中国晚前寒武纪地质研究成果之九

华北地台南缘
陕西部分
晚前寒武纪地层研究

陕西省地质矿产局区域地质调查队

李钦仲　杨应章　贾金昌　等著

西安交通大学出版社

华北地台南缘(陕西部分)晚前寒武纪地层研究

The Study of Late Precambrian Strata in the Southern Margin of the North China Platform (Part of Shaanxi Province)

李钦仲　杨应章　贾金昌　等著

西安交通大学出版社
XI'AN JIAOTONG UNIVERSITY PRESS
·1985·

内 容 简 介

《华北地台南缘(陕西部分)晚前寒武纪地层研究》是我国重点科研项目之一。本书重点论述了陕西境内华北地台南缘晚前寒武纪地层的层序、接触关系性质、划分、时代归属及其与区域的对比；建立了以小秦岭一代为代表的区内上前寒武系剖面。对震旦纪冰成岩的岩石特征、冰川类型、沉积相及沉积模式也进行了较全面的论述，并描述了大量的叠层石分子，划分了具有不同特点的叠层石组合，探讨了其生态特征及其地层学意义。此外，还分析了部分地层沉积时期的岩相古地理特征。本书内容丰富，文图并茂，对于晚前寒武纪地质研究，特别是对地层学的研究，具有一定的启迪，可供有关科研人员、地质院校师生以及从事晚前寒武纪地质工作的工程技术人员参考。

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西安交通大学出版社出版

(西安市咸宁路28号)

西安交通大学出版社印刷厂印装

陕西省新华书店发行 · 各地新华书店经售

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开本 787×1092 1/16 印张 13 插页 9 字数：315千字

1985年6月第1版 1985年6月第1次印刷

印数：1—3,300册 定价：平4.70元 精7.10元

统一书号：13340.019

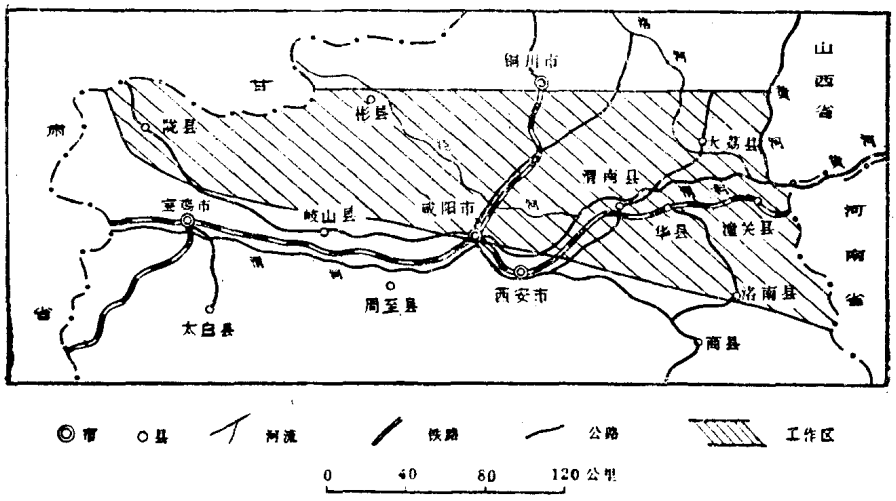
前　言

晚前寒武纪地层，在世界范围内是一个重要的含矿层位，并含有丰富的叠层石、微古植物及其它遗迹化石。晚前寒武纪这一地质历史时期，是研究由低等的藻类生物向较高级动物演化的关键时期。当前国际地质学界将要在寒武系之下建立一个“系”一级的地层单位，并确定寒武系—前寒武系界线及界线层型剖面。因此，对晚前寒武纪地质的研究，越来越被国际地质学界所重视。

广泛分布于我国南、北两大地质构造单元的晚前寒武纪地层，具有截然不同的生成时期的古气候条件、古地理沉积环境、沉积相、沉积建造及古生物群。在南方还有多处具备了研究寒武系—前寒武系界线的良好剖面，为争取在我国寒武系之下建立一个“系”、一级的地层单位及寒武系—前寒武系的界线层型剖面奠定了基础。晚前寒武纪地层，在我国蕴藏着丰富的铁、锰、磷、建筑材料等多种矿产资源。显然对晚前寒武纪地层的研究，不仅具有现实的经济价值，而且也有重要的理论意义。所以近几年来，晚前寒武纪地质研究，被列为我国的重点科研项目。

本书的研究成果属于这一科研项目之一，由陕西地质矿产局区调队承担。研究工作自1980年开始至1982年结束，1983年6月经地质矿产部组织召开的“中国晚前寒武纪地质研究项目科研成果评审会议”验收通过，并同意公开出版。

研究区的范围，北自大荔县以北—彬县一线，南到洛南县—岐山县一线，东起陕、豫交界，西至陕、甘交界。地理座标为东径106°20′—110°30′，北纬34°00′—35°40′之间。其大地构造位置，属华北地台南缘。



工作区及交通位置图
Regional setting and traffic map of work

本区及其邻侧，早在1929年我国地质界的老前辈黄汲清、赵亚曾等曾进行过路线地质调查。解放后，随着地质事业的迅速发展，其研究程度逐渐提高，资料也越来越丰富。特别是1958年以来，秦岭区域地质调查队，在秦岭地区系统地开展了1:200000区域地质调查工作，取

得了系统的区域地质资料，对地层进行了较详细的研究和划分，从而提高了研究程度。随后，陕西省地质矿产局区调队、第六、十三地质队、西北冶金地质勘探公司713队和西北大学地质系等单位，又相继开展了1:50000区域地质调查、矿产普查及专题研究等工作，在某些方面使研究工作有了进一步深化。现将以上有关单位对本区晚前寒武纪地层划分的意见及其沿革情况列成“陕西省华北地台南缘上前寒武系划分沿革表”。

这次研究工作，是在前人工作的基础上进行的。运用了岩石地层学、生物地层学、年代地层学、数学地质等学科的理论和方法，对区内上前寒武系的划分、时代归属及区域对比等方面，进行了较全面的研究，取得了比较丰富的地质依据。根据实际资料，对震旦纪冰成岩的岩石特征、冰川类型、沉积相及其沉积模式；对高山河组沉积时期的岩相古地理特征；叠层石的组合划分、生态特征及其地层学意义等基础地质理论问题，也进行了论述和探讨，其中某些认识和观点的提出，尚属首次。

出露于区内礼泉县唐王陵一带的“唐王陵砾岩”，近几年来对其时代归属及其成因争论较大，曾引起了省内外一些地质工作者的关注，其中有不少人认为该砾岩属震旦纪的冰成岩。在这次专题研究过程中，对其也进行了调查研究，研究结果详见附件三。

书中关于我国晚前寒武纪地层分类命名等有关问题，均系根据全国地层委员会于1982年召开的“晚前寒武纪地层分类命名会议”决议及附录中的若干建议确定的。

在研究工作及撰写本书过程中，曾多次得到陕西省地质矿产局区调队总工程师卢一伦（高级工程师）、副总工程师张二朋及陈家义、张维吉二位工程师的指导，省地质矿产局总工程师尚瑞均、阎廉泉（高级工程师）及科技处王郁文、方永安、方德生、姚鸥春（工程师）也提出了不少指导性的建议。岩矿鉴定工作由周青山、彭学兰工程师承担，并在撰写本书过程中，提供了岩石部分的镜下微观资料。叠层石由内蒙古区调队梁玉佐高级工程师、西安地质矿产研究所张录易工程师和西北大学邱树玉老师鉴定。微古植物及小壳化石由伊鹍英工程师鉴定。牙形刺化石由郭洪祥同志鉴定并经北京大学安泰痒副教授检查。书中图件由陕西地质矿产局区调队出版分队清绘，图版照片由罗定夫同志承担。在此一并致谢。

参加研究工作的除署名者外，还有李书民、何建社、张忠权、薛友智、张建平等同志。

陕西省华北地台南缘上前寒武系划分沿革表

黄汲清等 1931	李振等 1955	«洛南幅»地质图(1:200000) 1958		王日伦(洛南地区) 1958		«渭南幅»地质图(1:200000) 1959		西北大学 西冶713队 1975		«石坡幅»地质图(1:50000) 1976		西北编表小组 1977		本书 1984	
震旦——寒武系(未分)	下寒武统	下寒武统	砾岩、砂板岩层	下寒武统	砾岩、砂板岩层	下寒武统	三道撞组	震旦亚界	震旦系	震旦亚界	震旦系	震旦亚界	震旦系	上前寒武系	震旦系
	震旦系中——上部	上震旦统	冯家湾组	中震旦统	冯家湾组				青白口系		青白口系		青白口系		青白口系
			杜关组		杜关组				蓟县系		蓟县系		蓟县系		蓟县系
		下震旦统	巡检司组	下震旦统	巡检司组	下震旦统	龙家园组		长城系		长城系		长城系		长城系
			龙家园组		龙家园组										
			高山河组		高山河组		高山河组								
		下元古界	熊耳群	下元古界	熊耳群	下元古界	熊耳群								
							铁铜沟组								

罗圈组
大庄组
冯家湾组
杜关组
巡检司组
龙家园组
高山河组
熊耳群
铁铜沟组
石北沟组

华北地台南缘(陕西部分)晚前寒武纪地层研究

详细摘要

本书是中国晚前寒武纪地质研究成果之一。研究区位于华北地台南缘(陕西部分),包括秦岭北坡的一部分及渭北地区,地理座标大致在东径106°20′—110°30′,北纬34°00′—35°40′。

1980—1982年间,对区内晚前寒武纪地层通过岩石地层、生物地层、同位素年龄、岩相古地理、古冰川、矿产及数学地质等方面的研究,获得了丰富的实际资料,提出了较为全面而系统的认识。主要成果及基本观点概括如下:

一、在以往研究的基础上,对区内晚前寒武纪地层剖面进行了系统研究,重新划分了出露于岐山县及陇县景福山一带的上前寒武系,建立了以小秦岭一带为代表的陕西境内华北地台南缘上前寒武系剖面。其地层层序自下而上为:铁铜沟组、熊耳群、高山河组、龙家园组、巡检司组、杜关组、冯家湾组、石北沟组及罗圈组。下伏地层为太古界太华群,上覆地层为下寒武统辛集组。根据对代表性剖面的研究,本区上前寒武系中几个主要地层之间的接触关系为:熊耳群与铁铜沟组、高山河组与熊耳群、石北沟组与冯家湾组之间,均为不整合接触;龙家园组与高山河组、罗圈组与石北沟组之间,为平行不整合接触,其中罗圈组还具有不整合于冯家湾组之上的现象。铁铜沟组不整合于太古界太华群之上,罗圈组平行不整合于下寒武统辛集组之下。根据地层接触关系和罗圈组内所获得的同位素年龄数据为7.22亿年以及下寒武统辛集组底部所发现的*Helcionella*, *Brachiopods*等小壳化石,将区内上前寒武系顶界确定在罗圈组与辛集组之间的平行不整合面;根据侵入于铁铜沟组张家坪花岗岩体的年龄数据为15.00亿年,并根据地层接触关系以及区域对比资料,其底界确定在铁铜沟组与下伏太华群之间的不整合面。

二、系统研究了区内的叠层石,采集了大量的叠层石标本,共描述了17个群,27个型(其中14个未定型),划分了各具不同特色的三个叠层石组合:第一组合,产于高山河组中亚组,主要分子有*Cryptozoon* f., *Stratifera* f., *Litia dongqinlingensis*, *Kussiella* f., *Xiayingella* f.等。本组合的叠层石常组成小型似层状礁体,叠层体以层状和似层为主,次有包心菜状和柱状,个体较小,彼此紧密排列,相互界线不清,连接层发育,具带状和壳层状微构造。在垂直剖面上的分布有一定规律,下部层位中以层状、包心菜状和层柱状为主,向上则逐渐过渡为以简单柱状类型为主。叠层石的类型及其特征与蓟县上前寒武系层型剖面中的第一组合相似;第二组合,产于龙家园组和巡检司组,为区内分布最广且最稳定的一个组合。其代表分子有:*Conophyton shanpolingensis*, *Colonnella*, *Pseudogymnosolen*, *Luoyukouella*, *Longicolumella*, *Xiaoqinlingella*, *Microstylus*, *Lochmecolumella*, *Conophyton conicellosum*等,除以上代表分子外,与其共生的还有

Osagia, *Kussiella*, *Stratifera* 等。该组合类型复杂，叠层体大小悬殊，大者如 *Colonnella*, *Conophyton* 等，高可达 40 厘米左右，直径 5 厘米左右。小者如 *Pseudogymnosolenidae*, *Stratifera* 等，高仅有 0.5—3 厘米，直径 0.5—1 厘米。叠层体形态多样，收缩膨胀现象明显，一般具多次分叉，并以具有放射状排列的藻丝痕迹为其特征。这些迹象表明，该组合与第一组合比较，已发生了本质的变化。另外，个体较大的 *Conophyton* 和分叉复杂的 *Colonnella* 叠层石，在这一组合中首次出现，可作为区别于第一组合的重要标志。本组合的叠层石面貌特征与蓟县上前寒武系层型剖面扬庄组到雾迷山组的叠层石面貌相似，应相当于它的第三个叠层石组合；第三组合，产于杜关组和冯家湾组，代表性分子有 *Chihsienella*, *Baicalia*, *Tungussia* 和 *Anabaria* 等，另外有 *Pseudotielingella*, *Paracolonnella*, *Inzeria*, *Jacutophyton*, *Conophyton*, *Colonnella* 等与其共生。该组合的特征是：叠层体大，常组成规模较大的生物礁体，分叉频繁，多为两次到多次分叉，在柱体侧部常具有似粘液质所组成的特种壁。因此柱体之间界线清晰，具有清楚的带状、线状和凝块状微构造，这些特征与第二组合具有显著区别。在垂直剖面上，这一组合的变化特征是：下部层位以简单平行分叉类型为主；上部层位以复杂散开分叉为主。其形态，下部层位以个体巨大，具明显膨胀收缩现象的类型为主；上部层位个体逐渐变小，膨胀收缩现象不明显。该组合的面貌特征与蓟县上前寒武系层型剖面铁岭组的叠层石组合面貌相似，应相当于它的第四组合。以上资料结合地层、侵入体的年龄（高山河组、石北沟组、罗圈组全岩 *Rb—Sr* 等时线年龄分别为 13.94±0.42、9.02±0.48 及 7.223±0.05 亿年；熊耳群 U—Pb 年龄 15.45 亿年；侵入于铁铜沟组的花岗岩全岩 Rb—Sr 年龄15.00 亿年；侵入于冯家湾组的花岗岩 U—Pb 年龄 9.99 亿年），为确定本区上前寒武系的时代及其与区域对比，提供了生物及年代依据。

三、根据本区上前寒武系剖面及其沉积特征、构造运动面、生物组合和同位素年龄等资料，通过综合分析，分别与我国南、北方的上前寒武系层型剖面（三峡剖面及蓟县剖面）进行了对比。其中罗圈组可与三峡剖面震旦系南沱组对比，石北沟组、冯家湾组—龙家园组、高山河组—铁铜沟组，可分别与蓟县剖面的青白口系、蓟县系、长城系对比。同时与相邻地区（晋南及豫西）的上前寒武系也进行了对比。详细对比关系见正文。

四、对罗圈组冰成岩进一步作了宏观及微观研究，取得了一些新资料，为研究当时的冰川类型、发育特征及沉积相等提供了依据。根据所获资料结合罗圈组（宁夏称之为“正目观组”）在区域上的分布特征分析，认为罗圈组早期沉积时期的冰川类型，并不具有典型大陆冰川的特征，而显示出的特点说明它是属于山麓冰川。当冰川沿斜坡向下运动时，随着温度的增高，大量的冰川消融水形成了山前湖泊。罗圈组冰成岩的主体，就是在冰水湖泊环境中沉积而成的。从冰川纹泥的大量出现、浮冰坠石的堆积及部分指相元素(K、Ba、Sr、Rb、B、Ga)的比值等资料看，都说明了这一点。在冰成岩的底部，局部出露有不稳定的不具层理的块状砂砾岩，并在其下伏地层的顶部层面上，发育有具擦痕的冰溜面，这一事实说明，初期当冰川向前运动时，随着温度的增高而消融退缩，这种不具层理的块状砂砾岩就是当冰川退缩时，在冰川前缘局部堆积而成。到了罗圈组晚期，气候变暖并伴随有局部海侵，而逐渐过渡为比较稳定的浅海或海湾相正常沉积。这可以从罗圈组上段沉积物粒度细（泥质—粉砂级）、磨圆度及分选性好、结构成熟度高；成层性良好、层理清晰；上述指相元素的比值均接近于正常海相沉积岩中同类元素的比值等资料得以证实。由此可以概括整个罗

圈组的沉积过程是：始于冰川前缘的局部陆地堆积（构成下段冰成岩底部断续分布的块状砂砾岩），到冰一水沉积（构成下段冰成岩的主体），晚期以正常海相沉积而告终（构成上段正常海相沉积岩）。

五、比较系统地研究了高山河组沉积时期的岩相古地理特征，取得了较为丰富的相标志资料。根据所获资料，分别编制了高山河早、中、晚期的岩相古地理图。三个时期的沉积大相均为滨海相，其中早期划分出海湾、边缘浅滩和潮坪三个亚相，潮坪亚相中又进一步划分出高潮坪、中潮坪、低潮坪和潮下坪四个微相；中期划分出海湾、潮坪二个亚相，潮坪亚相中又进一步划分出高潮坪、中潮坪、低潮坪和潮下坪四个微相；晚期只能划分出一个滨海潮坪亚相。另外，对高山河组沉积时期以前的古构造轮廓及古地貌形态进行了分析。本区自太古代以后，基本处于相对稳定、长期遭受剥蚀的地区。但因位于地台边缘的台、槽衔接部位，构造运动较地台内部仍显得比较强烈，并且不同时期的构造运动所形成的古构造轮廓，具有一定的继承性。因此华北地台南缘小秦岭地区的华山、老牛山南侧，在这个时期不仅发育有活动性的华阳川东西向断裂和老牛山北东向断裂，而且还有较强烈的火山活动，主要表现为裂隙式一中心式的滨海—浅海相海底火山喷发，形成巨厚的熊耳群火山岩。在这一古构造轮廓基础上，小秦岭地区所形成的古地貌是一个起伏显著，高差较为悬殊的地貌形态。其总的趋势是：北高南低，西高东低，中间起伏不平。在渭南、洛南之间的黄龙铺和胡家湾一带，形成了两个相对低凹的地区，沉积了厚度相差很大(180－3920 米)的高山河组。

六、在进行本区上前寒武系研究的同时，对与其有关的矿产也进行了初步研究。本区与上前寒武系有关的矿种有：铁、磷、钾、锰、硼、石英岩、白云岩等，其中硼、锰、石英岩分布零星，且不稳定。

（一） 铁矿：本区与沉积作用有关的铁矿为赤铁矿，其分布具有固定的层位，主要分布在高山河组中亚组底部、上亚组底部、石北沟组底部及与下伏冯家湾组的不整合面上、罗圈组上段。虽然矿化层位较多，但其品位普遍较低，一般为 10－30%，个别最高 40%。规模也比较小，矿体长几米到 100 米，最长为 390 米，厚 0.1－1 米，最厚 2.3 米。因此，工业价值不大。

（二） 磷矿：主要分布于罗圈组上段。产出形式有两种：一种为透镜状，似层状含磷砂岩；另一种为角砾状磷质岩。其中以后者常见。P_2O_5 含量为 7－10%，由于矿化分散，规模小，不具工业价值。

（三） 钾：主要产于高山河组下亚组。含钾岩石为绿色、灰绿色粘土岩、粉砂质粘土岩。含钾岩层多达十余层，单层厚一般为 1－2 米，最厚 5－6 米。K_2O 含量一般为 7－8%，最高为9.24%。层位稳定，但钾的赋存状态尚未研究清楚。

（四） 白云岩：分布广泛，主要分布在龙家园组中上部和巡检司组的部分地段。在巡检司一黑峪一带有部分样品，其分析结果可达到熔剂、耐火材料和玻璃配料Ⅱ级品位要求，但规模不甚清楚。目前只有骡店白云岩矿床做过详查一勘探工作。矿体产于龙家园组的中上部，有两个矿体，长度分别为 450 米和 250 米，厚度分别为 65－95 米和 19 米。化学成份：MgO 平均为 21.20%，SiO_2 平均为 1.61%，Fe_2O_3 平均为 0.53%。符合熔剂、耐火材料工业要求，构成小型矿床。本区上前寒武系中的龙家园组—冯家湾组，白云岩颇为发育，继续寻找符合工业要求的白云岩矿床，仍然具有广阔的前景。

该项科研成果除正文外，另外附有三个附件：

附件一：《华北地台南缘（陕西部分）上前寒武系的叠层石》。重点叙述了本区叠层石的产出层位、形态特征、微构造及组合划分，对大量的标本磨光面及薄片进行了详细描述。同时对叠层石的生态特征及其地层学意义也作了初步讨论。由下到上共划分出三个叠层石组合，总结了每一个组合的特征及具有代表性的叠层石分子，并提出了与蓟县上前寒武系层型剖面中叠层石组合的对比意见。

附件二：《华北地台南缘（陕西部分）上前寒武系数学地质分析》。首次运用数学地质的理论和方法，对本区上前寒武系的沉积地球化学特征进行了研究。根据马尔柯夫概率模型，对剖面岩性演化的统计分析认为，本区上前寒武系中高山河组—冯家湾组这套地层的沉积环境，属于由河流冲积相向浅海相过渡的沉积环境。通过元素的沉积地球化学旋回性的研究，划分出具有不同特点的五个地球化学旋回：第一旋回（高山河组下亚组—中亚组），各曲线除个别特异点外，基本上在零得分值附近频繁振动，因子1与因子2曲线起伏趋势大致相反；第二旋回（高山河组上亚组），因子1在频繁振动后经过一个小的上升复而降到全剖面的极小值，后又迅速上升。因子2曲线却恰相反，从正值落到负值区，出现两三次起伏后又上升到剖面的最大正值。因子5、6曲线在111号及114号样品处出现特异值。本旋回向上与第三旋回之间曲线表现为突变特征；第三旋回（龙家园组—巡检司组），曲线较平稳，起伏不显著。因子1、2位于全剖面最大正值区，因子3、4、5、6伸展于零附近，曲线在平稳的背景下出现几个小幅度的起伏。148号样品，即巡检司组底部第一个样品，在各曲线上部都显示为特异值，证实了龙家园组与巡检司组以此分界的合理性。但此点上下这段曲线特征基本一致，表明龙家园组与巡检司组沉积环境的继承性；第四旋回（杜关组—冯家湾组），各曲线比较一致的表现为由低—高值的单向变化形态，与上下层段曲线（第五、三旋回的曲线）呈突变关系；第五旋回（罗圈组），因子1、3、5、6曲线表现为低—高—低的完整起伏。因子2、4曲线相反，为高—低—高的完整起伏，幅度一般不大。运用有序分割法对剖面的地球化学进行了划分，高山河组与上、下层之间，石北沟组与上、下地层之间，罗圈组与上覆下寒武统辛集组之间，均具有明显的分割界线。从而为地层划分、确定地层间的接触关系及对沉积相的研究，充实了新的依据。

附件三：《陕西礼泉“唐王陵砾岩”的时代及其成因》。关于“唐王陵砾岩”的成因及时代归属，以往争议较大，可概括为两种认识：一种认为该砾岩属正常沉积的“同生角砾岩”，其时代为奥陶纪；另一种认为属“冰碛砾岩”，其时代为震旦纪。为了查明其成因及时代归属，在本专题研究过程中，对“唐王陵砾岩”及其以下的页岩、灰岩这套地层，重新进行了剖面研究及砾度分析等微观方面的研究。根据在“唐王陵砾岩”及其以下的页岩和灰岩中所采到的牙形刺化石 *Aconfiodus* sp., *Tsmanognathus*, *Disfacodus* sp., *Panderodus* sp. 等，结合层序序次，将“唐王陵砾岩”的时代归入晚奥陶世，其下的页岩及灰岩归入中奥陶世；根据野外宏观研究及粒度分析资料，认为“唐王陵砾岩”的岩石特征及成因类型比较复杂。自下而上可划分为四大套：第一套（即剖面中的⑦－⑧层），为具有极复杂状硅质条带、团块及角砾的白云岩。呈厚—巨厚层状，层理清晰，白云质胶结。角砾成份单一，全由硅质岩组成。角砾形态多样，绝大部分呈棱角状—次棱角状。角砾往往沿一定方向排列，其间还有硅条纹藕断丝连地相互连接着。也有的角砾虽沿一定方向排列，相互之间却没有硅质条纹连接，但每一个角砾的棱角指向相邻角砾的棱角。此种现象说明白云岩中的硅质成分原始状态是相互连接的，后来由于沉积环境动荡使其拉长断开，形成互不连接的角砾。因此认为，此种

岩石是在动荡的沉积环境中形成的同生角砾岩；第二套(即剖面中的⑨－⑭层)，为砂砾岩。泥砾岩、含砾白云质砂岩夹粗砂岩及板岩。呈中一厚层状，层理清晰。砾岩的砾石成分以各类白云岩及灰岩为主，其次为硅质岩、砂岩及石英岩。砾石形态大部分呈次棱角状—半滚圆状，大小悬殊，最大砾径可达12厘米左右，最小仅有数毫米，磨圆度及分选性差到中等。砾岩常与砂岩及粉砂质板岩呈明显的过渡关系，构成自下而上由砾岩—细砾岩—砂岩—粉砂质板岩多次重复出现的粒序层，此种现象具有鲍马层序的特点。在砂岩层的顶部层面上，往往可见冲刷痕及槽模（？）等现象。为了进一步研究此种类型砾岩的成因，还进行了粒度分析。研究结果表明，其沉积物的搬运方式是以递变悬浮搬运为主，分选性由良好到差。做出的粒度分布曲线图和C M图，与典型的浊流沉积岩同类图件的图形基本一致。根据以上宏、微观研究结果认为，此类砾岩系由浊流沉积而成；第三套（即剖面中的⑮－⑯层），为粉砂质泥砾岩。成层性差，层理不甚清楚。胶结物主要由泥质组成，含少量粉砂质。砾石成分较复杂，主要为各类白云岩及灰岩，其次为硅质岩、板岩，偶而可见花岗岩砾石。砾石大部分呈半滚圆状，部分呈次棱角状，也有的呈磨圆度较好的滚圆状。分选性差，大小混杂，最大砾径达1米左右，最小者仅有数毫米。砾石分布不均匀，变化大，有时砾石可达到饱和程度，但在相距不远的露头上则变为稀疏分布，此种变化在倾向及走向上均可见到。此种岩石除砾石大小混杂及成层性差之外，未发现其它典型的冰川遗迹。从上述特点看，此类砾岩的成因目前还难以确定，有待进一步研究；第四套（即剖面中的⑰－⑱层），为灰质砂质角砾岩。层理清晰，呈巨厚层状，灰质及砂质胶结。砾石成分极复杂，其中以各类白云岩、灰岩、鲕状灰岩为主，其次为砂岩、石英岩硅质岩及板岩，偶而可见片麻岩、花岗岩及基性火山岩砾石。其形态以棱角状—次棱角状为主，少量呈半滚圆状。分选性差，最大砾石砾径为20厘米左右，最小为粗粒级砂屑。宏观这类砾岩的剖面，不具韵律性，但在一个巨厚的单层中，可以见到由下向上，其砾度由大逐渐变小，构成由粗砾岩—细砾岩—含细砾粗砂岩的沉积层序。根据上述特点，认为该类砾岩是在流水比较急，搬运速度比较快的条件下，于河流入海口附近所形成的岸边沉积砾岩。

通过几年来的专题研究，取得了上述主要地质成果。但还有些问题尚未得到妥善解决，例如本区上前寒武系底界的确定，还缺乏更充分的地质依据；高山河组的同位素年龄与其中所产的叠层石，还存在一定的矛盾，这些问题都有待进一步研究解决。

THE STUDY OF LATE PRECAMBRIAN STRATA IN THE SOUTHERN MARGIN OF THE NORTH CHINA PLATFORM(Part of Shaanxi Province)

Abstarct

This book is one of the results of a geological study of Late Precambrian strata in China. The investigated region lies in the southern margin of the North China Platform (Part of Shaanxi Province), including a part of the northern slope of Qinling and the Weibei region. Its geographical coordinates are east longitude 106° 21′——110°31′ and northern latitude 34°00′——35°40′.

During the period between 1980 and 1982, having made a study of rock strata, biological strata, isotopic age, lithofacies palaeogeography, fossil glacier, mineral resources and mathematical geology of Late Precambrian strata in this region, an abundant amount of factual information concerning them was obtained. Their whole and systematic views are suggested. The major results and the basic view-points are summarized as follows.

1. On the basis of former research, the systematic study of sections of Late Precambrian strata was given in this region. The stratum of Upper Precambrian System which cropped up in Qishan County and Jinfu Mountain in Long County were subdivided. The sections repressenting the Upper Precambrian in the southern margin of the North China Platform in the boundary of Xiaoqinling in Shaanxi were also subdivided. The succession of the stratum from the bottom to the top is: Tietonggou Formation, Xionger Group, Gaoshanhe Formation, Longjayuan Formation, Xunjiansi Formation, Duguan Formation, Fengjiawan Formation, Shibeigou Formation, and Luoguan Formation. The underlying strata is Taihua Group of the Archaeozic Erathem. The upper strata is Xinji Formation of the Lower Precambrian Series. According to the study of representative sections, the contact between several major stratum of Upper Precambrian in the region are: Xionger Group and Tietonggou Formation, Gaoshanhe Formation and Xionger Group, Shibeigou Formaton and Fengjiawan Formation are all in discordant contacts. There are parallel discordant contacts between Longjiayuan Formation and Gaoshanhe Formation, Luoquan Formation and Shibeigou Formation, among which Luoquan Formation still has a discordant phenomenon above the Fengjiawan Formation. Tietonggou Formation discords above the Taihua Group of Archaeozic Erathem. The Luoquan Formation is in parallel unconformity below the Xinji Formation of lower Precambrian Series. According to the contact of stratum, the isotopic age (722 million years) obtained from Luoquan Formation and micro-shell

fossils (such as *Helcionella*, *Brachiopods* etc.) discovered from the bottom of Xinji Formation of the Lower Precambrian Series, the top boundary of Upper Precambrian in this area is determined in the discordant plane between the Luoquan Formation and the Xinji Formation. According to the age data(1500 million years) in the Zhangjeaping Granitic Mass which intruded into the strata of the Tietonggou Formation, the contacts of stratum and analysis of information of the regional correla tion, its bottom boundary is determined on the discordant plane between the Tietonggou Formation and underlying Taihua Group.

2. Stromatolith in this area is studied systematically and a large number of specimens of stromatolite were collected. 17 groups and 27 types (among them 14 types are not determined) in all have been described. Three different characteristic assemblages of stromatolite have been divided: The first assemblage is found in the middle sub-Formation of the Gaoshanhe Formation. It mainly contains *Cryptozoon* f., *Stratifera* f., *Litia dongqinlingensis*, *Kussiella* f.,*Xiayingella* f. and so on. Stromatolite of this assemblage often makes up small stratoid reef bodies. The stromatolithic bodies are dominating in stratiform and stratoid-form, and in turn are the shaped cabbage and columnar. Each body is small and they arranged closely each other. The boundaries between them are not clear, developing conjunct layer and with shell microstructure. The distribution of the stromatolite in the vertical section has a certain regularity. The stratified form, cabbage form and stratified columnar form are mainly at the lower level, the simple columnar type is upwards. The types of stromatolites and their characteristics are similar to the Upper Precambrian in Ji County. The second assemblage is found in the Long-Jiayuan Formation and Xunjiansi Formation, which is widely distributed and the most consistent assemblage in the region. ir The representative examples are: *Conophyton shanpolingensis*, *Colonnella*, *Pseudogymnosolen*, *Luoyukuella*, *Longicolumella*, *Xiaoqinlingella*, *Microstylus*, *Lochmecolumella*, *Conophyton concellosum* etc. Besides of them, those with their symbiosis are: *Osagia*, *Kussiella*, *Stratifera* ect. This type of assemblage is complex and the size of the stromatolithic bodies is very different: The bigger ones, such as *Colonnella*, *Conophyton* etc, may be 40 centimeters high and 5 centimeters in diameter. The smaller ones, for example *Pseudogymnosolenidae*, *Stratifera* etc, may only be 0.5——3 cm high and 0.5——1 cm in diameter. The form of the stromatolithic bodies in general have multiple bifurcation and are characterized by algal filamentous traces of radioactive arrangement. These traces indicated that by comparison of this formation with the first assemblage, an essential change took place. The bigger body *Conophyton* and stromatolite *Colonnella* with complex bifurcation for the first time appeared as distinct in the first assemblage. The characteristics of the facies of stromatolite in this assemblage are similar to that of stromatolite from the Yang-

zhuang Formation to the Wumishan Formation of the stratotype sections of Upper Precambrian in Ji County. They are equal to its third assemblage of stromatolite. The third assemblage is found in the Duguan Formation and Fengjiawan Formation, Its repredentative examples arc: *Chihsienella*, *Baicalia*, *Tungussia*, and *Anabaria* etc. Besides, there are *Pseudotielingella*, *Paracolonnella*, *Inzeria*, *Jacutophyton*, *Conophyton*, *Colonnella* etc. with symbiosis. The characteristics of this assemblage are: The stromatolithic bodies are big and often make up a large scale bioherm bodies. They have frequent bifurcation and their bifurcation is a multiple of two or more times. By the side of columnar bodies there are special walls made of mimic sticky liquids. Therefore, the boundary between these columnar bodies is clear and has obvious banded, linear and coagulable block structure. These characteristics are obviously distinguished from the second assemblage. Above the vertical section, the changing characteristics of this assemblage are: Its lower position is a simple parallel bifurcation type in the lead. Its upper position has a complex dispersed bifurcation type in the lead. Their form is: The lower position mainly has a large body with an obvious phenomenon of expansion and contraction; the upper position has a diminishing body and is not the obvious phenomenon of expansion and contraction. The facial appearance of this assemblage is similar to that of the stromatolite assemblage of the Tieling Formation in the stratotype sections of the Upper Precambrian stratum in Ji County and should be equal to its fouch assemblage. The above information combined with the stratum and the ages of intrusive bodies (The ages of the all rocks Rb-Sr in Gaoshanhe Formation, Shibeigou Formation and Luoquan Formation are 1394 ± 42, 902 ± 48 and 722.3 ± 5 million years, respectively. The age of U-Pb in Xionger Group is 1545 million years; the age of all rocks Rb-Sr in granite intruded into the Tietonggou Formation is 1500 million years. The age of granite U-Pb intruded into Fengjiawan Formation is 999 million years. It has provided the biogenic chronological evidence for determining the ages of Upper Precambrian in this region and the correlation with this region.

3. According to the sections of Upper precambrian in this region, their sedimentation characteristics of the tectonic kinematic plane, the biogenic assemblage, isotopic age and other data, through comprehensive analysis, a correlation of the stratotype sections of Upper Precambrian in the south and in the north China (Sanxia section and Jixian section)was given respectively. Among them the correlation of Luoquan Formation with Nantuo Formation of the Sinian System in the Sanxia section was also given. The correlation of Shibeigou Formation, Fenjiawan Formation——longjiayuan Formation, Gaoshanhe Formation——Tietonggou Formation with Qingbaikou System, Jixian System and Changcheng System in the Jixian section is noted. At the same time the correlation with the Upper Precambrian

stratum of adjacent areas (south of Shanxi and west of Henan Province) is also given.

4. Having made a macrocosmic and microcosmic study of glacial rocks of Luoquan Formation, some new information has been obtained, which provides evidence for studying glacial types of that time, their development characteristics and sedimentary facies. According to the information obtained, combining with an analysis of the characteristics in the regional distribution of Luoguan Formation ("Zhengyueguan Formation" is called in Ningxia Province), it is thought that the glacial type during the early sedimentational period of Luoquan Formation does not have the characteristics of tne typical continental glaciers. It shows the properties indicating that it blongs to piedmont glaciers. When tne glaciers moved down along slope and as the temperature increased, a large number of the glacial meltwater has formed the glacial lake in front of mountain. The major bodies of glacial rocks of Luoquan Formation were deposited in the surroundings of aqueoglacial lakes. The appearance of a large number of glacial varved clay, accumulation of falling stone from the floe-ice and part of facies elements (K, Ba, Sr, Rb, B, Ga) all indicated this. Unsteady blocky sandy conglomerate rocks without stratification were exposed partially in the bottom of glacial rocks. On the top surface of the underlying strata, the glacier pavement with striae developed. This fact explains that in the early days, when glacier moved forward and as the temperature increased, the recession of ablation took place. These blocky sandy conglomerates without stratification were formed in front margin of the partial accumulation of glaciers when the glacier receded. The climate became warmer in company with a partial marine migration till late period of the Luoquan Formation. The Luoquan Formation gradually translated into a normal deposition of comparatively steady neritic facies or gulf facies. It may be shown by the fine grain size (argillaceous-silt grade), good psephicity and sorting index, high mature degree of texture, good stratified property and clear stratification. The ratios of above facies elements approached that of the same kinds of elements in the sedimentary rocks of normal marine facies. Therefore, the all depositional processes of Luoquan Formation may be summarized as follows: It began at local land accumulation of frontal margin of glacier (making up blocky rocks of sandy conglomerate of bottom intermittent distribution of glacial rocks in lower member) to ice——aqueous deposition (making up principal part of glacial rocks in the lower member). In the later stage, the deposition of normal marine facies ended (making up the sedimentary rocks of normal marine facies in the upper member).

5. We systematically studied the chraracteristics of palaeogeography of lithofacies during deposition of Gaoshanhe Formation, and obtained a wealth of data of the facies marks. According to the data gathered, the palaeogeographic maps of

lithofacies in early, middle and late periods of Gaoshanhe Formation was made respectively. The big depositional facies of the three periods are littoral facies. Among of them, three sub-facieses (gulf, marginal shallow and tidal flat) are divided in the early stage. In the tidal-flat subfacies, four microfacieses (high tidal flat, middle tidal flat, low tidal flat and tidal under flat) are further divided. In the middle period, two subfacieses (gulf and tidal flat) are divided. The four microfacieses of high tidal flat, middle tidal flat, low tidal flat and tidal under flat, in the tidal flat subfacies, are further subdivided. Only one subfacies of littoral tidal flat in the late period can be divided. Moreover, we analysed the palaeotectonic configuration and the palaeogeomorphological form of the depositional period of Gaoshanhe Formation ago. After the Archaeozoic Era this region was basically in a relatively steady and a long suffering denudation stage. Lying in the connective position of the marginal bench of the Platform and trough, the tectonic movement seems intenser than that in the interior platform. The palaeotectonic frameworks formed by the tectonic movement in different periods have certain continuity. At this time, the southern sides of Hua Mountain and Laoniu Mountain in Xiaoqinling region of the southern margin of the North China Platform, not only developed the active Huayangchuan E-W directional rift and Laoniushan N-E directional rift, but also had intenser volcanic activity. It may be noted from the fractural-central volcano eruption in sea bed of littoral-neritic facies, making up the thick volcanic rocks of Xionger Group, On the basis of the palaeotectonic framework, the palaeogeomorphology formed in Xiaoginling region is an obvious relief and a very different geomorphological form in altitude. Its general trend is: high to north and low to south, high to west and low to east, the relief not flat in the middle. In Huanglongpu and Hujiawan areas between weinan County and Luonan County, two relative low districts had been formed, in which the Gaoshanhe Formation with thickness rarying from 180——3920 metres was deposited.

6. At the same time with the study of the Upper Precambrian stratum in this region, a primary study of mineral resources concerning this region was produced. The types of ore in this region related to the Uppep Precambrian strata are: iron, phosphorous, Potash, manganese, boron, quartzite, dolomite etc. Among of them, the distributions of boron, manganese and quartzite are scattering.

(1) Iron ore: Iron ore (hematite) deposit concerning with sedimentation in this region has a fixed horizon in time and in space. It is mainly distributed at the bottom of middle and upper subformation of Gaoshanhe Formation, at the bottom of Shibeigou Formation, on the plane of unconformity of underlying Fengjiawan Formation and in the upper member of Luoquan Formation. Though there are more mineralized positions, their tenor, however, is lower in general. In generally,

the tenor of them is 10——30%, the highest tenor is 40%, the scale of them is smaller. The ore bodies are several metres to one hundred metres long. The longest one is 390 metres; the thickness in which them is 0.1——1 metre. The thickest one is 2.3 metres. Hence, its industrial value is not high.

(2) phosphorous ore: phosphorous ore is mostly distributed in the upper member of Luoquan Formation. Its occurrence is in two varieties: One type is lenticular and bedded phosphorous-bearing sandstone, the other one is brecciated phosphatic rocks. Of the two types, the latter is the more common. Their tenor of P_2O_5 is 7——10%, and the mineralization of phosphorite is dispersively. The scale of them is small and there is no industrial velue.

(3) potash: potash is mainly found in the lower subformation of Gaoshanhe Formation. The potash-bearing rocks are green, gray green clay rocks and silt clay rock. The potash-bearing rock formation reached more than 10 layers. The thickness of a single layer in general is 1 to 2 metres, and the thickest one in which is 5 to 6 metres. The tenor of K_2O content in general is 7 to 8%, the highest in which is 9.24%. Its position is steady, but the natural existing state of potash has not been studied clearly yet.

(4) Dolomite: Dolomite is widely distributed. It is mainly distributed in the middle——upper parts of the Luoquan Formation and in partial members of the Xunjiansi Formation. Through analysis, some of the dolomite samples in Xunjiansi -Heiyu areas may reach the requirements of sovent, refractories and the second grade tenor for glass materials, but the scale of which is not quite clear. At present, only the work of prospecting and searching for the Luodian dolomite ore deposit was made. Its ore body was found in the middle-upper parts of Longjiayuan Formation. There are two bodies within them, one body is 450 metres in length and 65——95 metres in thickness, the other one is 250 metres in length and 19 metres in thickness. The chemical components of them are: MgO (21.20%), Sio_2 (1.61%), Fe_2O_3 (0.53%). In Longjiayuan Formation--Fengjiawan Formation of Upper precambrian in this region, dolomite is quite development. The business of searching for the dolomite ore deposits which coincided with the industrial requirements continously has still very wide prospects.

Besides the text of the scientific research results in this item, there are three appendixes in follows:

The appendix 1 is: "The stromatolite of upper precambrian in southern margin of the North China Platform (Part of Shaanxi Province)". It mainly describes the occurrence position, morphological features, microstructure and assemblages partition of the stromatolite in this region. The polished surface and the slices of a large number of specimens have been detailed. At the same time, the ecological characteristics of stromatolite and its significance on the stratigrapy have been