西宁盆地新生代磁性地层研究新进展

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Advances of Cenozoic magnetostratigraphy of the Xining Basin

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西宁盆地是青藏高原向东北扩展生长的“前哨”,也是东亚季风湿润气候向中亚内陆干旱气候过渡的核心地带.盆地内堆积了厚层、几乎连续的以细粒河湖相为主的新生代沉积物,含有丰富的哺乳动物化石,尤以中国早中新世标准动物群——谢家动物群而著名.顶部河流阶地上覆盖了厚层风成粉尘堆积,它们详细记录了亚洲内陆干旱和东亚季风演化、动植物演替以及黄河形成与高原隆升过程等重要信息.因此,西宁盆地的古生物气候地层学自20世纪70年代发现谢家动物群以来,一直备受关注.然而,西宁盆地新生界年代学、特别是含谢家动物群化石地层的准确时间标尺至今并未能达成共识且争议颇大,严重阻碍了对上述热点科学问题的深入探讨.

为此,我们对不同研究组所开展的剖面地层序列、岩相特征和古地磁测年进行了详细的野外核查和分析,并在盆地中央选择了地层出露较为完整、连续的剖面开展新的高分辨率古地磁年代学研究,结合盆地古生物、地层序列、岩相和磁性地层的综合集成分析,以及含谢家动物群剖面底部最新发现的火山灰绝对测年结果^[1],获得了以下重要认识(图1): (1) 不同研究小组在盆地不同地点/剖面所获得的古地磁极性事件以及地层岩相序列都具有很高的相似性和可对比性,重新厘定和确定盆地新生代大约从54 Ma开始河湖相沉积并连续堆积至

4.8 Ma,从而建立了青藏高原东北部最完整、连续的新生代地层高精度年代序列; (2) 确证谢家动物群的年代为晚渐新世约25 Ma,为修订中国陆相“谢家阶”和相应的陆生哺乳动物分期“谢家期”提供了年代学依据; (3) 限定盆地纯风成粉尘红黏土的堆积时间以及最高阶地的形成时间均在约4.8~3.6 Ma以来,揭示黄河上游最大支流(湟水流域)自此开始形成; (4) 发现盆地新生代多种气候代用指标记录与全球温度变化趋势和事件基本吻合,暗示全球变冷可能是亚洲内陆干旱化的主控因子,高原隆升和副特提斯海退却的影响叠加其上; (5) 发现西宁盆地经历了盆地形成到消亡的完整沉积环境演化过程,记录了祁连山东段新生代经历的三大构造隆升阶段:早期开始于约54 Ma和中期22.5 Ma的缓慢隆升,晚期17 Ma、8~7 Ma以及4.8~3.6 Ma以来开始明显加速的幕式强烈隆升,它们是对印度板块与欧亚板块自约55 Ma开始碰撞以来持续推挤变形的远程同步响应,暗示需要新的青藏高原的变形隆升机制才能解释.这是高原东北部系统建立的新生代最完整、连续的高精度年代序列,为生物地层学、古气候学、地貌学及构造地质学等相关研究奠定了准确的年代学基础,对深入理解青藏高原隆升、干旱-季风系统和生物多样性演化与未来气候变化具有重要的促进作用.更多内容可参见Fang等人^[10]在*Earth Science Reviews*上最新发表的论文.

图 1 西宁盆地新生代磁性地层综合对比。(a)~(c) 塔山剖面岩性、磁性方向及极性柱^[2]；(d)~(f) 谢家山剖面岩性、磁性方向及极性柱^[5]；(g) 标准磁性柱^[1]；(h)~(i)和(k)~(n) 分别为后湾剖面和水湾-关家山-西宁东剖面岩性、磁性方向及极性柱^[6]；(j) 谢家山剖面中部含谢家动物群层段岩性、磁性方向、极性柱及其解释^[1]，最左侧为本文对其磁性柱的重新解释方案；(q)~(r) 水湾-铁佛-西宁东剖面岩性、磁性方向及极性柱^[3,8,9]；(s)~(u) 炳灵山剖面岩性、磁性方向及极性柱^[3] **Figure 1** Correlation of Cenozoic magnetostratigraphic sections in the Xining Basin. (a)~(c) Lithology, magnetic polarity directions and zones of the Tashan section^[2]; (d)~(f) Lithology, magnetic polarity directions and zones of the Xiejia-Tashan drilling sections^[3,4]; (g) Geomagnetic polarity time scale^[5]; (h)~(i) and (k)~(n) are the zones and directions of magnetic polarities and the lithology of the Houwan section and the Shuiwan-Guanjiaoshan-East Xining section, respectively; (o) Lithology, magnetic polarity directions and zones of the Mojiashan section^[6]; (p) Lithology, magnetic polarity directions and zones of the middle Xiejia section bearing the Xiejia fauna^[7], with the far left for the reinterpretation of the observed magnetic polarity zones in this study; (q)~(r) Magnetic polarity zones and directions of magnetic polarities and the lithology of the Shuiwan-Tiefo-East Xining section^[3,8,9]; (s)~(u) Lithology, magnetic polarity directions and zones of the Bingling shan section

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