青藏高原地质构造与大陆动力学研究丛书

青藏高原
隆升的地质记录及机制

GEOLOGICAL RECORDS AND MECHANISM OF THE UPLIFT OF THE QINGHAI–TIBET PLATEAU

李廷栋 潘桂棠 肖序常 陈炳蔚 等著

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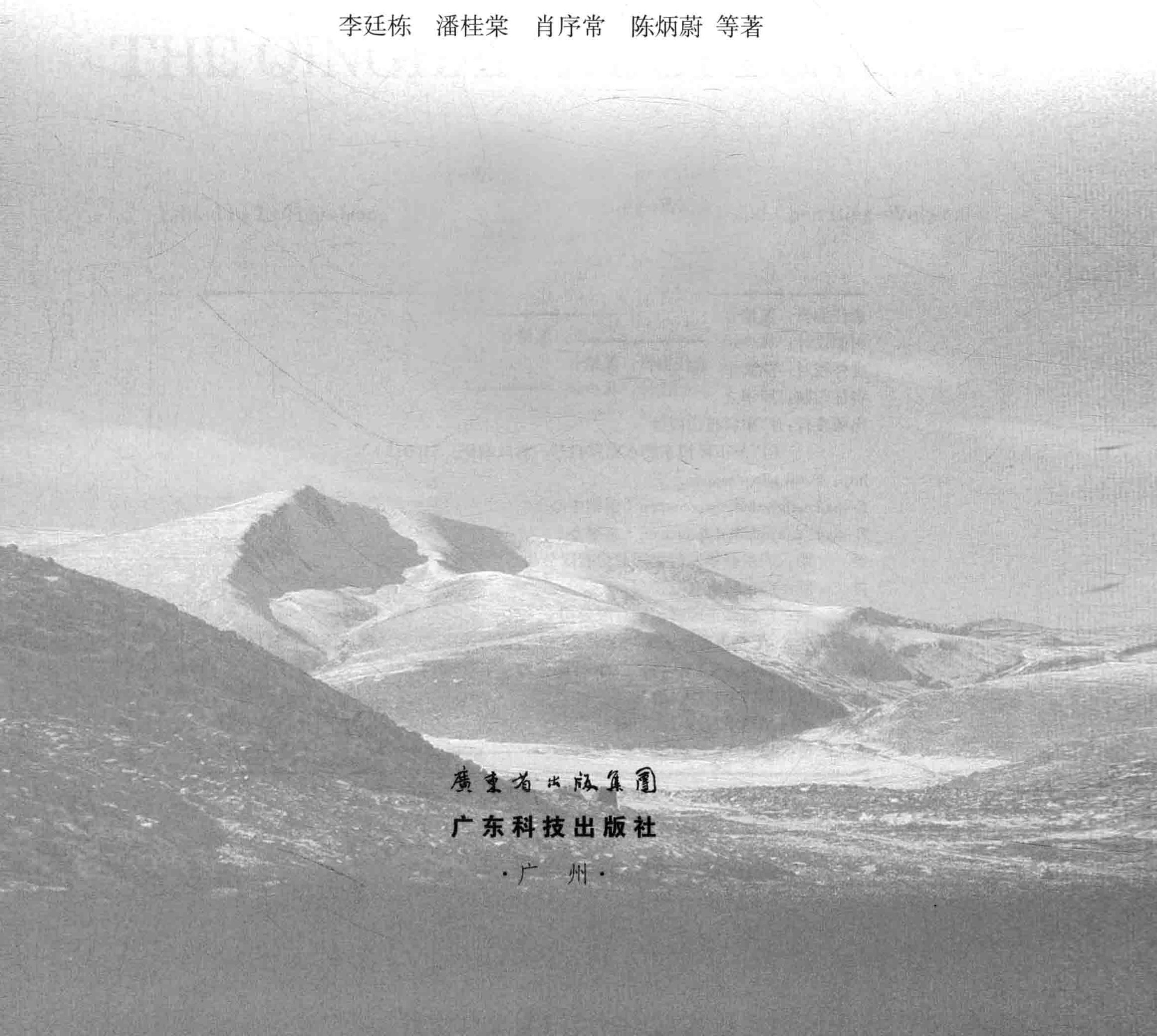

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SERIES IN RESEARCH ON GEOLOGICAL STRUCTURE AND CONTINENTAL DYNAMICS OF THE QINGHAI-TIBET PLATEAU

GEOLOGICAL RECORDS AND MECHANISM OF THE UPLIFT OF THE QINGHAI-TIBET PLATEAU

Edited by Li Ting-Dong Pan Gui-Tang Xiao Xu-Chang and Chen Bing-Wei et al

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内 容 简 介

青藏高原形成演化和隆升机制是当今国际地学界关注和努力探索的重大科学问题之一。本书以原地质矿产部重点科技项目“青藏高原隆升的地质记录及机制”各课题研究成果为基础，结合近年来高原地质研究所取得的新资料，在简要介绍高原区域地层要点、构造格架和岩石圈结构特征基础上，着重论述了西昆仑造山带和喜马拉雅造山带东段构造特点及山体隆升地质记录、冈底斯带白垩纪以来构造岩浆活动和高原北部新生代火山作用及深部作用、沉积盆地形成演化与高原隆升的耦合关系以及地壳形变监测及大陆动力学等重大地质科学问题。

本书内容丰富，资料翔实，提出一些新观点和新认识，可供地质调查、科研、教学部门及科技工作者参考。

序

青藏高原的地质调查研究已经有近200年的历史了。由于其独特的自然环境、地质条件和在资源环境及科学研究上的巨大潜力，一向引起国内外地学界的瞩目。

我国政府和有关部门十分重视青藏高原的地学调查研究工作，近半个多世纪以来，多次组织了规模宏大的有关资源环境的调查研究，获得丰富的研究成果，大幅度地提高了高原地学研究水平。

温故而知新，充分汲取前人的研究成果和经验，是深化一个地区地质规律的认识和在科学上进行创新的基础。“青藏高原隆升的地质记录及机制”研究项目的主要任务，是要在深入研究高原岩石圈结构、构造及其演化基础上，系统搜集研究高原隆升的地质记录，阐明高原隆升的过程、机制和效应。4年来，各课题组和科研人员刻苦钻研，求实创新，完成了合同规定的任务和目标，取得一些新发现、新数据、新成果和新认识，证实、完善并修正了过去的一些结论，解决了一些疑难的科学问题，取得的主要进展和成果可概要如下。

1. 重新厘定了西昆仑的构造变形期次，证实存在两种变质基底

通过地质剖面的详细观察研究，说明西昆仑造山带至少经历了前寒武纪、华力西期、印支期及喜马拉雅期4期构造变形，分别论述了各期构造变形的类型、时限和特点。根据新发现的微古植物化石组合，结合同位素年龄数据和其他地质证据，证实西昆仑造山带存在两种不同时代和类型的变质基底，以西昆仑中央断裂带为界，西昆仑北部基底为前蓟县纪角闪岩相变质岩系，被含叠层石的蓟县系和下古生界不整合覆盖；西昆仑南部基底主要为含丰富微古植物化石的新元古代—早寒武世变质程度深浅不一的变质岩系。两种类型变质基底表明，以库地蛇绿岩带为界，北昆仑和南昆仑属于两个不同的构造单元（地体）。

2. 盆地沉积特征研究获得重大进展

高原北部可可西里盆地立典性研究取得许多新认识：通过详细磁性地层研究并结合同位素测年及古生物化石资料，重新厘定风火山群（56 Ma ~ 33.2 Ma）及雅西措群（33.2 Ma ~ 30 Ma）的时代为始新世—渐新世，五道梁群（23 Ma ~ 16 Ma）为早中新世；重塑了盆地沉积充填史，揭示了风火山群经历了河流—湖泊—河流与扇三角洲—河流的沉积过程，并证明古近纪及新近纪时可可西里盆地为唐古拉山前向北东迁移的前展式前陆盆地；定量地计算了盆地演化7个阶段的沉积速率、沉积总量和堆积速率的变化，结果显示可可西里盆地古近纪及新近纪沉积物总量为297.15×10^{12} t，56 Ma ~ 32.2 Ma期间堆积速率平均400 t/（$m^2\cdot Ma^{-1}$），到32.2 Ma ~ 30 Ma期间快速增加为800 t/（$m^2\cdot Ma^{-1}$），反映早渐新世时期本区构造活动加剧。沉积速率曲线显示，古近纪时盆地沉积速率曾经在52.2 Ma ~ 52 Ma、41.5 Ma ~ 40 Ma及37.8 Ma ~ 34 Ma 3次大幅度增加，由10 cm/ka ~ 20 cm/ka增大到210 cm/ka，代表3次强烈构造活动期。此外，通过莺歌海盆地与滇西高原诸拉分盆地对比研究，把滇西高原隆升历史划分为4个阶段，证明5.3 Ma ~ 1.6 Ma隆升幅度达1 700 ~ 2 100 m，隆升速率0.5 ~ 0.57 mm/a，1.6 Ma以来，莺歌海盆地沉积速率猛增至1.39 mm/a，沉积通量陡增至1.74×10^8 t/a，说明滇西高原第四纪以来经历了加速隆升和剥蚀期；古夷平面抬高及河谷下切深度都证明，第四纪以来滇西高原再次抬升

610～700 m。

3. 重新厘定了冈底斯构造–岩浆岩带的时空结构及地壳生长方式

经过详细研究，把冈底斯构造–岩浆岩带划分为北、中、南3个亚带：北亚带为班公—怒江洋俯冲产生的火山岩带（100 Ma～60 Ma）；南亚带为雅鲁藏布洋俯冲—碰撞产生的火山—花岗岩带（70 Ma～45 Ma）；中亚带则为板内高钾火山岩与陆内俯冲产生的含白云母花岗岩（<20 Ma）。识别出俯冲、碰撞、碰撞后3个阶段的岩浆岩类型，总结出3个阶段的标志，初步建立了3个阶段的时间坐标为110 Ma～50 Ma，50 Ma～40 Ma，<40 Ma。通过花岗岩研究获得冈底斯区地壳生长的若干信息：俯冲阶段生成的含大量暗色包体的I型花岗岩是通过底侵作用把地幔物质转化为地壳物质的；而碰撞及碰撞后形成的S型花岗岩特别是白云母花岗岩是地壳重熔产物，其地壳生长方式表现为壳内物质的再迁移、再分配。研究结果发现，地壳显著增厚发生在主要岩浆活动期（65 Ma～40 Ma）之后；而快速隆升则发生在更晚的时期（<20 Ma）。

4. 进一步查明高原北部新生代火山岩岩石系列组合及演化特征，建立了岩浆部分熔融成因模型

根据岩石系列时空演化规律，把高原北部新生代火山活动划分为3个构造–岩浆活动亚旋回，构成3条火山岩亚带，各自具有不同的岩石系列组合，自南而北依次为：羌塘火山岩亚带（44 Ma～24 Ma），包括钠质碱性玄武岩系列、高钾钙碱性系列和钾玄岩系列；中昆仑—可可西里火山岩亚带（19 Ma～7 Ma），以钾玄岩系列为特征；西昆仑—玉门火山岩亚带（5 Ma以来），钾玄岩系列为主。各火山岩亚带均呈东西向或北西西向带状展布，由南向北，喷发时代逐渐变新，K_2O含量依次升高。测年资料表明火山活动存在4个高峰期：44.66 Ma～35 Ma，高钾钙碱性系列为主；29 Ma～24 Ma，为碱性钾质岩系列；19.6 Ma～7 Ma及5 Ma以来，均为钾玄岩系列，它们与高原隆升速率研究所显示的脉动峰期有一定耦合性。根据高原北部新生代火山岩岩石地球化学研究，建立了地幔上升流体与含水岩石圈绝热压缩增厚双重因素制约的岩浆部分熔融的成因模型。

5. 基本查明了南迦巴瓦构造结的地质组成和构造属性

雅鲁藏布江大拐弯地区南迦巴瓦群变质岩系，测得锆石U–Pb年龄1 312 Ma和525 Ma～552 Ma，Rb–Sr等时线年龄748 Ma～1 064 Ma，证明其时代属元古宙。在该变质岩群中多处发现石榴石单斜辉石透镜体，查明本区变质岩曾经历早期高压麻粒岩相变质作用到中期中压麻粒岩角闪岩相变质作用到最后的退变质作用。南迦巴瓦构造结由高原南部3个构造单元延伸部分组成，核部为喜马拉雅造山带，主要为元古宙南迦巴瓦群高级变质岩；雅鲁藏布缝合带分布于外侧，主要是一套绿片岩相—低角闪岩相的蛇绿岩套岩性组合，并在排龙—旁辛一带发现蛇绿混杂岩和具堆晶结构的橄榄岩；冈底斯岛弧带围绕雅鲁藏布江蛇绿岩带外侧呈弧形展布，主要为燕山期—喜马拉雅期侵入岩、基底变质岩系及古生代沉积岩。构造结主要是由喜马拉雅造山带组成的“楔入构造”，两侧发育着右旋及左旋走滑断裂系。

6. 全球定位系统（GPS）监测获高原北部地壳水平运动速率，发现两个涡旋构造

GPS测量结果表明，高原北部及邻区相对欧亚板块稳定部分水平运动速率变化为7.99～32.43 mm/a，其中，高原内部测站平均速率为26.41 mm/a，外围为15.24 mm/a。高原北部各测站相对成都平均速率为16.45 mm/a，外围各测站相对成都平均速率仅为6.84 mm/a。这些数据说明，青藏高原内部地壳运动活跃，且有高效调节、吸收功能。研究结果发现两个涡旋构造：一个为滇藏涡旋构造，以南迦巴瓦构造结为核心，呈顺时针旋转运动，平均运动速率为内圈11.38 mm/a、外圈8.22 mm/a、外围5.71 mm/a；另一个为甘青涡旋构造，涉及高原北部及邻区，总体呈逆时针旋转趋势，其地壳水平运动平均速率为内圈15 mm/a、中圈（高原内部）约12.5 mm/a、外圈（陇西地块）8 mm/a。拉萨相对成都作北北东方向运动，速率约23 mm/a。这种跨构造单元的涡旋运动可能是下地壳物质塑性流变的反映，是造成高原地壳形变不均一性的因素之一。

7. 获得若干有关高原隆升和地质年代的新数据和新资料

在西昆仑山和冈底斯山，运用裂变径迹法获得了高原隆升速率和地壳冷却史数据，证明高原于2 Ma以后隆升速率明显加快；西昆仑山皮山县新生代沉积磷灰石裂变径迹研究显示26 Ma ~ 23 Ma为一次快速隆升期，对应古近系、新近系不整合；综合研究了可可西里盆地、藏东滇西诸盆地及南海莺歌海盆地的沉积速率、沉积通量，定量计算了可可西里盆地7个演化阶段的沉积速率、沉积总量和堆积速率变化，计算得出南迦巴瓦构造结10 Ma以来剥蚀速率平均为（4.5 ± 1.1）mm/a；应用GPS监测、古地磁测量等研究了高原东北部地壳运动速率和若干断裂平移走滑速率；新获得一批古地磁及同位素年龄数据，借以厘定了可可西里盆地风火山群、南迦巴瓦群、羌塘地区古都尔片麻岩以及双湖地区蓝片岩等的年代。

8. 对高原隆升过程、机制及对气候影响等提出一些新认识

这些新认识包括：把青藏高原划分为3种岩石圈结构类型，分别代表造山带岩石圈演化的3个阶段：帕米尔型代表成根阶段，冈底斯型代表去根阶段，羌塘型代表减薄岩石圈再加厚阶段；认为青藏高原经历了一个脉动隆升过程，古近纪以来由热带低地森林环境脉动地渐变为热带、亚热带山地森林及灌丛草原环境，不存在大幅度降低阶段；提出下地壳增厚和重力均衡作用是晚上新世以来高原快速隆升主因，不具有地幔热隆起成因特征；发现古近纪出现过两次古气候变异事件：始新世早期全球变冷，渐新世早期全球变冷变干，提出青藏高原隆升对大气CO_2浓度降低起主导作用，对新生代全球气候变冷起了关键作用。提出青藏高原北部只存在中新世（20 Ma左右）一期古夷平面，不存在上新世另一期古夷平面。

从科学研究的历史长河来看，青藏高原的地质研究也可以说是刚刚开始，未被揭示的地质现象和科学问题还很多，科学研究上的潜力还很大。地质规律的揭示，科学问题的解决和科学潜力的发挥要靠一代又一代地质学家的努力探索，要靠丰富的科学积累。我们希望这套丛书和有关论文能够对增加青藏高原地质科学积累、进行地质科学理论探讨和解决某些实际问题作出自己的贡献，我们诚恳地期望得到地质界的批评指正。

李廷栋

2011年8月

Preface

Geological investigations and research on the Qinghai–Tibet Plateau have a history of nearly 200 years. Owing to its unique natural environment and geological conditions and great potential in resources, environment and scientific research, the plateau has long aroused interest of Chinese and foreign geoscience communities.

Our government and departments concerned have paid great attention to geoscience investigation and research on the Qinghai–Tibet Plateau. Over the past half of a century or more, large–scale resource and environmental investigation and research have been organized several times and abundant research results obtained, which has greatly raised the level of geoscience research on the plateau.

Reviewing the past helps one to understand the present. To draw on research results and experience fully is the basis for a deep–going understanding of the geological characteristics of an area and scientific innovation. The main task of the research project "Geological Records and Mechanism of the Uplift of the Qinghai–Tibet Plateau" is just to collect and study the geological records of the plateau uplift and elucidate its process, mechanism and effects. In the past few years, thanks to assiduous research with a innovative and realistic spirit, researchers in various subject groups have accomplished the tasks and targets stipulated in contracts, got some new findings, new data, new results and new knowledge, proved, improved or revised some previous conclusions and solved some knotty scientific problems. The major advances and results obtained are summarized as follows.

1. The tectonic deformation phases in the West Kunlun have been revised and the existence of two types of metamorphosed basement has–been verified

Intensive observation and studies of geological sections indicate that the West Kunlun orogenic belt underwent at least the Precambrian, Variscan, Indosinian and Himalayan phases of tectonic deformation. The types, timing and features of all the four phases of tectonic deformation are described separately. According to the microfloras found recently, combined with isotopic age data and other geological evidence, it has been verified that there exist two different types and ages of metamorphosed basement in the West Kunlun orogenic belt. With the central fault belt of the West Kunlun as the boundary, the basement of the northern West Kunlun consists of the pre–Jixianian amphibolite–facies metamorphic series, which is unconformably overlain by the stromatolite–bearing Jixianian System and Lower Paleozoic; whereas the basement of the Southern West Kunlun is mainly the Neoproterozoic–Early Cambrian metamorphic series of varying metamorphic grades, yielding abundant microflora. The existence of the two types of metamorphosed basement suggests that with the Kudi ophiolite belt as the boundary the North Kunlun and South Kunlun belong to two different tectonic units (terranes).

2. Major advances have been made in the study of the characteristics of basin deposits

Many new ideas have been got through a typical study of the Hoh Xil basin in the north of the Qinghai–Tibet Plateau. On the basis of a detailed magnetostratographic study, coupled with isotope dating and fossil data, the ages of the Fenghuoshan Group (56 Ma ~ 33.2 Ma), Yaxico Group (33.2 Ma ~ 30 Ma) and Wudaoliang Group (23 Ma ~ 16 Ma) have been revised, with the first two groups assigned to the Eocene–Oligocene and the last group to the early Miocene. The filling and depositional history of the basin has been reconstructed, and it has been revealed that the Fenghuoshan Group experienced the depositional processes of fluvial→lacustrine→fluvial and fan deltaic→fluvial deposits and proved that the Hoh Xil basin was a piggyback foreland basin resulting from northeast–directed migration of the front of the Tanggula Mountains during the Paleogene and Neogene. The variations in sedimentation rates, total deposit amount and accumulation rates in seven stages of evolution of the basin have been calculated quantitatively, and the calculation results show that the total amount of the Palaeogene and Neogene deposits in the Hoh Xil basin is 297.15 trillion tons, and that the accumulation rate averaged 400t/ ($m^2 \cdot Ma^{-1}$) at 56 Ma ~ 32.2 Ma and increased rapidly to 800 t/ ($m^2 \cdot Ma^{-1}$) during 32.2 Ma to 30 Ma, reflecting that tectonic activity was intensified in the early Oligocene. The curve of the sedimentation rate shows that in the Palaeogene the sedimentation rate of the basin increased by a big margin from 10 cm/ka ~ 20 cm/ka to 210 cm/ka in the 52.2 Ma ~ 52 Ma, 41.5 Ma ~ 40 Ma and 37.8 Ma ~ 34 Ma time intervals, which represent three phases of strong tectonic activity. In addition, a comparative study of the Yinggehai basin and various pull-apart basins of the western Yunnan Plateau defines four stages of uplift for the western Yunnan Plateau and proves the following: from 5.3 Ma to 1.6 Ma the uplift magnitude of the plateau was up to 1 700 ~ 2 100 m and the uplift rate was 0.5 ~ 0.57 mm/a, and since 1.6 Ma the sedimentation rate in the Yinggehai basin has increased abruptly to 1.39 mm/a and the deposit flux has increased abruptly to 174 million t/a, which indicates that the western Yunnan Plateau has undergone a phase of accelerated uplift and erosion since the Quaternary. The elevation of the ancient planation surface and the incision depth of river valleys both prove that the western Yunnan Plateau has been once more uplifted for 610 ~ 700 m since the Quaternary.

3. The temporal-spatial structure and growth mode of the crust of the Gangdise tectonomagmatic belt have been revised

Through intensive study, the Gangdise tectonomagmatic belt is divided into the north, central and south subbelt: the north subbelt is a volcanic belt resulting from subduction of the Bangong—Nujiang Ocean (at 100 Ma ~ 60 Ma) , the south subbelt is a volcanic—granite belt produced by subduction—collision of the Yarlung Zangbo Ocean (at 70 Ma ~ 45 Ma) , and the central subbelt consists of intraplate high-potassium volcanic rocks and muscovite-bearing granite generated by intracontinental subduction (at<20 Ma) .Types of magmatic rocks formed in the subduction, collision and post-collision stages are recognized, the indicators of three stages are summarized, and the time bases of the three stages are preliminarily established, which are 110 Ma ~ 50 Ma, 50 Ma ~ 40 Ma and<40 Ma. Granite study has yielded the following information of the crustal growth in the Gangdise area: I-type granite containing large quantities of dark-coloured inclusions formed in the subduction stage is crustal material resulting from transformation of mantle material by underplating, and S-type granite especially muscovite granite formed in the collision and post-collision stages is the product of crustal anatexis and the growth mode of its crust is marked by remigration and redistribution of material within the crust. Study indicates that significant crustal thickening took place after the main magmatic activity stage (65 Ma ~ 40 Ma) , while rapid uplift occurred in still later times (<20 Ma) .

4. The Cenozoic volcanic rock series and its evolutionary features in the northern Qinghai-Tibet Platean have been further ascertained and a genetic model of partial melting of magmas has been constructed

According to the features of temporal-spatial evolution of rock series, Cenozoic volcanic activities in the north of the plateau fall into three tectonomagmatic subcycles, which gave rise to three volcanic subzones, each with its own rock series. From south to north these volcanic subzones are: the Qiangtang volcanic subzone (44 Ma ~ 24 Ma) , including the sodic alkali basalt series, high-potassium calc-alkaline series and potassic basalt; the Central Kunlun—Hoh Xil volcanic subzone (19 Ma ~ 7 Ma) , which is characterized by the potassic basalt series; and the West Kunlun—Yumen volcanic subzomne (since 5 Ma) , dominated by the potassic basalt series. All the three volcanic subzones extend in an E—W or WNW direction, and from south to north the age of eruption becomes young progressively and the K_2O content increases successively. Age data indicate that there are four peak phases for volcanic activities: the 44.66 Ma ~ 35 Ma peak phase is characterized by the dominance of the high-potassium calc-alkaline series, in the 29 Ma ~ 24 Ma peak phase the alkali-potassic series predominated, and both at 19.6 Ma ~ 7 Ma and since 5 Ma the potassic basalt series was dominant. They display certain coupling with the pulsatory peak phases. A genetic model of partial melting of magmas constrained by the dual factors of rising mantle fluids and thickening due to adiabatic compression of the hydrated lithosphere is constructed according to the geochemical study of Cenozoic volcanic rocks in the north of the plateau.

5. The geological composition and tectonic attribute of the Namjagbarwa tectonic knot havc been essentially made clear

The metamorphic series of the Namjagbarwa Group in the great bend area of the Yarlung Zangbo River has been measured to have zircon U-Pb ages of 1 312 Ma and 525 Ma ~ 552 Ma and Rb-Sr isochron ages of 748 Ma ~ 1 064 Ma, which demonstrates that it is Proterozoic in age. Garnet-clinopyroxene lenses have been found at several places within this metamorphic series. It has been ascertained that metamorphic rocks in this area underwent high-pressure granulite-facies metamorphism in the early stage, medium-pressure granulite-amphibo-lite facies metamorphism in the middle stage and retrograde metamorphism in the last stage. The Namjagbarwa tectonic knot is composed of the extensions of three tectonic units in the south of the plateau: the core is the Himalayan orogenic belt, consisting predominantly of high-grade metamorphic rocks of the Namjagbarwa Group; the Yarlung Zangbo suture zone is distributed on the outer sides of the core, mainly represented by a greenschist facies—low amphibolite-facies ophiolitic association, and ophiolitic mélanges and peridotites with a cumulate texture are found in the Pelung—Bangxing area; thc Gangdise island-arc belt occurs in the arcuate form encircling the outer sides of the Yarlung Zangbo ophiolite belt, consisting mainly of Yanshanian—Himalayan intrusive rocks, basement metamorphic rocks and Paleozoic sedimentary rocks. The tectonic knot is mainly a "wedge structure" formed by thc Himalayan orogenic belt, with dextral and sinistral strike-slip fault systems occurring on both sides.

6. The rate of horizontal crustal movement in the northern Qinghai-Tibet Plateau has been obtained by Global Positioning System (GPS) monitoring and two vortex structures have been found

GPS measurements indicate that the rates of horizontal crustal movement in the northern Qinghai-Tibet Plateau and its adjacent areas relative to the stable part of the Eurasian plate vary from 7.99 mm/a to 32.43 mm/a, of which the average rate at the measuring stations in the interior of the plateau is 26.41 mm/a and that in the surroundings is 15.24 mm/a. The average rate of various measuring stations within the northern plateau relative to Chengdu is 16.45 mm/a and that of various measuring stations in the surroundings relative to Chengdu is only 6.84 mm/a. These data suggest that the crustal movement in the interior of the Qinghai-Tibet Plateau are active and have the functions of highly efficient regulation and absorption. According to the study results, two vortex structures are defined: One is the Yunnan—Tibet vortex structure, which rotates clockwise with the Namjagbarwa structure as the core and whose average rate of movement is 11.38 mm/a for the inner side of the vortical surface, 8.22 mm/a for the outer side of the vortical surface and 5.71 mm/a for the surroundings. The other is the Gansu—Qinghai vortex structure, which involves the north of the plateau and its adjacent areas. It generally rotates counterclockwise and the average rate of crustal horizontal movement is 15 mm/a for the inner side of the vortical surface, ~ 12.5 mm/a for the middle part of the vortical surface (the interior of the plateau) and 8 mm/a for the outer side of the vortical surface (Longxi block). Lhasa moves in a NNE direction relative to Chengdu, with a rate of 23 mm/a. Such vortex movement occurring across various tectonic units might be the manifestation of rheomorphism of lower crustal material and is one of the factors responsible for the inhomogeneity of the crustal deformation of the plateau.

7. Some new data and new information about the plateau uplift and geochronology have been obtained

In the west Kunlun and Gangdise mountains, data of the rates of plateau uplift and the history of crust cooling have been obtained using the fission-track method, which prove that the rates of the plateau uplift increased remarkably after 2 Ma BP. Fission-track analysis of Cenozoic sedimentary apatite from Pishan County, west Kunlun, shows that the period of 26 Ma ~ 23 Ma witnessed rapid uplift, corresponding to the Paleogene-Neogene unconformity. The sedimentation rates and deposit fluxes in the Hoh Xil basin, basins in eastern Tibet and western Yunnan and Yinggehai basin in the South China Sea have been studied comprehensively; the changes in sedimentation rates, total amount of deposits and accumulation rates in seven evolutionary stages in the Hoh Xil basin have been calculated quantitatively and the results show that the average rate of erosion of the Namjagbarwa tectonic knot is (4.5 ± 1.1) mm/a since 10 Ma BP. The rates of crustal movement and strike-slip movements of several faults in the northeastern Qinghai-Tibet Platcau have been studied by means of GPS monitoring and paleomagnetic measurements. A number of paleomagnetic and isotope age data have been got recently, which may be used to determine the ages of the Fenghuoshan Group in the Hoh Xil basin, the Namjagbarwa Group in the East Himalayas, the Gudur gneiss in the Qiangtang area and blueschist in the Shuanghu area.

8. Some new ideas about the process and mechanism of plateau uplift and its influence on the climate are proposed

These ideas include the following: The lithosphere beneath the Qinghai-Tibet Plateau is divided into three types of lithospheric types, which represent three stages of lithospheric evolution of orogenic belts respectively: the Pamir type represents the root-forming stage, the Gangdise type represents the unrooting stage and the Qiangtang type represents the thickening stage of the thinned lithosphere and then thickening. It is considered that the Qinghai-Tibet Plateau has a pulsatory uplift process and since the Paleogene the environment has changed pulsatorily from the tropical lowland forest to tropical and subtropical mountain forest and bushveld, and there was no large-magnitude subsidence stage. It is proposed that lower crustal thickening and gravitational isostasy are the main cause for the rapid uplift of the plateau since the late Pliocene, and that there are no features of thermal updoming of the mantle for its origin. It is found that there appeared two paleoclinatic variation events in the Paleogene: the climate of the earth became cold in the early Eocene and turned cold and dry in the early Oligocene; it is suggested that the uplift of the Qinghai-Tibet Plateau has played a dominant role in the decrease in the concentration of CO_2 in the atmosphere and a key role in Cenozoic global cooling. It is proposed that there only exists the Miocene (~20 Ma) planation surface in the northern Qinghai-Tibet Plateau, no Pliocene planation surface being present.

As view from the long process of the history of scientific research, geological research on the Qinghai-Tibet Plateau just begins and there are still many unrevealed geological phenomena and potential in scientific research. Revealing geological regularities, solving acientific problems and bringing scientific potenial into play depend upon energetic probe and study of generations of geologists and accumulation of bountiful knowledge. We hope that this series and relevant papers will be able to make their own contributions to adding to knowledge of the geoscience of the Qinghai-Tibet Plateau, probing into geoscientific theories and solving some practical problems. We sincerely expect your comments or criticism.

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