及周边地区生态保护与区域发展对策，促进国际国内在沙漠考察、荒漠化防治、干旱区生态保护与修复等领域的交流与合作，具有重要科学意义和实践意义。

《库姆塔格沙漠研究》一书，是项目主持单位与协作单位通力合作的成果，是全体参研人员组成的创新团队集体智慧的结晶。在项目实施的过程中，项目主持人、主要统稿人及各章主要执笔人在项目专家顾问组各位前辈的悉心指导下，先后召开了 11 次专题学术研讨会，并于 2009 年 9 月在敦煌召开了“库姆塔格沙漠国际研讨会”。库姆塔格沙漠综合科学考察成果的学术研讨和历练过程，正是通过大视野科学设想、悉心探索求证、广泛学术交流，逐步达成共识的科学研究过程。

本书主要编写人员分工如下。第一章，蔡登谷、卢琦、杨根生、褚建民、崔向慧、袁磊；第二章，鹿化煜、苏志珠、杜子图、赵存法、徐志伟；第三章，苏志珠、卢琦、吴波、鹿化煜；第四章，董治宝、屈建军、廖空太、王振亭、钱广强、牛清河；第五章，王式功、李耀辉、何清、尚可政、赵建华、曾淑玲、刘宏谊、霍文；第六章，严平、王学全、俄有浩、李文赞；第七章，肖洪浪、肖生春、宋耀选、邹松兵；第八章，王继和、袁宏波、张锦春、褚建民、林光辉；第九章，李迪强、张于光、马强、杨海龙；第十章，吴波，张怀清、鞠洪波、高志海、凌成星、李秀梅、王琣瑜；第十一章，卢琦、杨文斌、赵明、康才周、左合君、李得禄。全书由卢琦、褚建民、申元村、崔向慧负责文字统稿。由于时间和水平的限制，不妥之处在所难免，敬请读者批评指正。

值本书付梓之际，谨向所有库姆塔格沙漠科考的参与者和关注者致以崇高的敬意和衷心的感谢！借此机会，要特别感谢科学技术部、国家林业局、甘肃省人民政府、兰州军区、甘肃省林业厅、敦煌市人民政府、敦煌市人民武装部、阿克塞哈萨克族自治县人民政府、敦煌市林业局、甘肃安南坝野骆驼国家级自然保护区管理局、甘肃敦煌西湖国家级自然保护区管理局、新疆罗布泊野骆驼国家级自然保护区管理局等有关机构对库姆塔格沙漠科考的鼎力支持；也要感谢俄罗斯圣彼得堡大学李耀明博士、甘肃省阿克塞哈萨克族自治县林业局的马木利、阿利为本书提供前苏联绘制的该区域的地形图及相关图件资料。本次科考还受到了社会及媒体的广泛关注，新华社、中央电视台、《人民日报》、《光明日报》、《科技日报》、《中国绿色时报》等多家媒体作了系列报道；新华社和中国国家地理杂志社专门派记者全程跟踪报道，在此一并致以最衷心的感谢！

沙漠科考，尤其在地形复杂、人迹罕至、自然条件极端恶劣的库姆塔格沙漠地区，进行跨部门、大规模、综合性的野外科学考察，对项目承担单位和每一位科考队员都是十分严峻的考验与挑战。野外工作期间，科考队依仗的是大后方坚强的组织保障，严密的现场指挥和无间的团队协作；队员们依仗的则是对科学事业的无限忠诚和不懈追求。在千里荒漠戈壁环境中，队员们日夜兼程，风餐露宿，每天面对昼暑夜寒、风沙弥漫的荒野，身处瞬息万变、险象环生的环境，最终凝聚成了“献身科学、不畏艰险、勇于探索、甘于奉献”的科考精神。

库姆塔格沙漠对于科学工作者来说，永远是一个求之不尽、探之不竭的知识宝库和天然实验室。在那里所经受的所有酷暑严寒、饥饿疲劳、风暴沙尘、沙陷排险……铸造了科学工作者之魂，谱写了造福人类之歌。每一次科学实践，都是一次科学发展与人生价值的真实体现，都是一次献身科学与净化心灵的磨砺过程。沙漠科考项目虽然结束了，但沙漠科学研究仍在继续。2009 年 5 月，中国科学院生命科学与医学学部正式批准立项开展“大敦煌生态保护与区域发展战略研究”的院士咨询项目；2009 年 6 月，国家林业局正式批准组建“库姆塔格荒漠生态系统野外观测研究站”。

登上库姆塔格沙漠最东端的鸣沙山顶，俯瞰敦煌古城，黄沙百战穿金甲；远眺玉门远山，不破楼兰终不还；仰望阿尔金山，映日冰雪阿勒吞。此时更觉肩负的重任无尚光荣，前方的沙漠、戈壁征程漫漫……

卢　琦　谨识

2010 年仲夏于北京

Preface

The Kumtag Desert is located at the east end of the Tarim Basin and it strides across Gansu Province and the Xinjiang Uygur Autonomous Region in Northwest China. The desert extends eastward to the Mingsha Mountain (Whispering Megadunes) in Dunhuang, westward to the Lop Nur facing the Taklimakan Sand Desert, southward to the Altun Mountains and northward to the Aqike Valley and the Beishan Mountain ranges. The desert extends for 280 km from east to west and 120 km from north to south, with a total area of 22 800 km^2. The natural conditions are harsh and climate is extreme dry. The land surface is composed of complicated landforms and diversified dunes including the unique feather-like longitudinal dunes. Since the 1950s, China has sponsored and organized several large-scale desert expeditions and ground investigations in the arid zone but the Kumtag Desert, the fourth largest sand desert covered mainly by mobile dunes and shifting sands, had remained as the last untouched natural desert to be fully investigated in a scientific way.

In December 2006, the Ministry of Science and Technology of China formulated and validated the "Integrated Scientific Expedition of the Kumtag Desert Programme" as one of nine key research programmes of China National Science and Technology Basic Research Programmes. Under the leadership of the Chinese Academy of Forestry, in collaboration with the Chinese Academy of Sciences, Ministry of Education, State Meteorology Administration as well as other academic and educational institutions of Gansu Province, in total 150 scientists and experts of geology, geomorphology, hydrology, meteorology, zoology, botany, pedology, mapping and integration planning from 18 academic institutions were nominated and invited to form a scientific expedition team to implement this expedition programme. From June 2007 to December 2009, two integrated large-scale and multidisciplinary desert expeditions, more than 20 professional sampling surveys and ground observations were conducted. In total, the team worked for 150 days in the desert and travelled over 150 000 km.

The expedition team completed not only systematic and integrated scientific expedition of the Kumtag Desert and filled in the gap of the last unexplored desert in China, but also gained fruitful results in many scientific research subjects.

(1) On the basis of full knowledge of the formation of Aeolian landform and its development principle of the Kumtag Desert, the morphologic characteristics of feather-like longitudinal sand dune and its formation process are initially proved. According to the ground observation and field investigation, a classification system of sand dunes suitable to the Kumtag Desert was developed, in combination of interpretation of remote sensing images and, as a result, a geomorphology map of the Kumtag Desert was compiled. A unique Aeolian landform unit, sand-gravel-moraine, developed in the Kumtag Desert,

was defined and named for the first time and its specific geomorphologic system interlocking with nearby sand dunes and longitudinal dunes was attentively observed. On the basis of ground observations, interpretation of remote sensing images, similarity experiment and laboratory analysis, the feather-like longitudinal dunes, Aeolian landform is discussed from different points of view at various levels of morphology, characteristics of wind regime, sedimentation structure, particle gradient and mineral compositions, spectrum characteristics, particle shape and form. The so-called feather-like longitudinal dunes are in fact compound or complex linear sand dunes originated from barchan dunes and they comprise the following elements: ① speedy wind-energy regime and sharp double-peak pattern wind regime which enables commonly the formation of the linear dunes; ②relatively limited sand sources from sediments; ③high content of non-eroded coarse sands contained in sediments; and ④flat underlying land surface. Several research papers on Aeolian landform characteristics of the Kumtag Desert were published in Geomorphology and introduced and reprinted online in *Nature* (Feb. 6th, 2008) as the latest research highlight in the subject of geomorphology.

(2) The mineral composition and material sources of the surface sediments of the Kumtag Desert are investigated . The nature of the deposits and the stratigraphy of the Late Cenozoic Era is illustrated, moreover, a new geological map of the Kumtag Desert is complied. The minerals of the surface sediments are acquired by analyzing the heavy mineral and major element of the surface sediment samples of the Kumtag Desert. It was showen that there was a rich variety of heavy minerals containing mainly epidote and hornblende. The chemical compositions are mainly Si and Al and, by comparing with the average chemical compositions of the upper surface of the Earth, there is a high variation coefficient of the elements of Fe, Mg, Ca, P, Ti and Mn beside the elements of Si and Ca. The nature of surface sediment composition of the Kumtag Desert is almost consistent with that of outcrops and alluvial-diluvial deposits on the North foothill of the Altun Mountains, which shows that the surface sand deposits mainly originated from the Altun Mountains. The strong northeast wind in the northern part of the Desert blows the lacustrine sediments of the downstream of Aqike Valley and the Shule River into the hinterland of the Desert to form another important sand material source. The sediments of the Kumtag Desert of the Later Cenozoic Era are mainly composed of lacustrine, aeolian and fluvial depositions with manifestation of polycycle and phase transformation variation of the stratum chronology. The geological map of the Kumtag Desert is complied on the basis of the field investigations and the existed information. We find the ice wedge deposits in south of the Kumtag Desert that reveal a cold and wet climate in this region during the late Quaternary.

(3) The chronology of the paleo-Aeolian sand was essentially determined and the formation courses and evolution process of the Desert was illustrated. Based on the analysis of the deposit phase of stratum containing paleo-aeolian sands formed in the Later Cenozoic Era, in comparison of local stratum, and by chronologizing paleo-aeolian sands in each stratum by using optically stimulated luminescence (OSL) and electron spin resonance (ESR), it is concluded that the Kumtag Desert was formed at least from the Later Miocene Epoch to the Pliocene Epoch. For the first time researchers have

found sediments of ice melting and ice edge of the Later Quaternary Period, which illustrates that a cold and wet environment prevailed then. Based on the stratum chronology dating and the evidence of neo-tectonic movement, large areas of the denuded Yardang landform in the north of the Kumtag Desert were mainly formed from the later stage of the Meso-Pleistocene Period to the Early Stage of the Later Pleistocene Period. The formation of the Kumtag Desert is the interactive result of the neo-tectonic movement of the unceasing uplift of the Qinghai-Tibet Plateau and the long-term climatic change.

(4) The drainage distribution, hydrological and chemical characteristics of the Kumtag Desert rivers was thoroughly investigated and the Drainage Evolution Map of the Kumtag Desert Rivers was compiled. The drainage distribution pattern and evolution of the Kumtag Desert are the interactive results of river hydrologic processes and land surface erosion and denudation under the impacts of climate change and human development activities in accordance with the Qinghai-Tibet Plateau uplift, particularly the neo-tectonic movement in the Quaternary Period, since the Cenozoic Era. It is found that, by conducting sample surveys of the modern drainage distribution, discharge and water quality, the modern drainage of the Kumtag Desert originated from the Altun Mountains, the Qilian Mountains and the Beishan Mountains ranges and the south-north oriented rivers, streams, springs, swamps and lakes, which belong to the Hexi Corridor-Alxa inland drainage system (the Shule River system) and the Tarim inland drainage system (the Lop Nur). As a result, a Modern Drainage Distribution Map of the Kumtag Desert was compiled on the basis of these ground investigations. Meanwhile, the Evolution Map of the Drainage System of the Kumtag Desert Region and the Shule River Drainage since the Late Stage of the Meso-Pleistocene Period was compiled on the basis of relative geologic and historic records. In the Kumtag Desert region, spring water flow and river water flow are commonly insufficient due to dry climate. The water flows along the streams are gradually increasing before the runoffs flow out the outlet of mountains. The water flows will be gradually decreased after they flowed into water supply areas and the suspended sand content in water flow is higher. The chemical composition of water is mainly impacted by evaporation and concentration and consequently the mineralization is high and water is light blackish water and blackish water. The hydrochemistry of natural water is generally chloride-sulphate/sodium-calcium type.

(5) The formation processes, types and distributive characteristics of soil of the Kumtag Desert were fully studied. According to China's classification system of soil development and the regional characteristics of the study areas, the soil types of the Kumtag Desert were classified into 34 subtypes of 17 soil types and they fall into 14 subclasses of 9 soil classes, respectively. In the context of soil types and their distributive characteristics, the zonal soil types of the Kumtag Desert are brown desert soil and the non-zonal Aeolian sandy soil covers the largest distributive area. The vertical zonation of soil distribution is significant and there is a combination in micro-environment of various zonal and non-zonal soil types. In the context of soil formation, development and evolution, the phenomena of wind erosion and sand encroachment are