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内蒙古大青山侏罗纪生长地层对燕山运动“绪动”的制约

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摘要 在大青山石拐盆地南部中下侏罗统煤系地层变形前锋, 可见中侏罗统长汉沟组与倒转褶皱相伴生, 并呈现出生长地层特有的同构造沉积地层楔. 该特征暗示了煤系地层褶皱变形与其底部近水平拆离断层的发育密切相关. 生长几何形态由下部的上超和超覆过渡为上部的退覆, 刻画了变形初期构造抬升速率逐渐加快的过程. 长汉沟组上部火山灰夹层的锆石 U-Pb 定年(163.7±1.0 Ma)和区域地层对比限定了大青山陆内挤压变形起始于中侏罗世(~170 Ma). 因此, 这应该是制约燕山运动“绪动”最有力的证据.

关键词 侏罗纪, 燕山运动, 生长地层, 大青山, 石拐盆地

近年来, 随着大量板块构造研究成果与同位素测年数据的积累, 燕山运动被重新诠释为东亚多向汇聚体系下发生的区域性陆内造山事件, 其影响范围亦从中国东部扩展至整个东亚大陆[1~3]. 然而, 关于燕山运动启动时间的讨论仍在继续, 主要有中侏罗世和晚侏罗世-早白垩世之争[4~6]. 该问题的正确解答有助于深入理解东亚大陆侏罗纪板块构造与陆内变形之间密切的耦合关系.

大青山位于阴山山脉东段, 主要由南部的大青山褶皱-逆冲系统和北部的石拐盆地组成(图1). 研究区属于大青山褶皱-逆冲系统西段, 主要由一系列东西向展布、由南向北逆冲的构造岩片相互叠置而成, 推覆距离约10 km[7]. 石拐盆地保存了完整的侏罗纪沉积序列, 由老至新依次包括下侏罗统五当沟组、中侏罗统召沟组和长汉沟组以及上侏罗统大青山组. 其中五当沟组和召沟组均为煤系地层, 两者之间为整合接触. 断层带内同构造变形矿物的^{40}Ar-^{39}Ar测年结果指示大青山地区可能经历了两期构造挤压事件, 分别对应于印支期(193.7±3.9 Ma)和燕山期(121.6±1.6 Ma)[7]. 然而, 下侏罗统五当沟组底部同沉积正断层的发现[4,8]和呼和浩特变质核杂岩的厘定[9]证实了大青山地区在上述时期均受控于伸展构造体制. 基于地层切割关系, 多数学者认为推覆事件发生的时代应介于晚侏罗世至早白垩世之间[6,9]. 然而, 逆冲带前缘同构造生长地层的识别改变了这一论断.

生长地层记录了同沉积期构造变形的大量信息, 尤其在造山带领域的研究中取得了重大成功[10~14]. 研究区内, 石拐盆地南部裂陷期沉积的中下侏罗统煤系地层普遍卷入挤压缩短变形, 导致中侏罗统长汉沟组沉积中心显著向北迁移(图1). 在煤系地层变形前锋, 通常可见长汉沟组与倒转背斜相伴生, 并呈现出特征的同构造沉积地层楔, 即地层倾角向上趋于变缓、单层厚度向褶皱脊部逐渐减薄或尖灭(图2). 这些特征定义了长汉沟组为典型的生长地层, 而它与倒转背斜前翼煤系地层之间的接触关系称之为递进型角度不整合(图2(a)和(b)), 代表了构造运动与沉积作用同时进行的产物[10].

呈扇状展布的生长几何形态暗示了褶皱变形的主要机制为翼部旋转[10~12]. 由于当前涉及翼部旋转的断层相关褶皱模型中仅有滑脱褶皱, 又因主盆地区下侏罗统五当沟组主要由煤层、炭质页岩、粉砂岩等软弱岩层组成, 所以本文推测中下侏罗统煤系地层褶皱变形与其底部近水平拆离断层的发育密切相关(图2(a)和(b)). 此外, 生

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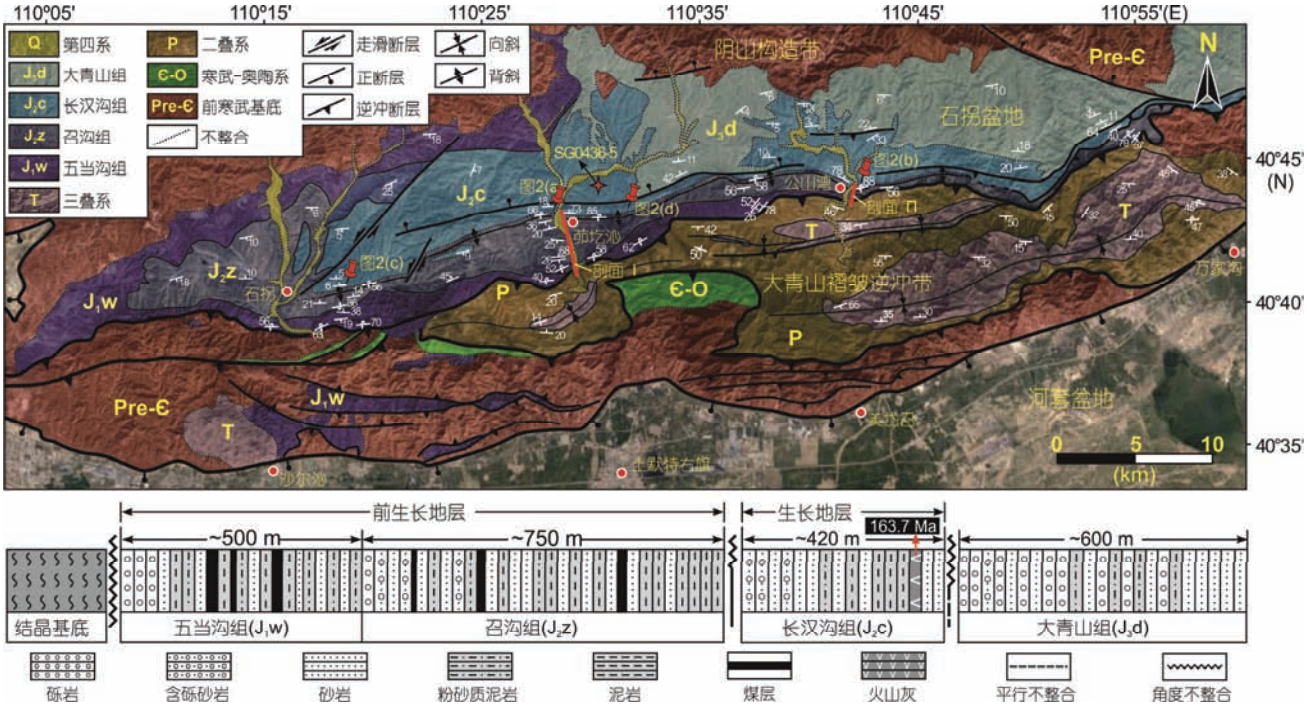


图 1 大青山西段地质构造简图与石拐盆地沉积充填序列

Figure 1 Geologic sketch map in the western part of Daqingshan range and sedimentary sequences of the Shiguai basin

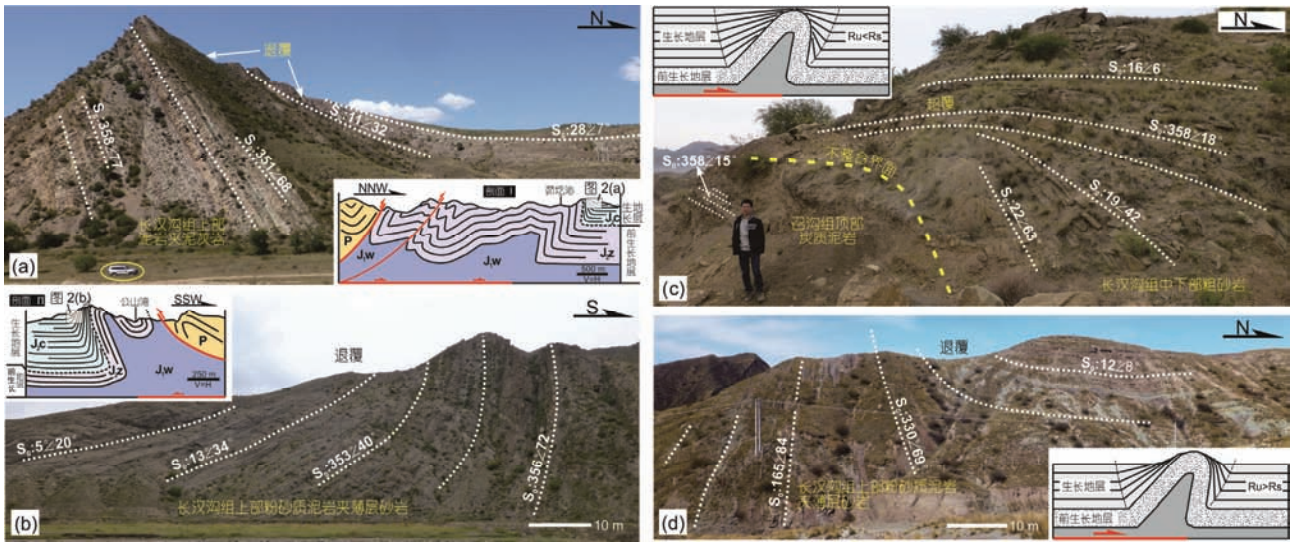


图 2 长汉沟组生长地层野外典型露头. (a) 茹圪沁一带构造剖面(剖面 I); (b) 公山湾一带构造剖面(剖面Ⅱ); 剖面位置如图 1 所示. (c), (d) 示意构造抬升速率(Ru)与沉积物堆积速率(Rs)对生长地层几何学形态的影响

Figure 2 Typical outcrops of the Changhangou growth strata. (a) Structural profiles across Maogeqin (profile I); (b) structural profiles across Gongshanwan (profile Ⅱ). See Figure 1 for locations of these two profiles. (c), (d) Influence of uplift rate (Ru) and sedimentary rate (Rs) on the growth geometries

长几何形态在长汉沟组中下部河流相砂岩中表现为上超和超覆(图2(c)), 而在上部湖相泥岩中过渡为退覆(图2(a), (b)和(d)), 刻画了变形初期构造抬升速率相对于沉积速率逐步加快的过程. 有幸的是, 本次野外工作首次在长汉沟组上部泥岩中发现了数套厚约10 cm的火山灰夹层. 测年样品(SG0436-5)采自最上部的火山灰夹层, 其中的锆石以长柱

状为主，振荡环带发育，长轴主要在50~100 μm之间. 在南京师范大学激光剥蚀等离子体质谱实验进行了LA-ICP-MS锆石U-Pb原位测年，获得了43个有效样品点，加权平均年龄为163.72±1.0 Ma(表S1). 结合最新报道的下花园组煤系地层(可与召沟组进行对比)顶部年龄为171±1.0 Ma[15]，推测大青山褶皱-逆冲系统初始启动时间约为170 Ma.

因此，长汉沟组生长地层的识别及其与挤压构造之间清楚的几何关系明确了大青山陆内挤压变形起始于中侏罗世，对于燕山运动“绪动”的制约及其与东亚大陆侏罗纪板块构造之间紧密耦合关系的理解具有重大意义.

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补充材料

表 S1 长汉沟组生长地层上部火山灰夹层(样品号: SG0436-5)锆石 U-Pb 年龄数据表

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Summary for “内蒙古大青山侏罗纪生长地层对燕山运动“绪动”的制约”

New time constraint on the initiation of Yanshan movement from Jurassic growth strata in the Daqingshan area, Inner Mongolia

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In recent years, based on the accumulation of new data of plate tectonics and isotopic ages, Yanshan movement has been reinterpreted as regional intraplate orogenesis responding to multi-directional convergent tectonic system that extended across the East Asia, which is a much larger region than originally thought. However, the timing of Yanshanian onset remains debated, mainly including the Middle Jurassic and Late Jurassic-Early Cretaceous. The correct answer to this key scientific problem will contribute to better understand the coupling relationship between Jurassic plate tectonics in East Asia and intraplate deformation.

The Daqingshan range is located in the eastern segment of the Yinshan belt, and mainly consists of the southern Daqingshan fold-and-thrust system (DFTS) and the northern Shiguai basin. In this article, the authors examined the western part of DFTS that is characterized by a series of E-trending, N-directed thrusts with a displacement no more than 10 km. The complete Jurassic sequences are well preserved in the Shiguai basin, including upwards the Lower Jurassic Wudanggou Formation, the Middle Jurassic Zhaogou and Changhangou formations, and the Upper Jurassic Daqingshan Formation. Note the contact between the Wudanggou and Zhaogou Formations is conformable and both of them are coal-bearing. ^{40}Ar-^{39}Ar dating of synkinematic minerals with two ages of 193.7±3.9 and 121.6±1.6 Ma indicate the Daqingshan range possibly underwent two phases of compressional events. Unfortunately, this conclusion is challenged by the discovery of syndepositional normal faults cutting the Early Jurassic-Archean unconformity and by the occurrence of Hohhot metamorphic core complex. Based on cross-cutting relationship, a Late Jurassic-Early Cretaceous age has been assigned to the thrust belt. However, growth strata preserved in the deformation front drew a very different conclusion.

Growth strata record much syndepositional tectonic information and have been widely used in the study of orogenic belt. In the study area, the Early-Middle Jurassic synrift coal-bearing sequences are generally involved into shortening deformation in the southern Shiguai basin, resulting in the depocenter of Middle Jurassic Changhangou Formation (J_2c) migrating markedly northwards. Along the deformation front, J_2c commonly crops out ahead of overturned anticlines and exhibits typical syntectonic depositional wedge with bedding dips gradually shallowing upwards and each single horizon thinning or tapering towards fold crest. These features indicate J_2c is typical growth strata, and the contact between it and synrift sediments preserved in the overturned forelimbs is called progressive unconformity, demonstrating the synchronicity of folding and sedimentation.

This kind of growth geometry implies limb rotation is the main folding mechanism. Because contractional fault-related folding theories invoking limb rotation only include certain classes of detachment folds and the Lower Jurassic Wudanggou Formation mainly consist of incompetent materials, folding deformation is considered to be controlled by the movement of basal bedding-parallel detachment fault. Moreover, an increasing uplift rate can be delineated by the transition of growth geometries from onlap and overlap to offlap upsections.

Fortunately, several 10-cm-thick volcanic ash layers have been found in the upper J_2c, and the uppermost one has been sampled (SG0436-5) for LA-ICP-MS zircon U-Pb dating. The dating experiment that was conducted in the LA-ICPMS Laboratory of Nanjing Normal University, obtained 43 concordia ages with a weighted average age of 163.72±1.0 Ma. Given that the latest reported zircon U-Pb age of the upper Xiahuayuan coal-bearing sediments (be well correlated with the Zhaogou Formation) is 171±1.0 Ma, the initial activity of DFTS should occur in the Middle Jurassic (~170 Ma). Therefore, these discoveries provide convincing constraint on the initiation of Yanshanian deformation and have significant implications for understanding its coupling relationship with the Jurassic plate tectonics in East Asia.

Jurassic, Yanshan movement, growth strata, Daqingshan, Shiguai basin

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