

中国北方新石器时代农业强化及对环境的影响

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摘要 人类世是当前备受关注的热点科学问题, 尚存在较多争议. 研究不同时空尺度人类活动对环境的影响, 对探讨该问题具有重要意义. 本研究系统总结了我国北方新石器时代植物考古、骨骼碳同位素和碳十四测年的研究进展, 并与古环境记录中黑炭研究进行对比, 梳理了中国北方新石器时代粟黍农业强化和扩张的时空过程, 及其对环境的可能影响. 结果显示, 距今10000~7000年前, 中国北方整体处于原始粟黍农业阶段, 距今7700年之后在内蒙古东部出现最早粟黍农业经济的迹象; 距今7000~6000年前, 粟黍生产中心转移至关中地区, 是粟黍农业建立的过渡时期; 距今6000~4000年前, 粟黍农业在中国北方广泛扩张, 推动了新石器晚期文化的繁盛和人口的显著增长. 中国北方新石器时代黑炭指标(EC-soot)的时空变化过程与粟黍农业强化和扩张过程有很好的对应, 显示粟黍农业生产活动对火灾频率产生了重要的影响. 本研究为理解新石器时代粟黍农业发展历程和人与环境的相互作用, 深入探讨人类世问题提供了重要的研究案例.

关键词 粟黍农业, 新石器时代, 人类活动, 环境变化, 人类世

人类活动正在对地球环境产生前所未有的影响. 工业化革命以来, 地球大气CO₂浓度持续快速增加^[1], 达到65万年以来的最高值^[2]. 全球人口在此期间从15亿增长到73亿, 伴随对地表的强烈改造和侵蚀速率的快速提升^[3~5], 人类活动已经在全球尺度改变了大气环境、生物多样性、海洋沉积中的化学性质^[6,7], 成为影响地球表面系统的重要营力^[8]. 人类活动对地球系统的影响引起了学术界的高度关注. 2000年, Crutzen^[9]首次提出人类世的概念, 随后在科学界引发了广泛的讨论, 成为国际学术界的前沿和热点科学问题^[9~11]. 目前人类世研究的主要焦点在于将其作为一个正式的地质纪元是否合适^[12,13]? 以及如何界定人类世起始的时间, 其在地层中的标志(“金钉子”标记物)是什么^[14]? Lewis和Maslin^[12]根据由欧洲人殖

民美洲导致土著农业人群大量死亡引发的冰芯记录中1610 AD前后CO₂浓度的显著下降, 以及1945~1964 AD密集核试验导致树轮记录中出现放射性碳峰值, 提出将这两个时段作为人类世的下限. Zalasiewicz等人^[15]进一步论证应将20世纪中叶的核试验导致的放射性核素在全球范围的峰值作为人类世开端的标志. 然而, 另一些科学家则提出不同意见^[11,16], 指出人类活动对环境的影响可追溯至史前时代, 在旧石器晚期可能导致了猛犸象等生物的灭绝, 新石器时代人类的农业生产活动对植被和土壤侵蚀速率都产生了重要影响^[5,17]. Foley等人^[18]为阐述人类活动在不同时空尺度对地球环境产生的影响, 提出了“古人类世(Palaeoanthropocene)”的概念. 理解史前人类活动何时、在多大空间尺度上对自然环境产

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生影响,对人类世问题的探讨具有重要价值^[19].

一些学者提议将人类世的起始时间设在距今10000年前,该时期是世界农业起源的关键时期,在西亚的肥沃新月形地带、中国的长江和黄河流域分别出现了小麦和大麦、水稻和粟黍的驯化^[20~24].人类与自然环境的关系随之发生了重大的改变,从依赖自然界获取食物,转为主动生产以获取充足的食物来源.农业起源促使欧亚大陆人口快速增长^[25],驯化的动物和植物从其起源中心随人群向外扩张,人类生存空间和活动强度显著增加^[26,27].距今8000年前,小麦、大麦种植已成为西亚的两河流域、尼罗河谷、欧洲和印度河谷先民的主要生计方式^[28].欧亚大陆史前农业的强化与扩张,极大促进了新石器和青铜文化的发展^[29],为文明起源奠定了基础^[30,31].同时,逐渐增强的人类农业活动还对自然环境产生了重要的影响.如:新石器时期人类的农业生产导致火灾频率的快速增加和森林的破坏^[32,33],土地利用的强化引起土壤侵蚀速率的增加^[17],人类对陶器和金属器的利用可能导致沉积物化学性质的改变^[34~36],距今5000年前开始的大气甲烷浓度的上升被认为是由水稻种植导致的^[37,38].以上研究对认识早期农业活动对环境的影响具有重要价值.然而,史前时代不同阶段农业的扩张和强化过程,与其相应的人类活动对环境影响强度的变化,已开展的研究工作较为有限,尤其是在东亚地区.

中国北方黄河流域是粟黍农业起源中心,植物考古研究为理解粟黍农业的起源和发展历史奠定了基础.在华北地区,旧石器晚期人类已经开始采集并利用禾草类植物^[24,39~42].最早的驯化粟黍证据出现在距今1万年左右^[22,23],到前仰韶时期(距今8500~7000年前),粟黍已成为黄河流域普遍利用的植物资源^[42~47],但粟黍种植可能仍是辅助的生计方式^[48~50].距今7000~6000年前可能是粟黍农业在黄土高原建立的关键阶段^[48,49,51],随后成熟的粟黍农业的快速发展,推动了黄河流域新石器文化的扩张和人群的扩散^[52].尽管粟黍农业起源与发展的时间过程已逐步清晰,但其在史前时代不同发展阶段空间扩张和强化的过程,及其对环境的可能影响,仍未得到清晰的阐述.本文通过系统总结中国北方新石器时代植物考古、骨骼碳同位素和测年研究进展,并将其与沉积物中黑炭含量变化进行对比,分析新石器时代中国北方人群粟黍种植范围和强度的时空变化,并试

图分辨其在古环境记录中留下的印迹.上述研究对理解史前时代人类农业生产活动对环境影响的时空变化,推进人类世问题的探讨具有重要的学术价值.

1 中国北方新石器时代粟黍农业的强化与扩张

根据中国北方出土粟黍作物遗存的新石器遗址的年代和分布,可以梳理新石器时代粟黍农业发展的过程,如图1所示.距今10000~7000年前,发现粟黍遗存的新石器遗址共有20个,其中仅有10个遗址出土炭化粟黍种子,这些遗址位置分散,多分布于35°~44°N的地区,其中燕辽地区遗址比例达40%(图1(a));距今7000~6000年前,出土粟黍大植物遗存的遗址数量较前一阶段明显增加,达到19个,遗址分布重心南移至34°~36°N的黄河中游地区,尤其是关中盆地(图1(b));距今6000~5000年前,出土炭化粟黍种子的遗址数量显著上升,分布空间广泛扩展,已遍及黄河流域全境,并向西扩散至河西走廊地区和青藏高原东部边缘地区,包括卡若遗址(图1(c)).由于开展植物大遗存鉴定和量化分析的遗址有限,不同遗迹单位(如灰坑、文化层、房址等)植物遗存比例的指示意义可能有差异^[53],很难进行有效对比.因此,仅根据植物考古研究无法准确认识粟黍农业强化的过程.

骨骼碳同位素分析为探讨粟黍农业强化问题提供了有效途径.中国北方新石器时代遗址出土的野生动物骨骼碳同位素值集中分布于-25‰~-20‰,说明自然植被主要以C₃植被为主,而粟黍是C₄作物.通过分析人骨碳同位素值,可判断粟黍在古人类摄食结构中的比例,进而推测粟黍种植在人类生计模式中的地位^[54,55].黄土高原已开展的骨骼碳同位素分析工作显示,家畜猪和狗骨骼的碳同位素值与人骨碳同位素值非常接近^[56~58],可能主要为人工饲养所致.因此,通过对中国北方新石器遗址出土的人骨和猪、狗骨骼碳同位素值的分析,可以定量评估粟黍农业强化的过程,如图2所示.距今10000~7000年前,大地湾遗址与月庄遗址猪和狗的骨骼与小荆山遗址人骨碳同位素值呈现C₃信号(<-17‰),白家遗址人骨碳同位素值呈现C₃和C₄混合信号(-17‰~-11‰),而兴隆洼和兴隆沟遗址人骨碳同位素值呈现C₄信号(>-11‰)(图2(a));距今7000~6000年前,关中地区姜寨、史家、鱼化寨和瓦窑沟遗址与内蒙古白音长汗遗址人骨碳同位素值呈现C₄信号,关中地区和沟湾、半

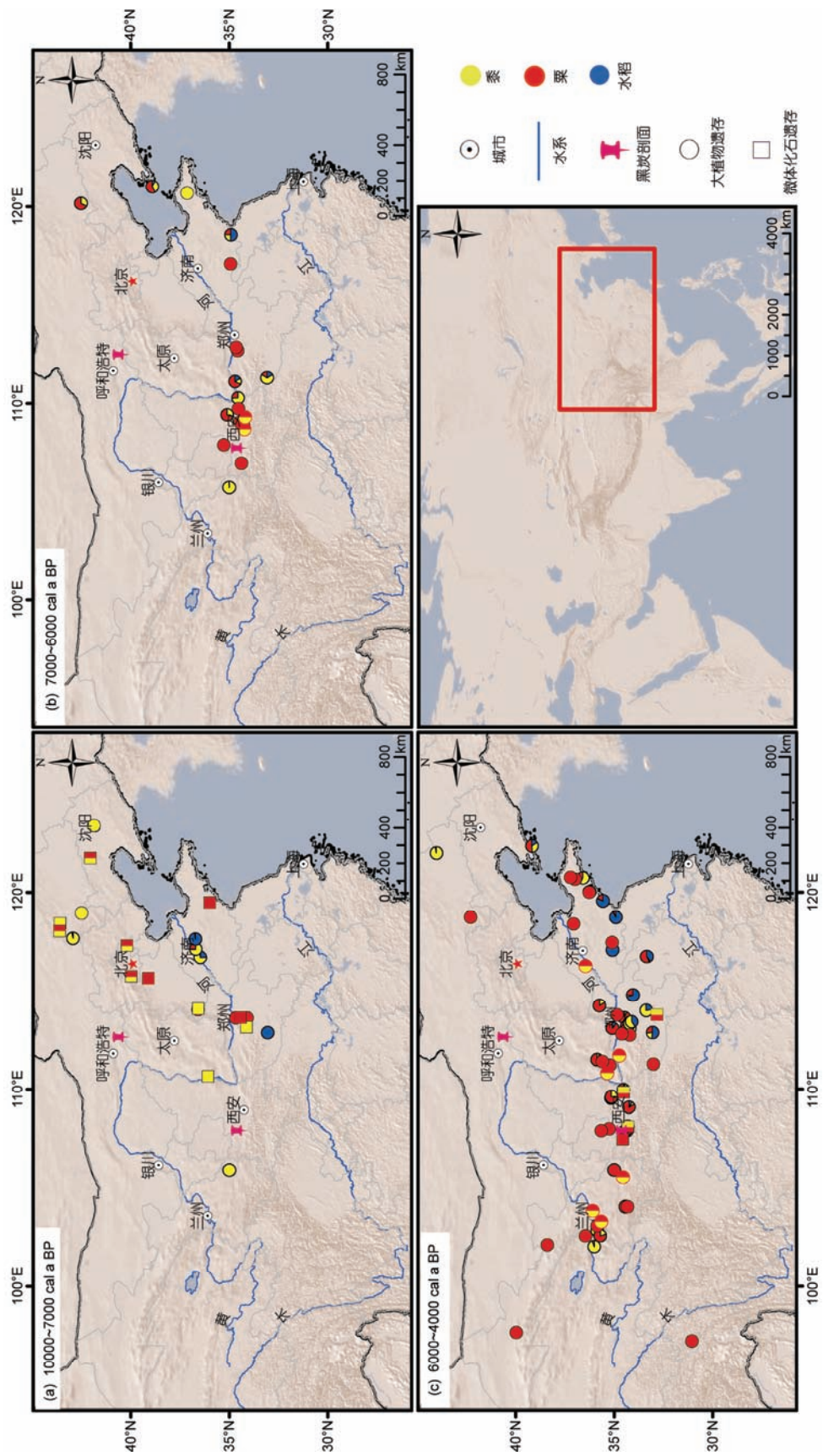


图 1 中国北方新石器遗址出土主要农作物遗存的时空分布
Figure 1 Temporal and spatial distribution of Neolithic sites unearthed crops remains in the northern China

坡和北首岭遗址人骨碳同位素值呈现 C_3 和 C_4 混合信号(图2(b));距今6000~4000年前,中国北方绝大多数遗址出土的人骨和猪、狗骨骼碳同位素值呈现 C_4 信号,仅沟湾和西公桥遗址人骨碳同位素值呈现 C_3 和 C_4 混合信号(图2(c)).

根据植物考古和骨骼碳同位素研究的进展,中国北方新石器时代粟黍农业的扩张与强化主要经历了3个阶段:原始粟黍农业阶段(距今10000~7000年前)、粟黍农业建立阶段(距今7000~6000年前)和成熟粟黍农业扩张阶段(距今6000~4000年前).

目前在4处距今10000~8500年前的遗址中发现了粟黍的遗存(图1).南庄头、东胡林等遗址出土的磨制石器淀粉分析显示,人类距今10000年前就已经加工粟黍植物^[24].在东胡林遗址出土了14粒炭化粟^[48],磁山遗址的植硅石分析和测年工作同样显示人类在距今10000年前开始利用驯化黍^[22].上述研究为认识粟黍最早驯化时间提供了关键证据,但由于缺乏驯化粟黍遗存的直接测年数据,尚需进一步的研究进行检验.

在兴隆洼、裴李岗、大地湾、磁山、后李文化等距今8500~7000年前的遗址中,都出土了炭化粟黍种子,说明该时期粟黍已经在中国北方前仰韶文化系统中得到了较普遍的利用^[48].在燕辽地区兴隆洼和兴隆沟遗址,粟黍已成为人类的主要食物来源^[59].在这两个遗址中浮选出了大量的粟黍遗存,其中兴隆沟遗址粟黍比例达42.15%^[60,61].兴隆沟遗址炭化粟黍直接测年结果为距今7700~7500年^[61],是目前最早的粟黍遗存可靠年代,显示从距今7700年前开始,粟黍种植已成为该地区人类重要的生计方式.相对而言,位于黄土高原的大地湾遗址、小荆山遗址和月庄遗址出土的人骨和猪、狗骨骼碳同位素显示其先民主要摄食 C_3 类食物(图2(a)),粟黍利用仅为其辅助生计方式^[49,61,62].关中盆地白家遗址骨骼碳同位素值呈现 C_3 和 C_4 的混合信号^[63],说明粟黍已成为该遗址先民的重要食物来源,但仍无法判断粟黍种植已成为最重要的生计方式.

上述结果显示,距今10000~7000年前,在黄土高原粟黍种植已经出现,但在生业模式中仍处于辅助地位,狩猎采集经济在该时期可能仍处于主导地位.大量发现粟黍遗存的该阶段遗址分布在燕辽地区(图1(a)),在兴隆洼和兴隆沟遗址,距今7700年之后粟黍种植可能成为最重要的经济方式.在前仰韶时代晚期,燕辽地区可能成为中国北方,乃至世界最

早的粟黍农业种植中心.

距今7000~6000年前,仰韶早期文化在关中、豫西和晋南地区兴盛起来^[64,65],中国黄河流域该时期的遗址分布较广,燕辽文化区的遗址分布密度和广度明显低于中原为代表的黄河流域^[66,67].在仰韶时代早期遗址中普遍发现了粟黍遗存^[49,65,67,68],同阶段在山东北辛文化和燕辽地区赵宝沟文化和新乐下层文化中的一些遗址中也发现了粟黍遗存^[60,69](图1).骨骼碳同位素分析结果显示,关中盆地不同遗址粟黍在人类摄食结构中的权重并不一致.在半坡和北首岭遗址中,人骨碳同位素值呈现 C_3 和 C_4 混合信号^[54,70],而在史家、鱼化寨、姜寨和瓦窑沟遗址中,人骨和猪、狗骨骼碳同位素值则呈现 C_4 的信号^[57,58,70].这很可能说明仰韶早期是关中地区粟黍农业为主的经济方式建立的关键阶段,粟黍种植在生计方式中的地位经历了从上升到主导的过程,植物考古研究进一步支持这个判断^[48].距今7000~6000年前粟黍农业中心从燕辽地区向关中地区的转移,很可能与黄土高原中部的平地资源丰富,水热条件更适宜粟黍农业的发展有关.该时期是黄土高原中部降水最为丰富的时期^[71],可能为仰韶早期文化的兴起和粟黍农业的发展提供了便利.

距今6000~4000年前,是中国北方新石器文化快速发展和繁盛的时期,文化空间显著扩张,每百年遗址数量达仰韶早期的3倍左右^[72].该阶段在黄土高原中部,仰韶文化中晚期(距今6000~5000年前)和龙山文化(距今4600~4000年前)先后发展兴盛,并对周边地区的新石器文化演化产生了重要影响^[52,73].在黄土高原西部,马家窑文化(距今5300~4000年前)和齐家文化(距今4200~3600年前)快速发展,向西扩散至青藏高原东北部^[74~76].在山东地区,大汶口文化和山东龙山文化先后发展兴盛.在燕辽地区,红山文化在距今6000~5000年前成为主流文化,出土大量的玉器和祭祀遗迹,呈现了高度发达的文化面貌,随后可能因浑善达克沙地环境的变化(沙漠化)而衰亡^[77].

距今6000~4000年前是黄河流域农业强化和快速扩张时期,仰韶文化中晚期和龙山文化遗址大量出土粟黍遗存,出土粟黍遗存的遗址数量和粟黍遗存的绝对出土量都显著高于前两个阶段(图1(c)).燕辽地区出土粟黍遗存的遗址较少,可能与气候变化和粟黍的生长习性有关.粟黍是耐旱农作物,但对温度变化响应敏感,其生长受积温限制.北半球中高纬

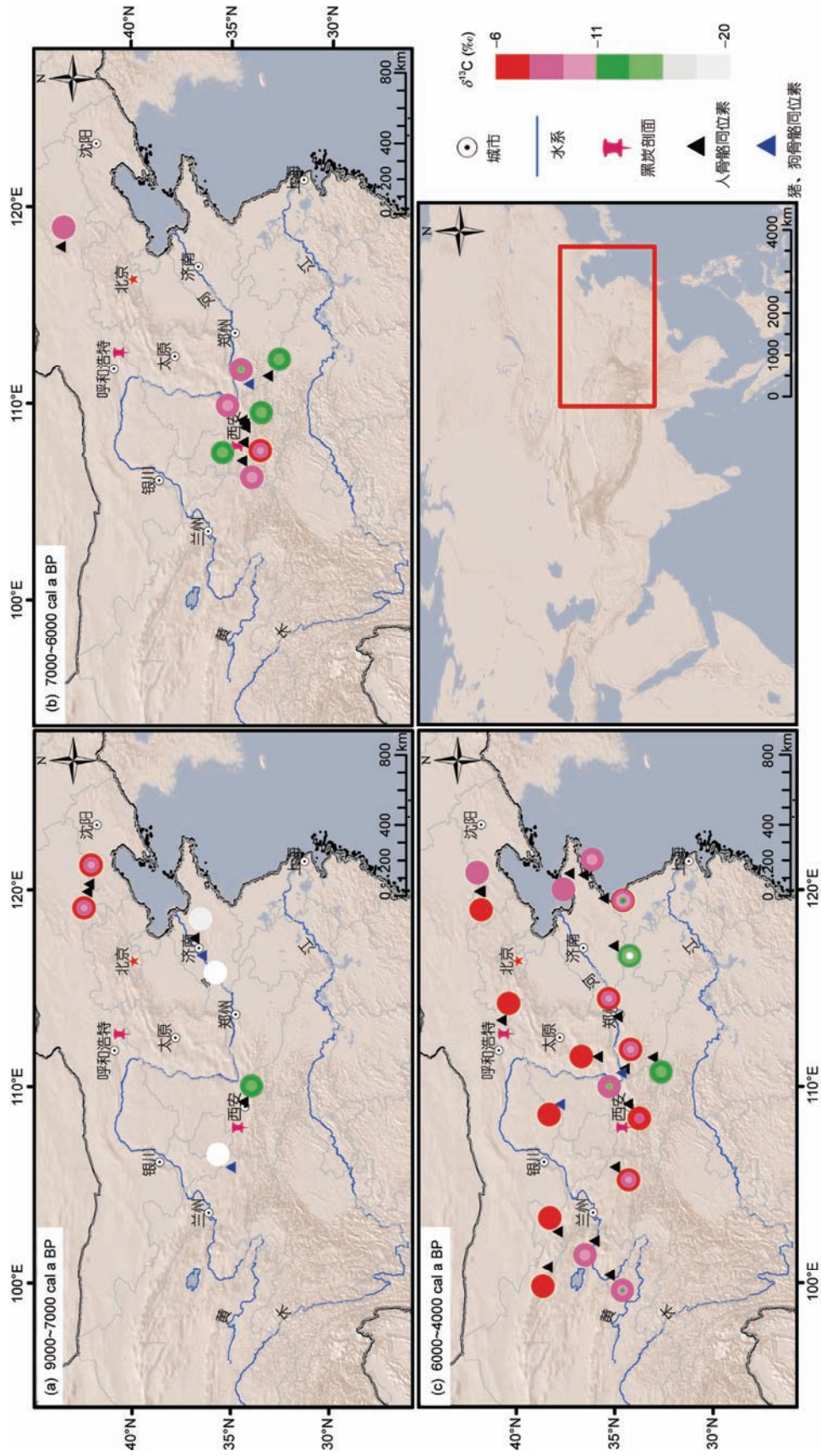


图2 中国北方新石器遗址人与猪、狗骨骼碳同位素值的时空分布
Figure 2 Temporal and spatial variation of carbon isotope value of human and pig/dog bones in Neolithic sites of northern China

地区的温度在早中全新世较高,在距今7000年之后总体呈下降趋势^[78]。燕辽地区纬度较高,温度较黄河中下游地区明显偏低,在北半球温度下降的背景下,很可能不利于从事粟黍种植。

中国北方新石器晚期遗址出土人骨的碳同位素值绝大多数呈现C₄信号,说明粟黍是该时段人类主要的食物来源^[79](图2(c))。仅在沟湾和西公桥遗址,人骨碳同位素值呈现C₃和C₄混合信号(图2(c)),可能与摄食C₃类食物有关^[80,81],这与植物遗存证据显示的沟湾遗址和邻近西公桥遗址的两城镇遗址出土水稻遗存是相符合的^[82,83]。距今6000~4000年前中国北方绝大多数遗址植物考古研究显示粟黍遗存是最主要的农作物遗存^[84],结合骨骼碳同位素值证据,说明该阶段粟黍农业生产是最主要的经济方式。新石器晚期成熟的粟黍农业生产为中国北方的先民提供了充足的食物来源,进而促使人口的快速增长和生存空间的显著扩张^[85],尤其在中原地区,为随后的中华文明起源奠定了重要基础。

2 中国北方新石器时代的农业扩张和强化对环境的可能影响

史前人类的刀耕火种农业活动对环境的影响主要体现在对植被的影响方面,如:导致火灾频率显著上升^[86,87],或是树本植被(或某些树种)的显著下降^[88]。古环境记录中的黑炭和孢粉分析可以有效反映火灾频率的变化和植被变化的历史^[89,90],可作为探讨史前人类活动对环境影响的重要指标^[91,92]。由于气候变化同样会影响到火灾频率变化和植被演替^[93,94],如何辨别人为和自然因素的影响是需要谨慎探讨的问题。将地质沉积载体的黑炭和树本孢粉指标的变化,与考古记录和温度、降水变化进行对比分析,是开展这一研究的有效途径^[95~97]。由于中国北方(尤其是中原地区)高分辨率古环境记录较少,且孢粉较多反映小区域的植被变化,因此本文着重讨论黑炭指标反映的史前人类农业活动对环境的可能影响。

黑炭(BC)也被称作元素碳(EC),包括EC-char和EC-soot两种主要的类别^[98]。两者都可用作反映化石燃料和植被火灾的不完全燃烧过程^[99],但物化性质有一定差别,指示的范围大小有所不同。EC-char是在低温条件下形成的可识别的植物固体残渣,尺寸在毫米到微米范围内,由于其粒径较大而不能被空气传播到很远的地区,因此通常指示数百米至数十

公里范围的火灾情况。而EC-soot是一种具有球状石墨环的亚微米级(<1 μm)气溶胶粒子,可以悬浮在空气中数月,随空气传播到很远的地方,可用于反映区域和全球尺度的火灾历史^[100]。在燕辽地区和关中盆地都曾开展了包括EC-char和EC-soot在内的黑炭指标分析工作^[86,87,91,97,101,102],为探讨新石器时期粟黍农业的扩张和强化与火灾频率的变化提供了基础。由于本文需讨论中国北方数百至数千公里的火灾频率变化,故选用EC-soot作为讨论对象。

燕辽地区科尔沁沙地和岱海沉积物中黑炭(EC-soot)含量从距今7500年前开始上升(图3(c)),在距今6200~4800年前达到高峰^[99,104],与该地区的考古记录有很好的对应。燕辽地区是最早的粟黍种植中心,在兴隆洼时期粟黍农业已经较为发达,高强度的刀耕火种农业活动很可能导致黑炭含量的上升。在红山文化时期,燕辽地区的史前文化达到鼎盛^[105],黑炭含量也达到峰值。尽管有学者认为黑炭含量的上升主要是由冷干气候引起的^[96,106],但无论是近200年观测记录,还是过去21000年全球尺度的研究,都显示温度升高是导致火灾频率增加的主要因素^[94,107~109],而距今7000年以来北半球的温度整体呈现下降趋势^[78],暗示燕辽地区距今7500年后火灾频率的显著上升主要是受人类活动影响。

相对于燕辽地区,关中盆地黑炭(EC-soot)含量开始上升的时间则较晚,在距今6000年后增幅达50%^[97],而成熟的粟黍农业在该地区出现的时间也是距今6000年前左右。距今4300~3500年前EC-soot含量再次显著增加^[96](图3(d)),该时期对应中原地区龙山晚期和二里头文化时期,涌现了大量的古城和大型聚落遗址,遗址规模和数量都达到空前水平。距今8000~4000年前温度呈下降趋势,中原地区降水尽管出现波动,但其与黑炭变化趋势并不同步^[97,103],显示EC-soot指标反映的火灾频率的变化主要是受粟黍农业相关的活动(如刀耕火种,燃火取暖、烹煮等)的影响。粟黍农业中心在燕辽地区和中原地区出现的时间不同,致使沉积记录中EC-soot含量的变化并不同步(图3(c)和(d)),燕辽地区EC-soot浓度的上升比关中地区约早1500年,这与植物考古和骨骼碳同位素值记录(图1和2)是非常吻合的。

3 讨论与结论

近20年科技考古方法在中国考古学中的应用,

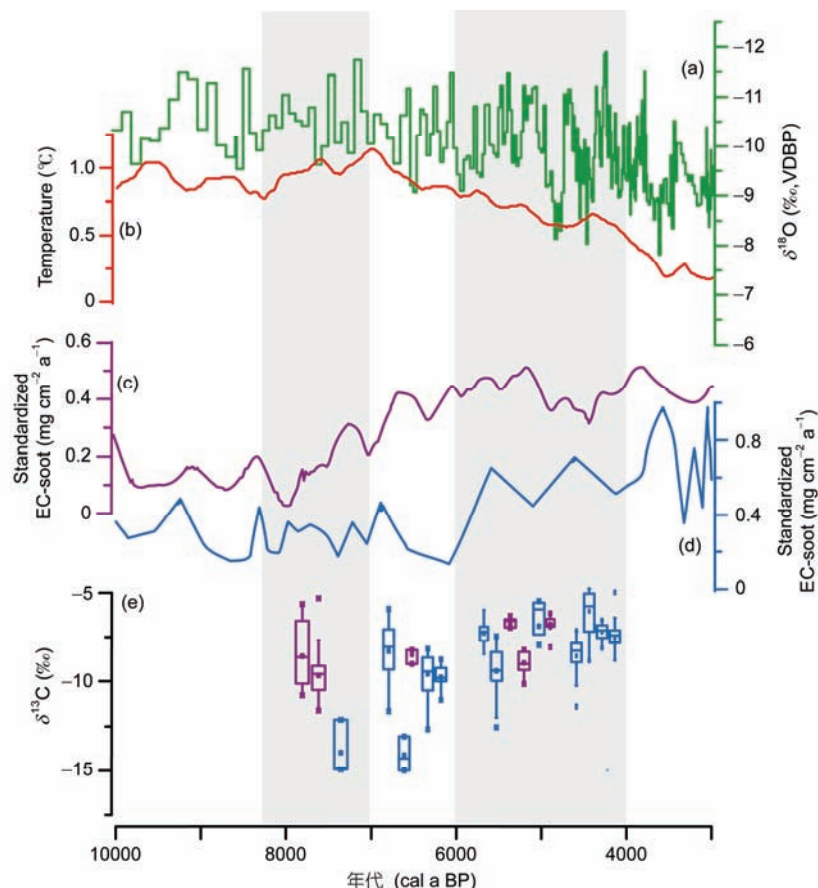


图 3 中国北方新石器时代遗址人骨碳同位素值与沉积物黑炭浓度和气候曲线对比。(a) 九仙洞石笋氧同位素记录^[103]; (b) 北半球(30°~90°N)温度重建记录^[78]; (c) 内蒙古岱海湖泊沉积物黑炭记录^[102]; (d) 关中盆地黄土剖面沉积物黑炭记录^[97]; (e) 骨骼碳同位素记录^[54-56,58,63,70,80](紫色代表燕辽地区, 蓝色代表关中地区)

Figure 3 Comparison of climate change, the variation of black carbon during early-mid Holocene, and carbon isotope of human bones in Neolithic sites in northern China. (a) The oxygen isotopes in stalagmite from Jiuxian Cave^[103]; (b) reconstructed temperature variation in Northern Hemisphere (30°-90°N)^[78]; (c) black carbon concentration of Daihai Lake^[102]; (d) black carbon concentration of Guanzhong Basin^[97]; (e) carbon isotope of human bones unearthed from Neolithic sites in northern China^[54-56,58,63,70,80] (purple and blue boxes represent Yanliao and Guanzhong region)

尤其是植物考古、动物考古和骨骼稳定同位素研究资料的积累,为探究中国新石器时代农业发展历程奠定了重要的基础。赵志军^[48]根据植物大遗存证据,将中国北方新石器时代农业分为3个阶段:距今10000年前出现耕作行为;距今8000年前出现最早的农业生产迹象,生产方式仍以狩猎采集为主;距今6500年前,粟黍农业经济建立。结合植物考古和骨骼碳同位素研究的最新进展,可以更清楚地反映中国北方新石器时代粟黍农业的时空发展过程。在前仰韶时期,中国北方大部分地区仍以狩猎采集经济为主,粟黍种植是辅助的经济方式。但前仰韶时代晚段,在内蒙古东部可能已出现以粟黍生产为主的农业部落,该地区前仰韶时代遗址的数量明显多于其他区域^[72]。距今7000年前,在黄土高原中部的关中

地区仰韶早期文化发展兴盛,粟黍农业为主的经济方式逐步确立,成为新的粟黍农业中心,该时期关中盆地也是中国北方遗址最为密集的地区^[72]。仰韶文化中晚期和龙山时代,粟黍农业快速发展和扩张,伴随着中国北方新石器文化遗址分布区域和数量的急剧扩张^[52,72],其影响已达南方的长江流域^[110,111]和中亚的哈萨克地区^[29,66]。

中国北方粟黍农业的扩张和强化,导致农业人群生存空间的拓展和人口数量的快速增长,进一步促使人类对环境影响的范围和强度逐步上升。尚无确切证据表明中国北方在最早的粟黍农业为主的经济方式出现之前,人类对自然环境产生了明显的影响。在内蒙古东部兴隆洼时期的农业强化,很可能导致该地区火灾频率的增加,是中国北方人类活动最

早在区域尺度上对环境产生影响的案例。随后的仰韶和龙山文化时代,更适宜粟黍农业生产和人类大规模定居的黄土高原成为粟黍农业建立和发展的中心,古人类生存的空间范围和活动强度较此前时期显著增强。该时期中国北方不同新石器遗址分布区域的湖泊沉积中都可以检测到人类对环境影响的信号,如:火灾频率的增加、木本孢粉的下降、侵蚀导致的沉积速率和化学性质的变化^[112,113]等。如何更有效地从古环境记录中识别人类活动影响的信息,对深入理解该问题是非常关键的。多学科方法的综合运用,会对推进该领域的研究起到促进作用。比如,通过在高分辨率古环境记录周边新石器遗址中开展炭屑鉴定,可以研究不同时期人类倾向砍伐的树木种类,与古环境记录的孢粉分析结果对比,很可能对认识古人类活动对植被的影响提供帮助。

一些学者分析了新石器时期以来中国黄河流域和长江流域的农业发展和人类活动对环境的影响,并尝试从人类世的角度探讨这一问题^[5,114,115]。这些工作为推进人类世的研究提供了思路。但认识人类在不同发展阶段,在多大空间尺度上对环境产生了多大程度的影响,并未得到充分的讨论。本文依据中国北方不同地区新石器遗址植物考古和骨骼碳同位素分析结果与古环境记录中黑炭(EC-soot)含量变化的对比,显示新石器时代粟黍农业的强化很可能对

区域尺度上的火灾频率变化产生了重要影响。在前仰韶时代和仰韶文化早期(距今10000~6000年前),中国北方不同区域粟黍农业强化的时间并不同步,导致人类对环境作用的强度也存在时空差异。在仰韶中晚期和龙山时代(距今6000~4000年前),随着粟黍农业在中国北方的快速发展和广泛扩张,人类活动对环境的影响已扩展至中国北方的大部分地区,其强度也呈现显著增加的趋势。

为理解人类活动对环境影响的尺度,Foley等人^[18]提出“古人类世”的概念,认为古人类世阶段人类对环境的影响是缓慢的和区域性的,而人类世阶段人类对环境的影响则是快速的和全球性的。从这个角度分析,新石器时代人类对环境的影响处于古人类世阶段,尽管影响的强度和范围在逐步增强。有学者指出,距今5000年前大气甲烷含量呈上升趋势,而温度呈下降趋势,很可能与新石器晚期水稻农业的快速发展有关^[37,38]。能否在全球范围的沉积记录中发现某种指示意义明确的、与人类活动直接相关的指标,尤其是可随空气扩散的生物化学标记物,对推进人类世的研究是很有意义的。我国已有学者关注人类世的研究^[116,117],但目前已开展的工作仍不充分,需要更多自然科学和社会科学不同学科领域学者合作探讨这一问题。本研究为通过多学科研究的分析和对比,推进人类世问题的深入探讨,提供了可参考的研究思路和案例。

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Agricultural intensification and its impact on environment during Neolithic Age in northern China

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The nature of an Anthropocene has been increasingly discussed and debated in the last two decades, with a focus on the arguments for or against the “Anthropocene” as a geological epoch. Some argue for an onset of Anthropocene between 1945–1964 AD, when intensive atmospheric nuclear testing resulted in peak values of ^{14}C that is widely recorded in tree rings and sediments, while other scholars argued its beginning may be traced back to the early Holocene. This latter argument is related to the beginnings of significant landscape modification through the development and spread of agricultural practices in old world since 10000 a BP. The Yellow River valley of northern China is the center for the domestication of millet crops (broomcorn millet and foxtail millet), however, the intensification and expansion of millet-based agriculture during the Neolithic period and its impact on the environment has not been well understood. Recent development of archaeometry methods and their application to archaeological research, such as archaeobotanical studies, and carbon and nitrogen isotope analysis of human and animal bones unearthed from Neolithic and Bronze sites in north China, has greatly deepened our understanding of the timing of millet-based agriculture and its development. In parallel, the analysis of paleoenvironment proxies including black carbon and pollen assemblages from natural sediments, has shed light on the impact of human slash-and-burn cultivation on their surrounding environments during both prehistoric and historical times. This paper reviews carbon isotope analysis of human, pig and dog bones, and radiocarbon dates from Neolithic sites, and compares them with black carbon content from palaeoenvironment records in northern China, in order to explore the temporal-spatial intensification and expansion of millet-based agriculture in the area and its possible impact on environment. It can be concluded that millet cultivation was an auxiliary subsistence strategy in northern China from 10000 to 7000 a BP with hunting-gathering the primary subsistence strategy, the earliest millet-cultivation might have emerged in eastern Inner Mongolia post 7700 a BP. Millet cultivation transited from a secondary strategy to become dominant in the Guanzhong area of north-central China during 7000–6000 a BP, and probably facilitated the development of early Yangshao culture in the middle reaches of the Yellow River valley. Intensive millet-based agriculture emerged and widely expanded across the Yellow River valley in northern China during 6000–4000 a BP. This promoted rapid population growth and cultural evolution in the late Neolithic period, and was key in the subsequent emergence of the ancient Chinese civilization. The temporal-spatial variation of black carbon (EC-soot) corresponds well with the intensification and expansion of millet-based agriculture during Neolithic period. The content of EC-soot increased in sediments of Daihai lake and the Horqin sandy lands in Inner Mongolia from about 7500 a BP soon after farming of millet appeared in Xinglongwa and Xinglonggou sites nearby, which evidently increased in Shaanxi Province of north central China post 6000 a BP, when intensive millet-based agriculture firstly emerged in the area. This suggests millet agriculture production activities exerted significant impact on fire frequency in northern China during the Neolithic, and thus the scale and intensity of the impact of farming increased from that period. This work provides a valuable case study for understanding the temporal and spatial development of millet agriculture, and human-environment interactions in northern China during Neolithic period from an Anthropocene perspective.

millet-based agriculture, Neolithic Age, human activities, environment change, Anthropocene

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