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杨 博,田继军,冯 烈,等.准噶尔盆地东部中侏罗世煤中记录的古野火事件[J].煤炭科学技术,2022,50(7):261-270.

YANG Bo, TIAN Jijun, FENG Shuo, et al. Wildfires recorded in Middle Jurassic coals in Eastern of Junggar Basin in Xinjiang, China [J]. Coal Science and Technology, 2022, 50(7): 261-270.

准噶尔盆地东部中侏罗世煤中记录的古野火事件

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摘要:煤中惰质组是植物体不完全燃烧的产物这一论述被越来越多的学者所接受,伴随而来的是其指示古野火的意义更加突出。通过准噶尔盆地东部中侏罗统西山窑组煤层样品的惰质组含量和反射率信息,同时利用快速溶剂萃取法得到了煤岩样品中的16种多环芳烃的含量特征,综合分析了该组煤层在沉积过程中所经历的古野火事件。试验结果显示,西山窑组煤层中惰质组含量31.14%~82.64%,平均55.78%,惰质组平均反射率1.08%~1.54%,惰质组含量高是该煤层的主要特点。多环芳烃的试验结果显示不同层位间PAHs含量变化范围相对较大,范围3 881~6 525 ng/g,均值4 433 ng/g,且同层位不同种类的多环芳烃的含量相差极大。将惰质组含量、惰质组反射率和PAHs含量特征进行综合分析,得出了该煤层在沉积期间至少经历过3次野火频发的时期,根据木炭反射率数据进行的温度解释,这3个时期的野火类型均为中低温的地表火。同时从全球碳循环的角度对野火可能造成的气候环境影响做出了理论分析与推测,泥炭的堆积对全球气候产生了净降温效应,但是野火的发生能在一定程度上削弱这种效应并会将大量的碳排放到大气中。本研究结合多环芳烃特征对准噶尔盆地的古野火事件进行了识别与分析,对今后这一地区的煤田地质研究有一定的借鉴意义。

关键词:惰质组;反射率;古野火;多环芳烃;准噶尔盆地;中侏罗世

中图分类号:TD163 **文献标志码:**A **文章编号:**0253-2336(2022)07-0261-10

Wildfires recorded in Middle Jurassic coals in Eastern of Junggar Basin in Xinjiang, China

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Abstract: The argument that the inert group in coal is the product of incomplete combustion of plants has been accepted by more and more scholars, and its significance of indicating ancient wildfires has become more prominent. In this paper, the content characteristics of 16 kinds of polycyclic aromatic hydrocarbons in coal and rock samples were obtained through the information of inertinite content and reflectivity of coal seam samples of Middle Jurassic Xishanyao Formation in the eastern Junggar Basin, and the content characteristics of 16 kinds of polycyclic aromatic hydrocarbons in coal samples were comprehensively analyzed. Ancient wildfires experienced during the deposition of coal formations. The experimental results show that content of inertinite ranges from 31.14% to 82.64%, with an average of 55.78%, and the average reflectivity is from 1.08% to 1.54%. The high content of inertinite is the main characteristic of this coal of Xishanyao Formation. The experimental results of PAHs show that the variation range of PAHs between different layers is relatively large, ranging from 3 881 to 6 525 ng/g, with an average value of 4 433 ng/g, and the content of different types of PAHs in the same layer varies greatly. A comprehensive analysis of the characteristics of inertinite content, inertinite reflectivity and PAHs content shows that the coal

收稿日期:2021-10-02 责任编辑:常 琛 DOI:10.13199/j.cnki.cst.2020-1024

基金项目:新疆维吾尔自治区自然科学基金资助项目(2019D01C056);国家自然科学基金资助项目(41662010);2019年国家级大学生创新训练计划资助项目(201910755095)

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seam has experienced at least three periods of frequent wildfires during the deposition. The temperature interpretation based on the charcoal reflectivity showed that the types of wildfires in these three periods were all ground fires of medium and low temperature. At the same time, from the perspective of global carbon cycle, theoretical analysis and speculation are made on the possible climate and environment impact caused by wildfires. The accumulation of peat has a net cooling effect on global climate, but the occurrence of wildfires can weaken this effect to a limited extent and release a large amount of carbon into the atmosphere. In this study, the wildfire events in Junggar Basin were identified and analyzed for the first time by combining the PAHs, which will provide some reference for the future research on coal geology in this area.

Key words: inertinite; reflectivity; ancient wildfire; polycyclic aromatic hydrocarbons; Junggar Basin; Middles Jurassic

0 引言

野火是森林沼泽系统演化过程中一个重要的干扰因素,高强度野火毁灭现有的生物群落,随着生态系统的自然恢复,新生的生物群落可能会产生跳跃或倒退形式的演化,这极大改变了地区生物群落原有的演化进程^[1-3]。大规模野火事件会产生大量二氧化碳、氨气、二氧化硫和气溶胶等排放物,这不仅会改变大气反射率和成分,甚至能在一定时期内改变区域的气候环境^[4-6]。野火燃烧使生物有机质中的碳一部分以二氧化碳的形式释放到大气中,一部分则以生物残骸的形式贮存在沉积物种,因此野火的发生加速了自然界中的碳循环^[7]。研究野火事件对古生物群落演化、古气候分析和地质历史时期的碳循环有着重要意义,而识别古野火事件更是研究的前提^[8-11]。确定野火发生的条件能够为我们识别古野火事件排除干扰。现有研究结果表明火源、燃料和氧气浓度是野火发生的三大要素^[12]。其中火源是随机因素,它可能是雷击、自燃和落石火星等。除海洋和湖泊的有机质外,任何有机质都可充当燃料^[13]。氧气浓度是影响火灾发生的重要因素,已有的研究表明当氧气浓度低于15%时,植物体是无法被点燃的^[12,14-15],这就很好解释了为什么现有的古野火事件均发生在泥盆纪植物登陆以后^[16-18]。在确定了三要素后,就需要对古野火发生的证据进行发现和整理。目前,古野火的识别标志主要有炭屑、碳黑、燃烧源多环芳烃和树轮火疤等,这些物质统一的特征是既易长时间保存在地质体中又是物质燃烧的特征产物^[19-22]。SCOTT利用扫描电镜观察和反射率测定的方法从外形和物理性质上对现代植物组织不完全燃烧形成的木炭和沉积岩的丝炭进行了研究,试验结果表明无论是在宏观特征(易形成立方体小块)和微观特征(具有植物胞腔结构)上,两者都具有一致性。并且现代植物体在缺氧条件下经加热后产生的木炭拥有着和煤中丝炭类似的理化性质,如植物组织细胞壁的均质化、反射率升高和碳含量的增加。因此他认为木炭等同于宏观煤岩类型中的丝

碳和煤岩显微组分中的惰质组^[23-24]。近年来,随着对惰质组研究的不断深入,惰质组是植物体不完全燃烧的产物这一论述被越来越多的学者所接受,因此其用作指示古野火的意义也更加突出^[12,25-27]。同时惰质组的反射率也被证明与其形成温度成正相关,当惰质组反射率大于1%时,其形成温度大于350℃,显然绝大部分地区的地温梯度是达不到的,而自然界中的野火可以轻易达到这一温度,大规模森林火灾形成的高温甚至在800℃以上^[8-10]。因此,炭屑反射率的测定对判别古火灾同样有着重大的意义。多环芳烃(PAHs)主要以气溶胶和固体的形式广泛存在于土壤、大气、水体及动植物组织等环境介质中,并且由于其稳定的化学性质而很难被生物所利用。VENKATESAN等^[28]在世纪20世纪80年代研究白垩纪古野火事件时就将PAHs作为判别证据。YUNKER^[29]更是进一步依据多环芳烃不同种类之间的比例将其划分出了3个来源,分别是石油源、生物质燃烧源和化石燃料燃烧源。

目前,国内对古野火的研究主要集中在生物大灭绝时期,强度大、范围广、影响深是这一时期野火的主要特点^[24,30-32],而对于那些区域性的古野火事件研究则相对较少。事实上,我国西部地区中侏罗统蕴藏着大量煤炭资源,这说明其在中侏罗世时期有着丰富的植被。同时期的各种模型也显示中侏罗世氧气浓度在20%以上^[1-2,33-34]。侏罗纪是全球重要的成煤期,我国侏罗纪煤更是占到了煤炭资源总量的2/3^[35-31],但是关于该时期古野火的研究却相对较少^[12,34,37-38]。通过煤岩样品中惰质组含量和反射率信息,结合PAHs数据对中侏罗世准噶尔盆地东部的古野火事件进行了识别,并对其产生的古环境影响进行了分析。

1 地质背景

研究区位于新疆准噶尔陆相含煤盆地东部,卡拉美丽山南麓。研究区煤岩样品均采自准噶尔东部煤田的五彩湾矿区。五彩湾矿区位于准噶尔东部煤田西北部(图1),北邻卡拉麦里山南麓,东邻沙帐褶

皱带。含煤地层为中侏罗统西山窑组,含煤层厚62 m,厚度稳定,分布广泛。

准噶尔盆地经过印支运动期间秦-昆洋于三叠纪末闭合和昆仑-秦岭崛起的构造挤压远程效应,使得盆地周缘造山带进一步隆起,逆冲推覆广泛发育,盆山整体构造抬升,聚煤作用微弱;燕山早期,

早-中侏罗世盆、山构造抬升已趋于平静,而盆地开始向“广盆”“大湖”的方向发育,因此该阶段为准噶尔盆地乃至西北地区最大规模聚煤事件。并且自二叠纪以来,盆地内就少有火山活动,尤其是研究区自侏罗纪以来更是少见岩浆侵入^[41]。

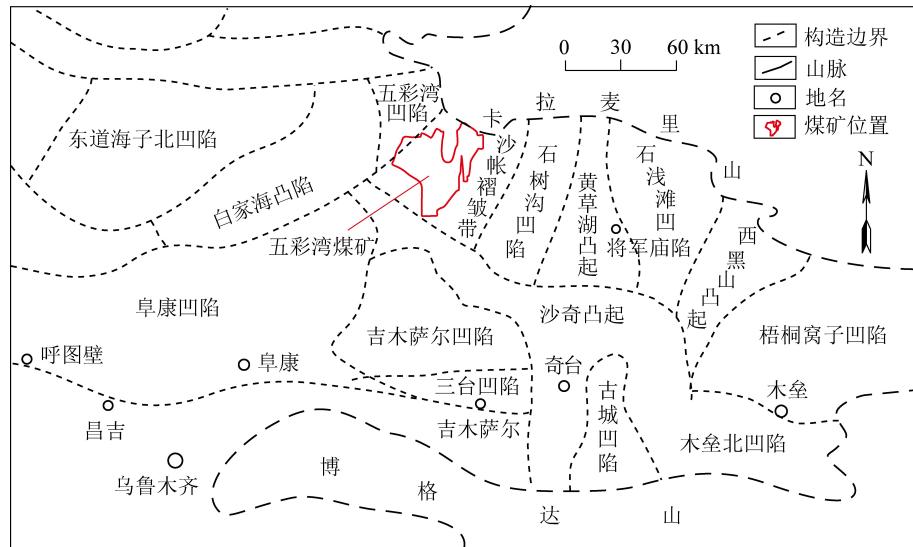


图1 研究区地质概况
Fig.1 Outline map of study area

2 采样与测试方法

参照《煤层煤样采取方法》(GB/T 482—2008),对准东煤田五彩湾矿区一露天矿坑垂直采样20件,样品均来自同一巨厚煤层(63 m),自上而下编号为SH1-20(图2)。煤岩光片制备按照GB/T 15590—2008的标准进行,并利用光学显微镜对煤岩光片进行观察。所采取的手段是通过蔡司Axio Scope A1显微镜配以放大倍数为10倍的目镜和50倍的油浸镜头对制备好的抛光块进行观察,在进行壳质组的观察时再配以紫色荧光,每个抛光块均匀分布至少500个计数点。采用同样的显微镜和镜头并配以J&M的MSP200显微分光光度计对惰质组反射率进行测定。煤中PAHs的提取与测定参照并改进王道玮^[42]萃取土壤中PAHs的方法,利用快速溶剂萃取装置对PAHs进行提取,氮气吹扫浓缩后再通过弗罗里硅土固相萃取柱对PAHs进一步提纯,然后再进行氮气吹扫浓缩。16种PAHs外标液浓度分别为0,0.1,0.2,1.0,2.0,4,10 μg/mL,内标液为5种氘代多环芳烃。由于煤岩样品中有机质含量较高且较为致密,因此在前处理时要减少样品量至5 g,采用33 mL的萃取池,煤岩颗粒应控制在0.150 mm

以下。

3 试验结果

3.1 煤中的惰质组

对煤中显微组分的观察和定量分析表明,本次样品显微组分以镜质组和惰质组为主,壳质组含量极少(表1)。其中惰质组含量38.89%~87.72%(平均53.26%),镜质组含量11.08%~59.68%(平均45.66%)。各层位惰质组均以半丝质体和碎屑惰质组为主,丝质体含量较少,并见少量微粒体。镜质组均以基质镜质体和碎屑镜质体为主,见少量的均质镜质体。惰质组反射率测定的主要目标是微观木炭,即丝质体、半丝质体和碎屑惰质体(图2)。惰质组反射率测定结果显示各样品间除最大反射率相差较大外(1.95%~3.17%),其平均反射率和最小反射率相差均在0.5%以内,标准差范围0.29~0.54。

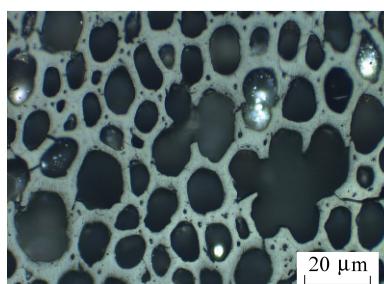
3.2 煤中的PAHs

根据提取的20个样品中16种PAHs含量数据显示,这16种PAHs分别是:萘(Nap)、苊(AcPy)、苊(Acp)、芴(Flu)、菲(PA)、蒽(Ant)、荧蒽(FL)、芘(Pyr)、苯并(a)蒽(BaA)、屈(CHR)、苯

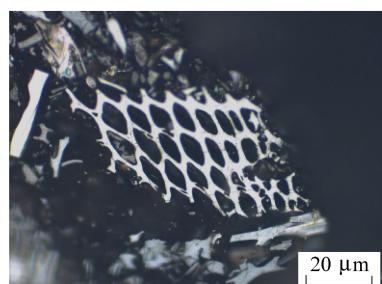
表1 样品的显微煤岩组分占比及惰质组反射率统计

Table 1 Maceral compositions and inertinite reflectivity of samples

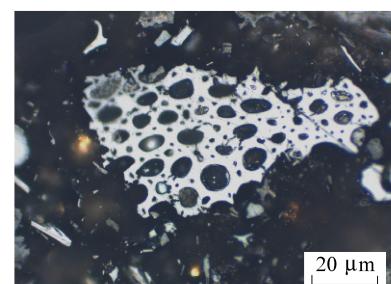
样品号	惰质组	镜质组	壳质组	最小反射率	最大反射率	平均反射率	%
SH-1	41.86	56.16	1.98	0.88	1.86	1.23	
SH-2	46.21	51.78	2.01	1.02	2.19	1.46	
SH-3	42.44	55.72	1.84	0.79	2.12	1.25	
SH-4	38.89	59.34	1.77	0.77	2.50	1.24	
SH-5	48.92	49.48	1.60	0.70	2.45	1.14	
SH-6	87.72	59.68	1.38	0.75	3.17	1.42	
SH-7	38.94	11.08	1.20	0.90	2.61	1.41	
SH-8	49.03	49.62	1.35	0.82	2.24	1.11	
SH-9	51.59	47.44	0.97	0.73	2.55	1.09	
SH-10	86.38	12.66	0.96	0.79	2.86	1.54	
SH-11	50.17	48.88	0.95	0.80	2.06	1.18	
SH-12	42.53	56.54	0.93	0.76	1.95	1.17	
SH-13	58.38	40.75	0.87	0.75	1.96	1.14	
SH-14	52.67	46.48	0.85	0.75	2.47	1.22	
SH-15	58.58	40.58	0.84	0.73	2.46	1.08	
SH-16	43.35	55.82	0.83	0.88	2.51	1.18	
SH-17	51.21	48.34	0.45	0.74	2.23	1.12	
SH-18	46.94	52.72	0.34	0.80	2.55	1.39	
SH-19	64.66	35.05	0.29	0.72	1.91	1.14	
SH-20	53.66	46.01	0.33	0.72	2.11	1.24	



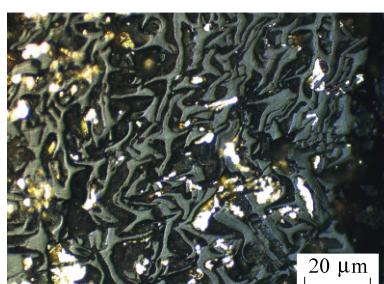
(a) 具有明显细胞结构的丝质体



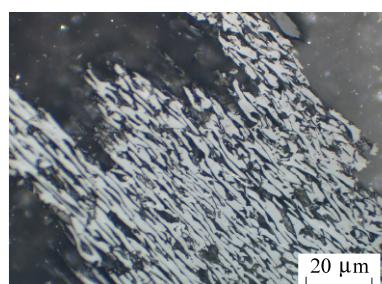
(b) 具有明显细胞结构的丝质体



(c) 具有明显细胞结构的丝质体



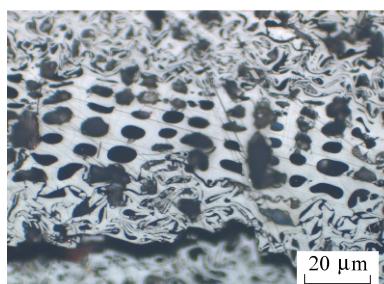
(d) 半丝质体与黄铁矿



(e) 碎屑惰质体



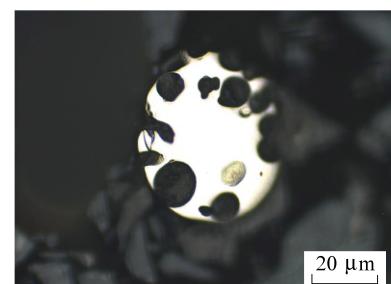
(f) 粗粒体, 可见高突起



(g) 丝质体与半丝质体



(h) 丝质体与半丝质体



(i) 煤中天然木炭

图2 煤中部分惰质组

Fig.2 Partial inertinite of coal

并(k)荧蒽(BkF)、苯并(b)荧蒽(BbF)、苯并(a)芘(BaP)、茚并(123-cd)芘(IND)、二苯并(ah)蒽(DBA)和苯并(ghi)芘(BghiP)。研究区内不同层位间PAHs含量变化范围相对较大(表2),范围3 881~6 525 ng/g,均值4 433 ng/g,且同层位不同

种类的多环芳烃的含量相差极大。PAHs含量数据表明苯并(k)荧蒽、苯并(b)荧蒽和茚并(123-cd)芘的含量要普遍高于同层位其他种类的含量,以PAHs环数分类,二环芳烃占4.51%,三环占28.69%,四环占23.57%,五环占24.83%,六环占18.41%。

表2 样品中16种PAHs的含量

Table 2 Content of 16 PAHs of samples

ng/g

样品	SH-1	SH-2	SH-3	SH-4	SH-5	SH-6	SH-7	SH-8	SH-9	SH-10	SH-11	SH-12	SH-13	SH-14	SH-15	SH-16	SH-17	SH-18	SH-19	SH-20
Nap	274.8	189.8	171.4	188.4	176.8	252.8	190.2	194.8	230.8	287.4	178.2	176.8	178.6	174.6	170.4	179.0	196.8	306.4	170.8	183.0
AcPy	234	232.6	232.6	233.0	232.4	233.0	232.4	232.4	232.8	234.0	232.6	232.2	233.0	232.4	232.4	232.4	232.4	234.2	232.4	232.4
AcP	233.6	233.8	233.8	234.2	234.0	234.8	233.6	233.4	234.0	237.6	233.4	233.4	233.8	233.4	233.6	233.6	233.4	235.2	233.4	234.6
Flu	244.2	243.6	243.6	244.4	243.8	246.2	243.8	244.6	243.6	249.2	243.4	243.4	243.8	243.6	243.4	243.4	245.2	245.2	243.4	243.2
PA	261.4	259.0	256.4	260.4	259.2	262.4	255.6	258.6	256.0	271.4	255.4	254.4	256.2	254.2	254.6	255.8	255	261.2	255.4	254.6
Ant	427	306.2	302.6	302.0	301.8	309.4	301.6	301.8	302.0	318.2	298.0	300.2	300.6	299.6	301.4	300.2	301.4	322.4	299.6	299.6
FL	282.6	279.0	270.4	270.4	271.4	294.2	270.4	272.0	272.2	292.4	270.0	271.6	272.4	269.0	272.6	271.2	273.2	294.2	269.8	269.0
Pyr	267.8	266.6	259.6	263.8	260.8	282.8	260.8	262.2	261.4	281.8	258.6	261.4	262.4	262.2	264.0	261.2	262.2	273.4	261.4	260.4
BaA	291.6	283.4	285.6	284.4	283.2	309.2	286.2	284.8	284.4	301.2	284.4	284.4	284.4	284.6	286.2	284.8	285.2	292.6	283.8	283.4
CHR	227.2	224.0	210.6	212.8	207.6	297.4	208.2	208.8	218.2	230.2	201.6	208.8	211.4	200.4	207.4	204.4	206.4	275.6	201.0	201.4
BkF	282.2	295.6	303.8	315.2	351.0	637.6	271.8	276.2	505.8	696.0	272.8	358.8	478.2	337.6	324.4	364.6	367.2	1286.6	294.0	468.4
BbF	409.6	302.0	354.0	301.8	319.8	529.0	288.6	305.8	553.4	841.8	344.2	305.2	366.0	444.0	357.2	385.6	373.2	858.6	467.0	492.0
BaP	196.2	200.2	211.2	205.8	212.8	295.0	198.0	209.8	216.8	301.0	207.6	204.4	221.0	227.0	211.0	225.8	227	405.8	220.2	203.2
IND	302.8	248.4	289.6	251.2	282.6	441.4	237.4	271.8	252.2	657.2	281.6	255.6	299.6	345.8	277.6	316.4	286.6	583.6	368.4	459.0
DBA	221.4	216.4	218.8	215.8	220.4	236.2	215.0	216.6	215.6	254.0	216.6	215.2	220.6	223.0	218.0	221.2	222.4	248.2	223.4	229.2
BghiP	227.4	192.4	214.0	193.6	214.4	293.0	187.6	206.4	196.2	425.2	215.2	201.2	214.4	245.2	224.6	227.4	225.8	402.4	252.6	449.2
总量	4 383.8	3 973.0	4 058.0	3 977.2	4 072.0	5 154.4	3 881.2	3 980.0	4 475.4	5 878.6	3 993.6	4 007.0	4 276.4	4 276.6	4 078.8	4 207.0	4 193.4	6 525.6	4 276.6	4 762.6

4 讨 论

4.1 古野火存在的证据

4.1.1 木炭方面的证据

前人的研究结果显示煤中10~500 μm的惰质组分可以当做古野火证据^[23]。许云等^[44]通过煤中惰质组的含量和反射率确定了侏罗纪鄂尔多斯盆地古野火类型和事件造成的气候影响;WANG等^[40]也通过同样的手段对我国东北地区早白垩世的古野火范围,类型和强度进行了分析,同时对当时的古气候环境进行了推断;蔡垚峰^[45]通过对新疆大龙口剖面木炭化石的显微观察和反射率测定,确定了古野火的发生层位和古环境信息。惰质组相关数据显示,样品惰质组含量31.14%~82.64%,平均55.78%。这一平均含量是被认为发生过野火事件二连盆地的1.6倍,更是高于当前环境下泥炭中4.27%惰质组含量^[39],并与鄂尔多斯盆地相持平^[44]。这

表明研究区煤层沉积时期野火的频率要高于二连盆地聚煤时期的野火频率。依据煤岩学理论,较多的惰质组含量,极少的壳质组代表了其成煤植被以灌木和乔木为主,同时前人研究结果也显示研究区成煤环境以干燥-潮湿森林沼泽为主^[46]。大量发育的木质类植物和较为干燥的环境也为野火的发生提供了物源和前提。现代研究表明煤中的丝质体和半丝质体是有机质受到野火影响热变质形成的,在低阶煤中其反射率要明显大于镜质组。因此样品中含量较多且反射率较高的丝质体和半丝质体表明研究区在聚煤阶段发生过古野火事件。

4.1.2 PAHs方面的证据

SHEN等^[31]在研究中国眉山二叠-三叠纪生物灭绝事件时,认为大规模的野火事件是生物灭绝的主要原因之一,并将PAHs的含量异常作为野火发生的重要证据;VERGNOUX等^[21]对法国南部森林表层土壤中PAHs的分布特征进行研究,得出了森

林火灾主要产生低分子量的多环芳烃的结论;赵红梅等^[47]对三江平原沼泽土中多环芳烃的含量分布进行了研究,结果发现有火烧迹象沼泽土中的多环芳烃含量高于无火烧迹象的沼泽土。

由于热事件、生物降解和风化会导致 PAHs 的降解,当 PAHs 作为古野火事件指标时一定要排除这 3 个因素的干扰^[3,9,48]。现有的研究显示准噶尔盆地东部侏罗纪之后没有规模性的岩浆侵入事件,而生物降解在同一地质历史时期的差异性又极小,采集新鲜样品又排除了风化因素的干扰,因此本次试验得出的 PAHs 的数据是有效的。将试验数据代入到 YUNKER 等判别 PAHs 来源的模型中,可以得出所有样品的 PAHs 主要来源均为有机生物质燃烧(图 3)^[29];另一方面,SH-6,SH-10,SH-18 所在层位,无论是 PAHs 总量还是常见的 8 种被认为是燃烧源的 PAH^[21,31]含量要明显高于其他层位(图 4);最后将木炭丰度和反射率数据与 PAHs 含量数据对比,可以观察到两者有较高的吻合度(图 5),均在 SH-6,SH-10,SH-18 所在层位出现了异常。结合现有的研究成果,足以说明研究区在聚煤期间至少发生了 3 次规模较大的野火事件。

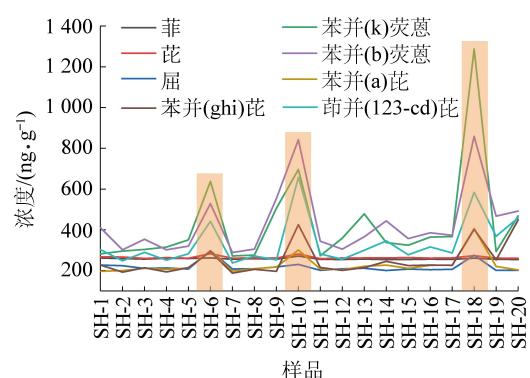


图 3 常见的 8 种燃烧源 PAHs 含量

Fig.3 Concentration of 8 combustion-derived PAHs

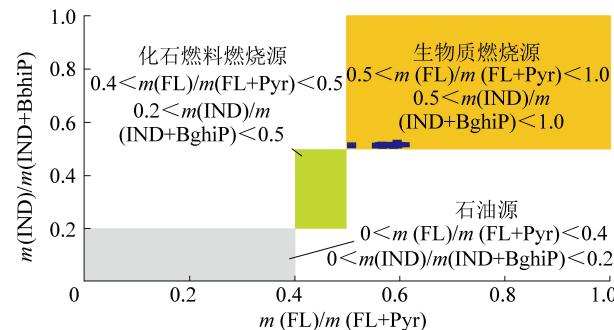


图 4 PAHs 来源模型^[29]

Fig.4 Model of source of PAHs^[29]

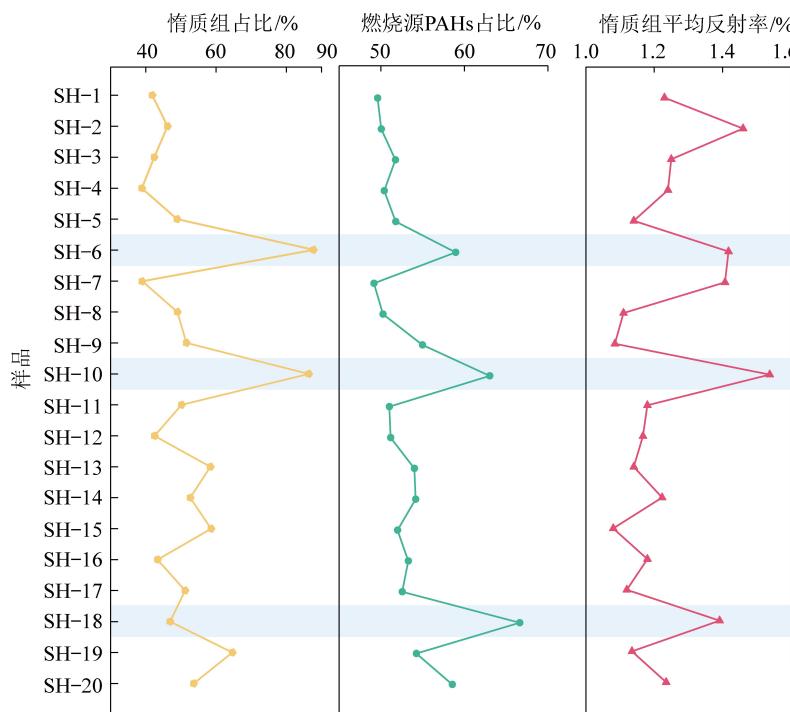


图 5 惰质组和 PAHs 特征综合分析

Fig.5 Comprehensive analysis of inertinite and PAHs

虽然模型显示所有样品 PAHs 的来源均为生物质燃烧,但是全都处于化石燃料燃烧源和生物质燃烧源的边界上,而与化石燃料燃烧源没有十分清晰

的界限。这可能是因为原本已经沉积的泥炭受到后期野火事件的影响,野火产生的高温使得已沉积泥炭中的 PAHs 产生了类似于化石燃料燃烧的热解反

应,一定程度上破坏了原有PAHs成分,造成了在模型上的偏移。事实上,采样点是一整套厚约63 m的煤层,如此厚的煤层其沉积时期必定是漫长的,期间可能发生过多次的野火事件,各种指标也指示出了至少3个时期的高频率野火事件,即SH-6,SH-10和SH-18所在层位的野火事件。因此研究区在聚煤期间至少有过3次规模较大的野火事件是可靠的。

4.2 古野火的类型

根据燃烧物质和温度的不同,野火的类型可分为3类:①燃烧地表落叶层之下有机质的地表火,温度在300 °C左右;②燃烧地表落叶层、草本植物和灌木的地表火,温度在600 °C左右;③燃烧树木树冠和大型灌木的树冠火,温度在800 °C,甚至更高^[12,16,49]。JONES^[50]最早得出了惰质组反射率与形成温度之间的对应关系并沿用至今,尽管这种关系不是完全的线性关系,但是燃烧温度大致可以通过式(1)进行计算^[51-53]。

$$T = 184.10 + 117.76R_o \quad (r^2 = 0.91) \quad (1)$$

其中,T为惰质组形成时的温度;R_o为所测得的惰质组反射率。利用惰质组反射率判别古野火类型的研究早已屡见不鲜^[40,44]。将测得的惰质组反射率代入式(1),再结合古野火划分依据即可得出研究区中侏罗世西山窑组沉积期间的野火类型。在选取反射率值时应当考虑到微观木炭(惰质组)可能会被周围空气产生的热气流卷入高空,然后随风进行远距离搬运到几百甚至几千公里以外的地方,因此常见的选取惰质组平均反射率来判断古野火类型。事实上,利用平均反射率来判断古野火类型也并非是最准确的,因为无论是何种强度的野火,在其发生时总有燃烧不充分和温度较低的位置,这些位置的反射率不具有代表性,因此在判别古野火类型时应当将这一部分数据多加处理,尤其是在判别地表火和树冠火时应该尤为注意。但是现有的研究还未明确在利用惰质组反射率判别古野火类型时应当如何对数据进行处理和修正,解决这一问题需要大量的室内试验和数据分析,暂用惰质组平均反射率来判别古野火类型。研究区西山窑组沉积煤层中SH-6,SH-10和SH-18样品平均反射率对应的形成温度分别为351,365和347 °C,表明这3个样品沉积期间野火主要以中低温的地表火为主。

4.3 侏罗纪古野火事件与古气候的关系

众多研究表明三叠-侏罗边界发生了6亿年来最大生物灭绝事件,大西洋中部岩浆省火山的大规

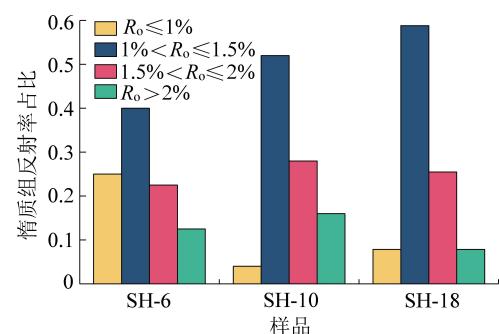


图6 部分样品惰质组反射率占比

Fig.6 Proportion of reflectivity of inertinite in some samples

模活动增加了大气中的CO₂浓度,而进行光合作用的植物大量灭绝则导致了氧含量的急剧下降。由于岩浆活动和大部分进行光合作用的植被灭绝,大气CO₂含量上升的趋势一直持续。根据SELLWOOD^[53]的大气环流模型,在早、中侏罗世全球气温比现代高5~10 °C,海水温度比现代高8 °C。大气CO₂含量增加产生了强烈的温室效应,直至中侏罗世,此时大气中CO₂含量达到顶峰^[54],植物种类变得丰富^[55],大量植物进行光合作用消耗CO₂产生O₂,在提升了大气氧含量的同时固定大气中的碳。BAKER^[56]的研究结果表明,在全球碳总量不变的情况下,地层中有机碳含量的增加将会导致大气氧含量的增加,而在氧含量上升的影响下,即使是湿润燃料依旧能被点燃并保持燃烧^[39]。因此在这一时期野火频发,野火对植被的破坏和产生的大量CO₂气体又极大干扰了植物对C的固定作用,使得大气CO₂含量削减变缓,去温室效应减弱。

BERNER^[37,57]的研究显示:频繁的野火会将大量的碳固定在沉积物中,导致大气中碳含量降低,继而引起氧气浓度升高。然而PAGE^[58]和VAN DER WERF等^[59]的研究则证明1997年和1998年的印尼大火使得约0.95 Gt的碳被释放到大气中,这大约相当于当时15%的全球化石燃料的碳排放量^[60]。此外,野火产生的烟雾对光合作用的影响也会抑制植物对大气中二氧化碳的吸收从而延长温室效应的周期^[5-6]。

泥炭的积累对整个全新世的地球气候产生了净降温效应^[61],与全新世一样,侏罗纪也是全球重要的成煤时期。泥炭沉积区的野火会干扰碳储量,导致土壤碳流失^[62],同时减缓去温室效应的进程。但是已沉积的泥炭是否会在野火或其他因素影响下(大气氧含量、温度和加热时间)被点燃,使泥炭地成为碳排放的一大来源,从而更深层次的影响全球碳循环,还需要进一步的研究。

6 结 论

1)准噶尔盆地东部中侏罗世西山窑组煤中惰质组含量较高,惰质组含量38.89%~87.72%,平均53.26%,各层位惰质组均以半丝质体和碎屑惰质组为主。

2)PAHs特征表明,该煤层PAHs来源为生物质燃烧源,且在SH-6、SH-9、SH-18层位生物质燃烧源PAHs含量明显增多,该异常与惰质组特征相吻合,这表明在该煤层(62 m)沉积期间至少发生过3次广泛的古野火事件,且这3次古野火类型均为中低温的地下火。

3)古野火产生的CO₂、烟尘和对植被的破坏能够在一定程度上干扰植被对大气中碳的固定,使得大气中碳含量增加,温室效应加剧。

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