A World-Ecological Perspective on Socio-Ecological Transformation in the Appalachian Coal Industry

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Abstract
This article discusses the exhaustion of socio-ecological relations in the coalfields of West Virginia. We use the term socio-ecological to signify "the interwoven character and the indispensable unity of social and natural life" (Araghi 2009: 115). In particular we use classic literatures on labor history in the coalfields of central Appalachia and contemporary studies of mountaintop removal to think about phases of socio-ecological relations of the coal industry. We argue for the interrelationality of the social and the ecological in place of conventional eco-Marxist approaches which treat these as relatively independent units. This enables us to situate nature as an active component of capitalist developmental processes. We argue that the exhaustion of socio-ecological relations in the coalfields of West Virginia is an outcome of material practices within the phase of extraction using mountaintop removal, historical changes in the conditions of production in the coalfields, and of new forms of competition from other regions and energy sources. We find that the relative exhaustion of central Appalachian coal is tempered by favorable international markets and a specialization in metallurgical coal.

Keywords: world-ecology, energy, capitalist development, Appalachia, nature

West Virginia has historically been tied to the world-economy through the extraction of coal, which has fed steel mills and provided energy that powers the electricity grid throughout the United States. West Virginia's coal dependency has provided jobs and been at the center of struggles for rights among miners, their families and communities. The history of miners' struggles over labor conditions both inside the mines and in coal communities dominates intellectual inquiry into central Appalachia more broadly. A relatively recent shift to mountaintop removal coal mining has replaced this narrative with one of environmental degradation (e.g. Scott 2010; McNeil 2012). This article seeks to bridge these fields of scholarly

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inquiry. It situates the most recent phase of coal extraction as a reworking of the relation among human and extra-human natures, while accounting for the diversity of human natures in the dynamics between miners and coal companies. As one phase of extraction gives way to another, local and regional socio-ecological relations in the coalfields are reorganized to reflect conditions of the world-economy. We use the term socio-ecological to signify "the interwoven character and the indispensable unity of social and natural life" (Araghi 2009: 115). We argue that the exhaustion of socio-ecological relations in the coalfields of West Virginia is an outcome of material practices within the phase of extraction using mountaintop removal, historical changes in the conditions of production in the coalfields, and of competing regions and energies. The exhaustion of socio-ecological relations is a crisis that arises when the conditions that once freed capital from its constraints become a limit on profitability and prevents an industry from keeping pace with the expansion of the world-economy. We find that the relative exhaustion of central Appalachian coal, favorable international markets and specialization in metallurgical coal have tempered exhaustion in West Virginia and central Appalachia more broadly.

Using exhaustion as a framework for analyzing the coalfields of West Virginia moves beyond causal models of environmental degradation and promotes a relational approach that highlights the inseparable aspects of society and ecology, the socio-ecological relations, that together form the organization of capitalism in a place, such as central Appalachia. Current scholarship fails to address exhaustion in a way that progresses conversations in the overlapping fields of political ecology and environmental sociology. Fields that address the environment from the social sciences are limited by frameworks rooted in the dualism of nature and society as distinct entities. Exhaustion for these scholars is an absolute exhaustion, characterized by a definite lack of a resource. Rather, we use ecological Marxism and world-systems studies to address exhaustion as relative and dialectical, where a resource exists but the profitability of extraction is constrained by socio-ecological conditions. Eco-Marxist interpretations of exhaustion tend to remain within the fixed boxes of nature and society, where capitalism causes exhaustion through environmental degradation and hinders the ability of social reproduction wherever it manifests. Recent efforts by world-systems scholars have integrated eco-Marxist ideas within a relational field that integrates nature and society as interpenetrating, where one cannot be spoken of coherently without addressing the other. Here, exhaustion signifies the declining profitability and increasing instability of organizational structures in relation to the world-economy (Arrighi 1994; Moore 2011a; 2011b).

With the vast majority of scholarship on environmental degradation deeply committed to a causal mode of explanation, the qualitative attributes of how processes of degradation occur in relation to the development of capitalism are overlooked. This fails to help us understand the geographic displacement of regions by new ones and the way regions remain linked to the world-economy even as new frontiers come into production. Eco-Marxists have been successful in moving conversations on environmental issues forward and their scholarship critically engages with ecology and systems thinking (Smith 1984; O'Connor 1998; Foster 1999, 2000; Bell and York 2010). Eco-Marxism incorporates ecological thinking into the dialectical relations of capitalism, beyond the analysis of capital and labor. This relational thinking has challenged scholars such that world-systems studies have recently critiqued the dualism of eco-Marxist's tendency to situate nature as distinct from society, beyond nature as source and sink (Moore 2011a, 2011b). In these analyses, ecology is not something formative and influential to the contours of capitalist development. This article contributes to a developing and paradigm shifting world-ecological perspective.

Below we sketch out the contours of eco-Marxism before outlining our interpretation of world-ecology. We then go on to discuss exhaustion in the coalfields of West Virginia as a situated place in the world-ecology. In addressing the relative exhaustion of coal production in West Virginia, we are concerned with how socio-ecological conditions in West Virginia influence and are influenced by world-ecological conditions of capitalist development. We are specifically interested in: *how are human and extra-human natures interwoven in West Virginia's coalfields? How have socio-ecological relations changed over time? What do the socio-ecological relations tell us about the form of capitalism in this place? What are the important elements of exhaustion of the socio-ecological project in West Virginia?*

Literature Review: Transcending the Binary of Nature and Society

Working in the classroom, it is evident that many students think capitalism or society as distinct from nature. Even scholars that recognize that these spheres are intimately related situate them in distinct ontological spheres (Foster, Clark, and York 2010; Peet, Robbins, and Watts 2011). When pressed to think otherwise, almost all would agree that society exists within nature but once we begin to analyze environmental issues we implicitly fall back into the thinking that society is independent of nature and can be controlled. One need only look to United Nations Development Program (UNDP) meetings, government management of environment, and grassroots organizations working to create sustainability. The problem with the Cartesian model that creates a dualism of nature and society is that it limits what questions can be asked and what can be known while reproducing an ontological understanding of society and nature as distinctive spheres.

The dualism of nature and society is an abstraction associated with capitalist modernity and extends into various spheres, all of which relate to human control over production and therefore use industrial activity as a frame for understanding environmental degradation. The technological innovations of an expanding capitalist system increase labor productivity as machines replace workers and output expands. This process increases the rate at which natural resources are used, leading to geographically extensive extraction. This process is known as the treadmill of production, and the profit motive is its *raison d'etre* (Schnaiberg 1980). The treadmill of production leads to the constant necessity to seek out new and different resources, generating a mobile commodity frontier. The idea of a mobile frontier is relevant to world-ecological understandings of the socio-ecological exhaustion of the coalfields. However, the treadmill of production is situated as a binary where capitalist processes yield environmental degradation. Nature becomes something that is used, as a source of resource extraction to be used as input into capitalist production. While the resources extracted from nature are productions of nature, the landscape is a production of nature itself, as an outcome of capitalist processes (Smith 1984). Smith internalized the expanding use of natural resources in the treadmill of production by internalizing this relation of capitalist production processes. The drive for endless accumulation produces a form of nature that reflects the domination of exchange value over use value. Economic "efficiency" is elevated above social and ecological "efficiencies", meaning concerns with the production of capital take precedence over the re/production of life While material life is filled with produced natures, the result of human activity, the biogeophysical aspect of nature is also a production that must be taken into consideration (Bunker 1985). The biogeophysical aspects of ecology are productions of geological time that determine the location and quality of natural resources. This in turn situates the temporalities of capitalism and ecology at different rates. Our long term project is to understand how these temporalities coincide in order to gain a better comprehension of capitalism as *world-ecology*, or as a way of organizing nature.

Eco-Marxist literatures generally look to the internal relations of capitalist production processes in analyzing capitalism. Nature for eco-Marxists is something acted upon and used by capital, but it is not recognized as an integrated ecological system with its own internal logic, spatiality and temporality. Rather, nature tends to be viewed as passive and relatively unchanging. World-systems scholars and others working in the eco-Marxist tradition, such as O'Connor (1998), have argued that the degradation of the conditions of production (labor power, built environment, and natural environment) limits the possibilities for expanded accumulation. In O'Connor's (1998) second contradiction of capitalism, degradation is framed within the internal relations of capital such that the limits to capital are capital itself. O'Connor argues that as the conditions of production are degraded an ecological crisis emerges which in turn generates economic crisis (1998: 183). This dualism repeats itself as an economic crisis causes an environmental one. The dialectical process O'Connor (1998) identifies begins to recognize the relationality between society and nature while reifying these as two distinct spheres of life.

Later interventions by eco-Marxists have fruitfully formulated the concept of metabolic rift, taken from Marx's conception of social metabolism (Foster 1999, 2000). The metabolic rift is illustrated through Marx's discussion of the division of labor between town and country. The country sends nutrients and resources to the towns, while towns accumulate waste in nature and the wealth derived from the usage of the countryside's energy and resources. The organization of society under capitalism breaks down this social metabolism and treat ecosystemic cycles as linear histories. Again we see the axiom of social systems disrupting natural systems. Humans are said to create the rift, illustrating the dualism of society and nature. But humans are part of nature! Further, non-human natures contribute to the production of nature and actively make environments (through climate, geology, biophysical environments). We can no longer view nature as "a passive substance upon which humanity leaves its footprint. Rather, it becomes an inclusive and active bundle of relations formed and reformed through the historically and geographically-specific movements of humans with the rest of nature" (Moore 2011b: 119). This idea is frequently absent from left ecology.[2] The domination of nature by humans is firmly rooted in the epistemology of capitalism, where humans manage nature. Only recently has a developing perspective on world-ecology (as a recent innovation in world-systems) begun to emerge challenging this seemingly axiomatic knowledge.

Recent scholarship by Jason Moore has challenged the Cartesian dualism that situates society and nature in distinct ontological spheres in the study of capitalism. Moore's world-ecology perspective posits that instead of capitalism acting on nature, capitalism develops *within* and *through* nature. This signifies that there is a dialectical relation of the accumulation of capital and the production of nature forming the *capitalist world-ecology* (Moore 2011a). The dualism of nature and society is an outcome of this relation rather than a point of departure for analysis (Moore 2009). To begin analysis from the point of dialectical unity, we look to the messy bundles of human and extra-human nature that constitute the relations of "a symbolic and material matrix, co-created through the activities of humans with the rest of nature" (Moore 2009: 348). The ontological formation of society-in-nature differs from traditional formulations that posit society acting upon nature. Nature and society then should not be conceptualized as discreet categories of sociological analysis. They are interrelated and reproduced from the scale of the body to the scale of the world-economy where the logic of capital becomes the principle organizing force of this ontological unity (or *oikeios* to use Moore's term) (Moore 2011b).The significance of a unified analysis of nature and society is that it eschews academic attempts at resolving ecological crises within the logic of the capitalist system. Reforms to the capitalist system are not possible within a system premised on accumulation for accumulations sake.

The world-ecology perspective opens possibilities for understanding the production of nature as part of the historical development of capitalism. The production of nature and accumulation are dialectically bound through relations of human and extra-human natures such as the geological production of nature in terms of biogeophysical properties of natural resources that contribute to capital accumulation. The exhaustion of socio-ecological conditions in the organization of human and extra-human relations periodically challenges capital to reorganize relations in an effort to jumpstart accumulation. This involves the geographical movement of commodity frontiers as well as the introduction of new management practices and scientific-technological innovations (Moore 2009, 2011a, 2011b). We organize this paper around the socio-ecological relations of coal production in West Virginia and the periodic exhaustion of the organizational structures and conditions of production. We specifically focus on the period of mountaintop removal coal mining that emerged in the 1980s and the conditions of the world-ecology that have recently signaled the exhaustion of this ecological regime in central Appalachia.

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[2] Non-western scholars have been vocal about the holistic relation of ecology and economy and have argued for an alternative epistemology. Such important scholars include Boaventura de Sousa Santos, Vandana Shiva, and Ariel Salleh among others.

Methods

This study was conducted over six weeks in the summer of 2012 in southern West Virginia. Twenty in-depth interviews were conducted with coal miners, community members, and environmentalists on the practice of mountaintop removal coal mining and the economic changes occurring in southern West Virginia since the 1970s. Interviews were collected using the snowball sampling method. While interviews were crucial to the development of this research, they only partially inform a general understanding of this study. Information was also collected from local historical sites, museums and curators on the history of coal mining as well as the blog *Coal Tattoo* written by Ken Ward. *Coal Tattoo* was an invaluable resource that linked statistical data to the real life experiences of West Virginians.

A history of activism by West Virginia's citizens has been significant to the contours of coal operations in the state. Participant observation during an activist training conference and subsequent direct action protest were informative on the strategies local populations are currently using to fight for the land and people of West Virginia. Beyond the conference, one of the authors worked with two families on their farms and attended community gatherings. Participant observation illuminated the everyday practices of local peoples and helped gain an understanding of the economic challenges facing communities.

We use southern West Virginia as a representation of central Appalachia because it produces the largest quantity of coal among the central Appalachian states. In 2011, southern West Virginia produced 92,813 thousand short tons of coal. The second largest producer in central Appalachia was eastern Kentucky with 67,930 tons. The whole of central Appalachia produced 184,813 tons of coal (EIA 2011). Central Appalachia is defined by the Energy Information Administration as encompassing southern West Virginia, eastern Kentucky, and northeastern Tennessee. We use southern West Virginia as a representative of wider processes occurring in central Appalachia in comparing this coal basin to competing coal basins such as that of the Powder River Basin in Wyoming. The patterns occurring in southern West Virginia reflect broader socio-ecological processes of the region as a whole. Further, important historical events occurred in the southern West Virginia coalfields that influenced the wider region, especially the formation of the United Mine Workers of America in the early 20^{th} century. This research was part of a larger project to examine the restructuring of the coal industry and how social movements are contributing to the development of this industry. Throughout this paper we use West Virginia, southern West Virginia, and central Appalachia interchangeably to avoid repetition.

Before proceeding, a brief methodological note is in order. Jason Moore has set out on an ambitious task of building a framework for analyzing the capitalist world-ecology by transcending Cartesian dualisms that situate nature and society as separate spheres of analysis. Moore seeks to broaden and enrich world-systems analysis by integrating ecological systems within historical social science. The analysis of capitalist world-ecology is not simply a bridge built between society and environment-nature-ecology but a rethinking of the relationship between these two spheres which emerged from enlightenment thought. Using ecosystems as a foundation, social processes can be seen in a new light and capitalism analyzed as a configuration of human and extra-human natures. A full volume would be required to demonstrate the innumerable ways these relations manifest in the production of the coalfields and coal communities.

This article narrows the macro-scale analysis of capitalist world-ecology in order to illuminate processes on the ground in Central Appalachia and is based on field research done in West Virginia. In focusing on this region as opposed to the history of coal in the capitalist world-ecology and the production process, we have honed in on the transition in the coalfields of central Appalachia since the late nineteenth century. The capitalist world-ecology framework encompasses both the processes of the world economy and the reproductive capacities of people situated in places. We aim to transcend these spheres, articulating a limited discussion of the reproductive aspects of labor as well as the world-economic influences on production processes, including those of the coalfields and miners' participation in that process. As such, the diverse reproductive processes of coal communities (and the diverse social groups within this categorization) are largely absent from the text.

Our task in this article is two-fold. First we aim to understand changes in the coalfields from a world-ecological perspective. This requires us to look closely at labor, as coal required large quantities of labor in the late 19th century and later this labor migrated out of the coalfields in large numbers as the production process transitioned to less labor intensive production. This leads to the second task of this article which is to understand how labor participated within the world-ecology from a micro-level at the coalface to the macro-level within world-economic processes. For this reason, reproductive processes in the coal camps and contemporary conditions of reproduction largely remain outside the present analysis, even while these activities are central to understanding socio-ecological change.

The focus on transformations in the production process within a world-ecological context highlights the significance of workers situated in a place, e.g. central Appalachian coalfields. Towards this end, the productive and reproductive processes of coal miners are central. The broader goal of the paper is to understand world-ecological transformations, of which workers are only a part. Further research is needed on the reproductive capacities or informal economies of labor within the coalfields that can illuminate the resilience of these mountain peoples. This research would highlight labor's participation in the reproduction of capitalism as well as the reproduction of communities and the dynamic interactions between these spheres of action.

Nature, Society, and Resource Exhaustion

"'Nature is [not] a passive substance upon which humanity leaves its footprint. Rather, it [is] an inclusive and active bundle of relations formed and re-formed through the historically and geographically-specific movements of humans with the rest of nature" (Moore 2011b: 119). Once we internalize the capitalist system within earth as an ecological system, questions once obscured take form. This is particularly relevant to the study of spatio-temporal dynamics in the world-system. Understanding the spatio-temporal dynamics of a socio-ecological bundle of relations on the scale of the world-economy is a difficult project. We seek to make sense of these dynamics at the regional and local scale, always maintaining awareness of how these dynamics are fundamentally constituted by and constitutive of activities occurring at a broader scale. Looking at a small component of the larger world-ecology, we can see how each local history comprises part of the larger history of the capitalist world-ecology.

The biogeophysical aspects of coal are interrelated with human natures. As Marx (1978) argued, humans work on nature and nature simultaneously works on humans. While it is easy to relate the ways humans work in and through nature in terms of labor, as most scholarship does when it discusses labor conditions in the coal fields, this leaves out important elements of the ways that nature works in and through humans. In the coal industry the health and safety of miners is the primary interface through which nature works on humans. Diseases such as black lung occur after only a few years in the mine, due to constant exposure to coal dust and particulate matter. Coal mines have varying properties that influence the work environment; for example some mines are more gaseous than others (Long 1991). As time has passed, the socio-ecology of production has dispersed nature's work on humans into the generalized environment. Today black lung and other respiratory diseases are experienced in communities located near mountaintop removal sites and are not limited to miners (Burns 2007; Hendryx 2009; McCoy 2014; see Table 1).[3] The following section articulates the socio-ecological relations in the coalfields of southern West Virginia through the organization and conditions of production.

West Virginia's Socio-Ecological Relations

Coal is a fundamental mineral for the world-economy, supplying the energy resource for electricity production and steel making. West Virginia is currently the second largest producer of coal among the states (EIA). Mining companies moved to central Appalachia's rich bituminous coal deposits after anthracite coal veins were exhausted in Pennsylvania in the nineteenth century (Simon 1980; see Figure 1). The resource dependency of West Virginia has been extensively studied for its labor exploitation and more recently the devastating environmental impacts of mountaintop removal. In this section of the article, we seek to integrate histories of labor exploitation within a narrative on the bundle of human and extra-human natures in this region as elements constituting and constituted by the world-economy. In order to make sense of the processes operating in West Virginia, we look at the socio-ecological organization of extraction in the coalfields with specific attention to the phase of mountaintop removal that emerged in the 1970s. We argue that the exhaustion of organizational structures of extraction requires a reorganization of socio-ecological relations in order to liberate accumulation. The scaling up of extraction exhausts socio-ecological relations of production pushing the energy frontier to new

[3] Detailed maps of the human costs of mountaintop removal outlining population change, cardiovascular disease, lung cancer, and other ill effects of MTR can be found at: http://ilovemountains.org/the-human-cost.

sources and regions. Before addressing the more contemporary period, we discuss the geographic qualities and previous socio-ecological organization of mining in West Virginia. We begin with the labor history of coal since historically this was the predominant principle governing the relations of production and the central focus of scholarly research.

Labor and the Socio-Ecological Regime Prior to Surface Mining. West Virginia's economy was historically dominated by the coal industry. Until 1986, West Virginia was the largest producer of coal in the country (EIA). Today, West Virginia produces 17% of the coal produced in the United States (EIA 2013). However, it leads in the production of bituminous coal. This coal has been used for electricity production and steel-making. In steel production, central Appalachian coal is ideal, as it burns at and sustains higher temperatures (Goodell 2006). High quality coal seams in the oldest mountain chain in the world are located closer to the surface than in many other areas due to thousands of years of erosion. As new methods of extraction, competing regions (e.g. Powder River Basin in Wyoming), and new energies became economically viable, West Virginia's centrality in coal has declined.

Figure 1. Types of Coal

Types of Coal	**Definition and Use**
Anthracite	Has highest carbon content, 86-98%. Most of which is found within Pennsylvania, many deposits have been exhausted and it has largely fallen out of use.
Bituminous • Metallurgical or Coking Coal • Steam Coal	Most plentiful and commonly used, especially for industrial purposes. Carbon content is 48-86%. Metallurgical or coking coal is used for the steel industry. Steam coal is used primarily to generate electricity
Subbituminous	Cleaner burning coal but with a low carbon content of 35-45 percent. Found mostly in Western states and Alaska.
Lignite	Has the lowest carbon content, 25-35%. Used for electricity generation.

Source: Energy Information Administration

The history of coal production in West Virginia begins with the wide-spread, large-scale underground mining of bituminous coal. This labor intensive production exploited large numbers of cheap immigrant workers who migrated into the region in the late nineteenth century (Corbin 1981; Lewis 1987; Trotter 1990). Between 1880 and 1920, the population in the southern West Virginia coalfields nearly quintupled from 93,000 to 446,000 (Lewis 1993: 300). Its geographic proximity to population centers in the east was important to industrialization in the United States, both in supplying labor to the coal industry and energy to urban centers. There was a geographic consolidation of capital, labor, and resources that situated central Appalachia socio-ecologically within a developing world-economy organized under an emergent U.S. hegemony.

As the principal source of coal, West Virginia was central to providing the coal that generated seventy-seven percent of the United States' energy during the late 19^{th} and early 20^{th} century (Long 1991). The organization of production at this time occurred using a room and pillar method with two people involved in the extraction of coal. This form of production allowed miners to know the sights, sounds, and scent of the mine, the 'feel' of the mine, and was facilitated by a sufficient level of independence that permitted miners to assess risks themselves (Goodrich 1925; Dix 1988; Andrews 2008). Miners' intimate knowledge of the mountain enabled them to anticipate dangers such as damps, cave-ins, floods, and other hazards.[4] Miners' relationship to the earth they worked with occurred through the interface of the tools of the trade, enabling them to understand the tacit qualities of the mountains they mined. While laboring for companies with production quotas, miners had the autonomy from oversight to work with nature to extract coal while maintaining their personal safety (Amsden and Brier 1977; Simon 1980; Dix 1988). This organization of production quickly changed with the mechanization of the mines in the 1930s.

The socio-ecological organization of production in the region, both underground and on the surface was dramatically altered with the emergence of mechanization in the coalfields. Mechanization emerged to increase the rate of extraction and as a means of controlling labor (Dix 1988). Inside the mines, miners no longer had control over production as mining companies replaced workers with machinery. Machines such as the undercutting machine delivered 200 picks per minute at the face of a coal seam, doing the work of tens if not hundreds of men employed by mining companies (Long 1991). The machinery eroded worker autonomy since workers were no longer owners of their own tools. Further, the noise of the machinery eliminated an important form of knowledge that kept miners safe. This period saw employment in the mines decline as production skyrocketed (Perry 1984; Maggard 1994). Later, the introduction of the continuous miner in West Virginia eliminated thousands of jobs, with employment dropping from 127,304 in 1950 to 40,513 in 1970 (U.S. Bureau of Census 1950 and 1970; cited in Lewis 1993). The socio-ecology of hand mining was exhausted as industrialization proceeded apace and mechanization facilitated high rates of extraction that removed large numbers of workers from the mines.

The reorganization of socio-ecological relations meant capital controlled more of the production process and people had less control over their labor and livelihood. Above ground, coal companies gained control over the region through a consolidation of land ownership, either directly or through land-holding companies (Morrill and Wholenberg 1971; Bradshaw 1992). "Syndicates of northeastern bankers and industrialists accumulated vast tracks of coal lands by

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[4] Damps were areas where gases and vapors would collect due to lack of ventilation in the mines. Three types of damps existed. Firedamp where methane concentrated and caught fire when mixed with five percent oxygen. Whitedamp was the least common and consists of carbonic oxide gas concentrates after a firedamp explosion or from routine blasting during mining. Blackdamp is an atmosphere deficient in oxygen and was common in the unventilated mines. See: Long 1991.

reorganizing and consolidating numerous small-holdings into fewer large ones" (Lewis 1993: 300). Small landowners sold their land for fifty cents or one dollar an acre, were the subject of legal traps, and others signed broad form deeds that allowed companies to extract "by any means desired" (Gaventa 1978; Reece 2005; Bell and York 2010). Coal companies came to own 90% of the land in four of the five counties with the most coal (Appalachian Land Ownership Taskforce 1983).

With the majority of land under the ownership of coal companies, companies were able to foster worker dependency on the mines, as subsistence agriculture was largely replaced by company-owned coal camps far from population centers that had the civic liberties afforded "ordinary urban centers" (Gaventa 1980: 86; Lewis 1993; Maggard 1994). This made workers dependent on the mine for a job as well as everyday needs: company-run stores only accepted 'scrip', a form of currency each mining company issued in lieu of actual money (Gaventa 1980; Bradshaw 1992). Mechanization meant the decline of real wages and exacerbated poverty through the forced use of company stores and their unique scrip in the coal towns, where prices were frequently twice as high as outside the camps (Fishback 1986; Lockard 1998; Cook 2000; Andrews 2008; Bell and York 2010). This period is marked by an organization of socio-ecological relations that places power definitively within the hands of the coal companies. This power extended over the bodies of women whose coerced sexual labor was known as *esau scrip*. This form of scrip found women reducing their family's debt or obtaining food through sexual relations with company men, whether from the town store or mine bosses (Kline 2011). The totalizing control companies had over workers generated immense profits and fueled the industrialization of the United States that eventually manifested in its hegemony of the post-World War II world-economy (Wheeler 1976; Simon 1980; Podobnik 2006). Whether above ground or below, workers were losing control over production during this period.

Facing a loss of control over the labor process, unions emerged in the 1930s after a prolonged struggle with the state and mining companies (Gaventa 1980). Unions were a way for miners to gain partial control over their work and the negative health effects of the profession after losing their autonomy in the mines. The mechanization of the mines generated a socio-ecological rift between miners and the work they did. This rift meant a loss of autonomy and of knowledge of the mountain. The shift from underground hand mining where workers had a tacit knowledge of the mountains to mechanized extraction and the loss of that knowledge meant facing new dangers in the mines and the near total control of the coal towns. In response to these forces, workers organized. The culmination of the tensions surrounding the right to unionization manifested in the Battle for Blair Mountain in West Virginia in 1921.

The Battle for Blair Mountain was the second largest civil uprising in U.S. history, second only to the civil war (Blizzard 2004; Shogan 2004). Over 10,000 miners stood their ground against coal company mercenaries over a five day period. The Battle for Blair Mountain was one of the most important events in U.S. labor history, bringing the United Mine Workers of America's (UMWA) fight for human rights to the coalfields. Miners were specifically concerned with the right to organize, political representation, prohibition of blacklisting, and making sure that the check weighman (the person responsible for weighing the coal tonnage pay rate) was from the union and not the company (Dix 1977; Blizzard 2004). There was a significant decline in union organizing in the aftermath of the Battle for Blair Mountain but just over a decade later unionization gained ground. The struggle was enacted with the passage of the National Industrial Recovery Act, or the New Deal, in 1933 that for the first time protected workers' rights to unionize (Bradshaw 1992).

Through the booms and busts of the 1930s to the 1960s and the great migration out of Appalachia, the union remained an important organizing mechanism for miners and communities in the socio-ecology of the coalfields. When Miners for Democracy emerged in the late 1960s, the union had been colonized by corrupt leaders answering to the coal companies. Miners for Democracy were an organized front that challenged entrenched political control over the union (Clark 1981). Miners for Democracy sought to regain control over the union, ousting corrupt leaders and replacing them with rank-and-file members of the union (Brisbin 2002). In this effort, they were successful in securing benefits for Black Lung and the diseases' management (Chomsky and Montrie 2012). Here we begin to see a struggle playing out between miners and a concern for their health on the one hand and the companies' maneuvers attempting to undermine financial responsibility to those miners. The socio-ecological dynamic revolves around the health and safety of miners and their ability to confront capitalist power.

Neoliberal Extractions and the Exhaustion of Socio-Ecological Relations in Central Appalachia

The 1970s saw the globalization of the coal industry through restructuring around global coal markets, internal consolidation and mergers that formed energy and mining conglomerates (Perry 1984; Seidman 1990; Mitchell 2011). For example, Gulf Oil Company acquired Pittsburgh and Midway Coal Company and Conoco merged with Consolidation Coal Company (Martin 1981). Historically the coal industry had been limited by transportation costs associated with this low-value bulky commodity (Pomeranz 2000; Podobnik 2006; Mitchell 2011). Newly created conglomerates consolidated to boost economies of scale in the extractive industries both in terms of price and return on investment (Perry 1984). Since the 1970s, there has been a doubling in the international trade of coal that has been facilitated by rising oil prices and the increasing the use of sea-shipment for transporting coal (Ellerman 1995). From 1960 to 1990 coal experienced its most dramatic globalization, with seaborne trade increasing from 145 billion ton-miles in 1960 to 1,849 billion ton-miles in 1990 (Ciccantell and Bunker 2002). The transformation of the coal industry through globalization meant that coal could be shipped throughout the world and was now competing internationally rather than regionally. Appalachian coal was at least partially insulated from these globalizing conditions due to its high quality metallurgical coal used in steel production. However, new strategies of extraction were essential for the industry to compete and internal conditions in Appalachia were implicated in the exhaustion of the socio-ecological conditions of mechanized production that led to the scaling up of surface mining in the form of mountaintop removal mining.

The exhaustion of the socio-ecological relations in the coalfields was at its nadir in the 1970s. The world-economy was in crisis due to rising oil prices and stagflation (Harvey 2005). Within the coalfields, the crisis of profitability was due to challenges from miners and new regulations on the industry. These challenges led to the reorganization of coal production in central Appalachia in the form of extensive surface mining. The introduction and expansion in the use of mountaintop removal mining dramatically changed the socio-ecological relations in central Appalachia. This form of mining uses explosives to literally blow the top of a mountain away to expose coal seams, while overburden (soil and rock) is pushed into surrounding valleys (see Figure 3).[5] Thousands of miles of streams and waterways have been buried, causing changes in watersheds that result in flooding (EPA 2005). Water, soil, and air contamination arise from the toxic chemicals used in blasting operations and the release of heavy metals naturally present in the earth.

The implementation of the United States' first environmental policies such as the National Environmental Protection Act (1970) and the creation of the Environmental Protection Agency (1970) emerged at the same time mountaintop removal was initiated in West Virginia. The unexpected effect of 1970s environmentalism was a surge in policies that inadvertently promoted the larger-scale mechanization and use of surface mining. The Mine Health and Safety Act of 1969 as well as state and federal surface mining laws imposed new requirements on underground operations such as inspections, training, and surveillance in an effort to reduce coal dust and increase ventilation (Perry 1984; Ellerman 1995). New regulations meant that coal companies had to internalize the costs associated with the health and safety consequences of underground coal mining.

Coupled with new regulations of underground mining was the federal government's channeling of funds towards the mechanization of the coal industry in the 1960s war on poverty that created the Appalachian Regional Commission (Ziliak 2012).[6] Together these factors pushed the industry towards the large scale use of surface mining, which minimized the health and safety issues present in underground mining. The Appalachian Regional Development Act of 1965 commissioned a *Study of Strip and Surface Mining in Appalachia* (Udall 1966) that justified the use of strip mining in the name of development, and dismissed its negative environmental impacts by claiming that reclamation of sites would make them viable for future uses in agriculture, industry, recreation, and commerce.[7] Development ideology of the time saw nature as an interchangeable entity where a dynamic mountain ecosystem could be destroyed through

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[5] The typical blast on an Appalachian strip mine is ten times the 4000 pounds of ammonium nitrate (mixed with fuel oil) used in the Oklahoma City bombing (Reece 2005).

[6] The Appalachian Regional Commission received federal funds for infrastructure development and innovations in the coal and timber industries in addition to social safety nets and early education.

[7] Reclamation of abandoned strip mines has been partial at best. Companies are responsible for setting aside money as a bond for reclamation. In most cases, coal companies reseed newly barren landscape, in which few trees are able to regrow (Burns 2007).

the removal of soil, flora, and fauna and turned into a site for economic investment. Although the Appalachian Regional Commission study (1964) highlighted the varying degrees of environmental destruction associated with surface mining, it simplified nature into something that can be easily managed by humans and failed to see complex ecological relations that sustained life in the region.

During this period, the coal industry faced a crisis of profitability that was resolved through the help of grants and loans associated with the Appalachian Regional Commission's objective of generating sustained economic development. In the 1970s the U.S. steel industry was in decline and increasing competition from international markets that led to an overall decline in demand for coal (Yarrow 1990). These conditions pressured companies to transform the coal industry of the central Appalachia. Strategies employed by companies included mechanization, lobbying for fewer environmental and safety regulations on the industry, subleasing to smaller coal operators, and the introduction of production bonuses (Yarrow 1990). The culmination of these strategies was the introduction of mountaintop removal coal mining.

The first mountaintop removal (MTR) mine began operating at the Bullpush Mine in 1970 in West Virginia (Burns 2007). The practice became generalized in the 1980s after the passage of Surface Mining Control and Reclamation Act of 1977 (SMCRA). SMCRA effectively legalized the destruction caused by strip mining by recognizing mountaintop removal as an approved mining technique and thereby not requiring special approval for MTR operations (Montrie 2003). Further, contradictory definitions of 'fill material' in the Clean Water Act led operators to assume in their favor, that they needed a general permit rather than a more stringent one (Copeland 2013). In 2002 with pressure from the coal industry the Bush Administration redefined mining waste as 'fill' to allow the coal industry to fill in valleys and waterways with the overburden of surface mining from MTR (Devine 2004; Burns 2007; Shapiro 2010; Chomsky and Montrie 2012).

For labor, the use of mountaintop removal spelled defeat for the United Mine Workers of America. In 1984 one company, A.T. Massey, refused to sign the UMWA's national contract negotiated through the Bituminous Coal Operators' Association (BCOA). The BCOA is an institution charged with mediating relations between coal operators and miners. The UMWA and coal companies had historically both agreed to the conditions of the contract. When A.T. Massey refused to sign the contract negotiated through the BCOA, it effectively signified that they were no longer willing to work with the union. A.T. Massey then proceeded to buy out union mines in southern West Virginia only to close them and later re-open them as non-union mines (Brisbin 2002). Frequently these mines employed the same supervisors and overseers. Massey proceeded up and down the Coal River Valley of southern West Virginia buying up union mines, closing them down, and later reopening to a non-union workforce. The consequence of Massey's union-busting was the diffusion of these practices to other coal companies and a broad defeat of the union.

The union was the backbone of the communities of central Appalachia and with the breaking of the union, communities no longer had strong unified leadership to represent their interests. Historically the workers were situated in an antagonistic relationship to companies, but during this period the union sided with the companies by supporting mountaintop removal practices in an effort to save jobs and retain the benefits of a union (Burns 2007; Chomsky and Montrie 2012). As mountaintop removal became entrenched, employment in the coalfields

Figure 2. Mountaintop Removal vs Non-Mountaintop Removal

	Life Expectancy change: 1997-2007	**Deaths from Cancer per 100,000: 1999-2007**	**Deaths from Chronic Cardio. Disease per 100,000: 1999-2007**	**Poverty Rate (%): 2010**	**Population Change (%): 1980-2010**
U.S.	1.51	165	201	15.3%	36.3%
MTR-Counties					
Boone	-1.15	220	265	19%	-19.2%
Fayette	0.5	203	246	23%	-20.4%
Lincoln	-0.46	214	272	24%	-8.5%
Logan	-0.82	239	293	22%	-27.5%
McDowell	-0.73	218	326	34%	-55.5%
Mingo	-0.6	224	306	24%	-28.3%
Clay	.44	230	218	26%	-16.8%
Raleigh	1.02	167	228	18%	-9.3%
Wyoming	-1.21	199	308	20%	-33.8%
Non-MTR Counties					
Barbour	0.58	171	257	18%	-0.5%
Brooke	-0.12	168	226	15%	-22.6%
Doddridge	0.52	173	271	21%	9.8%
Gilmer	.41	175	256	29%	3.5%
Marshall	1.16	168	241	17%	-20.4%
Monongalia	0.81	165	216	22%	27.6%
Ritchie	-0.08	175	298	20%	-8.8%
Taylor	0.89	173	256	20%	1.8%
Wood	.93	162	289	16%	-7.2%

Source: *The Human Cost of Coal* ilovemountains.org

dramatically declined. "The union work force in that area (West Virginia and Virginia) has shrunk from approximately 58,000 in 1980 to 17,200 in 1987…Employment here has been particularly hard hit, shrinking by 83 percent in the past decade" (Yarrow 1990: 39). Overall "between 1979 and 2003 more than half the regional [Appalachian] mine workforce was 'wiped out'" (Moody 2007: 70). Company efforts to break the union included paying non-unionized workers higher wages in a precarious moment when labor was already suffering from unstable coal markets and a move towards less labor intensive production.

The organizational structure of MTR has expanded the scale and impact of mining and dramatically altered socio-ecological relations in the coalfields. According to a 2009 study by Appalachian Voices (2009), surface mining has disrupted over 1.2 million acres of land in central and southern Appalachia. Of the nine counties in West Virginia with the most MTR activity, seven had a declining population of between 16.8 and 55.5 percent from 1980-2010 (see Figure 2). Declining employment, the depopulation of the coalfields, the breaking of the UMWA, the elimination/rewriting of important regulatory measures, and the geographic management of MTR such that highways obscure the reality of the landscape and keep the scale and impact of mining hidden from the eyes of those who might have political power are all important elements of the socio-ecological relations of MTR's organizational structure. The geographical management of MTR means that West Virginia's citizens living outside southern WV are not fully aware of the extent of disruption associated with MTR mining.

Figure 3. Mountaintop Removal Operation

Courtesy: ilovemountains.org

Technologies of mass extraction (see Figure 3) used in mountaintop removal mining include thousands of pounds of explosives, machinery costing over twenty-five million dollars, and massive coal trucks that transport illegally overweight loads of coal.[8] With thirty years of mountaintop removal in central Appalachia, thick coal seams have become scarce, and the economic viability of MTR practices is in crisis. The exhaustion of this organization of production is a product of the over-productive power of the extractive technologies and the underproduction of coal through geological time. Initial windfalls from mountaintop removal where fewer than 10 miners could extract the coal from a single mountain is giving way to a paucity of mountains with sufficient coal seams to justify the use of the practice.

Widespread use of MTR reflects global conditions of production in a neoliberal period where time and space are diminishing in significance as technology and transportation networks advance. The expectation of this "annihilation of space by time" situates each region in a global network of socio-ecological relations that coerce regions into specializing in their comparative advantage commodity (Harvey 1990). In central Appalachia, coal is the commodity in which the region is comparatively advantaged. Coal reserves are being relatively exhausted as time and space contract and coal from the Powder River Basin in Wyoming challenges the supremacy of Appalachian coal. Further challenges include the emerging sector of natural gas, which is promoted as a cleaner burning substitute for coal in electricity production.

Policy provisions seeking to reduce carbon dioxide, sulfur, and mercury emissions by recent administrations have pressured the coal industry to locate new reserves that burn more cleanly. Appalachian coal has a higher sulfur content, and the industry is reluctant to spend money on emissions technology and green innovations. Thus, the Powder River Basin has emerged as a competitive region where sulfur content is lower (Bell and York 2010). A significant shift occurred with the passage of revisions to the Clean Air Act in 1990, which limited sulfur emissions from coal-fired power plants and has since boosted Powder River Basin coal demand by 6% annually (Learn 2012). Further, railroad networks were needed to bring coal from the Powder River Basin to market and several capacity expansions have brought coal as far east as Massachusetts (Goodell 2006; Union Pacific 2006). The capacity limitations of the railroads attenuated the transition away from Appalachian coal. By 2011, Wyoming coal accounted for 20% of US coal output while all of central Appalachia's coal production accounted for only 17% (EIA 2013). Despite being sub-bituminous coal, Wyoming coal's lower sulfur content makes it a better option for electricity production given rising environmental standards on coal-fired power plants. These favorable socio-ecological conditions make operating costs in the Powder River Basin significantly less than in central Appalachia. In Figure 4, we show operating costs for Arch Coal, demonstrating the significant cost savings of extraction in the Powder River Basin.[9]

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[8] The dragline is a 20-story machine that takes years to assemble and can move more than 110 cubic yards of earth in one scoop of the dragline's bucket (Fox 1999; Burns 2007). Overloaded coal trucks commonly exceed 220,000 pounds with a legal limit of 120,000 pounds (Lexington Herald Leader 2005).

[9] Arch Coal, Inc. was chosen for its clearly outlined operating costs divided according to the two regions under study in this article.

Figure 4. Operating Costs for Arch Coal

	Central Appalachia	Powder River Basin
2005	$43.32	$7.30
2006	$46.10	$8.67
2007	$44.34	$9.35
2008	$50.08	$10.28
2009	$55.38	$11.43

Source: Arch Coal, Inc. Annual Reports

In electricity production, Powder River Basin coal is definitively cleaner burning than coal from central Appalachia. More steam coal (the type used in electricity production) is needed overall when using sub-bituminous coal but the vast quantity of coal extracted in the Powder River Basin has led to a decline in demand for steam coal from central Appalachia (McIlmoil et al 2013). The Powder River Basin is the largest reserve of sub-bituminous coal in the United States and has thick coal seams of as much as 200 feet (EPA 2004). Further, the relatively flat landscape's surface makes Wyoming coal easier to access through large-scale surface mining and transport. The socio-ecological conditions of production in Wyoming, the largest producer of coal since 1986, make labor productivity much higher than in central Appalachia (where labor productivity has been declining). In 2011 Wyoming had only 234 underground miners, out of a total mining force of 7039 (EIA 2012). Compare this with West Virginia's larger labor force and several times smaller production capacity (see Figure 5). The flat landscape of Wyoming and railway competition contributes to lower transportation costs as compared with West Virginia's mountainous terrain and relatively high transportation costs (Goodell 2006; Baruya 2007; International Energy Agency 2011). Conditions in Wyoming thus favor the movement of production away from West Virginia and central Appalachia, providing further evidence of the relative exhaustion of central Appalachia.

Figure 5. Coal Employment and Production 2008

	Employees	Wages in millions	Underground Production*	Surface Production	Total Coal Production
West Virginia	20,454	$1516.11	88,369	69,409	157,778
Wyoming	6843	$529.14	3501	464,143	467,664

*thousand short tons

But central Appalachia remains integral to domestic and international coal production, reworking its location in the capitalist world-ecology. Just as anthracite's relative exhaustion in Pennsylvania in the late 19th century saw the shift in coal production to lower energy content bituminous coal in central Appalachia, high sulfur content bituminous coal of central Appalachia is being largely substituted for sub-bituminous coal from Wyoming coal for use in electricity production. As steam coal production declines in central Appalachia, met coal (used in metallurgy) has emerged as the primary type of coal produced there. International demand for met coal, which burns evenly and maintains a high temperature needed in the production of steel, has propped up the coal industry of central Appalachia. West Virginia exported 45.5 million short tons of met coal in 2011 (McIlmoil et al 2013). This accounts for nearly a third of West Virginia's total coal production.

China's market dominance in demand for coal is significant in determining Appalachian coal prices and volumes (Kasey 2012). China imported nearly 70 million short tons of metallurgical coal in 2011 but has recently shown signs of a waning economy (Sewell 2012). As China's economy falters, market demand for steel is declining. Chinese demand for met coal was down by fifty percent in 2012. Appalachian coal prices fluctuate strongly with international prices since Appalachia competes with global suppliers (International Energy Agency 2011). As the shockwaves of China's economic downturn made their way to central Appalachia, the coal industry was forced to reorganize in order to remain globally competitive. "Understanding their [railroad's] interdependency with Appalachian coal and a strong export market, at the end of November both CSX and Norfolk Southern railroads announced they would cut rail tariffs by approximately 15 percent to help exports of metallurgical coal remain competitive" (Sewell 2012).

The exhaustion of the coalfields of central Appalachia is further marked by declining labor productivity, despite high levels of production and record low levels of employment. With rising coal prices and international demand for met coal, it is still feasible to continue using MTR in central Appalachia with declining labor productivity (McIlmoil et al 2013). However, international coal prices are stagnating as the Chinese economy falters (International Energy Agency 2011). Labor productivity peaked in central Appalachia in 2000 and has been declining since (McIlmoil et al 2013). Declining labor productivity marks the relative exhaustion of the organizational structures surrounding the most recent phase of the current ecological regime. As these organizational structures reached their limits, new socio-ecological relations governed by conditions of the world-economy have shifted the centrality of Appalachian coal, the specific type of coal produced, and geography of coal consumption.

Conclusion

We have provided a socio-ecological analysis of the webs of social and ecological relations occurring in the coalfields of the United States. Over time, the relative costs and benefits of particular modes of production are constituted by natural resources limits and other ecological constraints as well as by the social and economic factors that are extra-local in nature. There has been a correlating increase in the technological capacity of coal production as the world-economy expands. Mountaintop removal's dragline technology increased the scale of extraction in Appalachia but has recently run up against declining labor productivity. Further, competing regions and energies influenced a shift in production to regions with thicker seams of cleaner burning coal that is easily transported across a relatively flat landscape. The biogeophysical aspects of coal production, paired with the socio-ecology of the capitalist system have pushed the coal commodity frontier towards the Powder River Basin while leaving behind a scarred landscape. The terrain of West Virginia is being leveled as metallurgical coal continues being produced for predominantly transnational markets in East Asia. We have found that while the major coal producing region of the United States has shifted, Appalachian coal's relative exhaustion has been tempered by specialization in metallurgical coal and favorable global market conditions.

While historical research on the coal fields focuses on labor and contemporary research largely focuses on environmental destruction, we have made the case for integrating the social and ecological components of coal extraction in central Appalachia by highlighting the ecological elements surrounding extractive labor historically and the global conditions surrounding the biogeophysical conditions of contemporary coal production. The interweaving of human and extra-human natures into an organizational structure of extraction eventually reached its limit, requiring a reorganization of these socio-ecological relations that would free capital for further expansion. As labor declined in the centrality of coal exploitation, the socio-ecological relations in the coalfields shifted to become more centered on globalized markets.

The viability of coal in West Virginia's future is under debate as labor productivity decreases and more effort is required to extract lower quality coal seams. We have argued that as this exhaustion occurs, the energy frontier is moving to new regions. The Powder River Basin has emerged as the predominant region of coal extraction. It has been the largest producer of coal by a factor of more than three. The significance of this shift cannot be underestimated. However, competitive energies have recently become economically viable. Natural gas is increasingly used in the production of electricity in the United States. A detailed analysis of natural gas in relation to central Appalachia is beyond the scope of this paper, and in the future will provide further breadth to the current subject of inquiry.

In focusing on the transformations in the coalfields from a world-ecological perspective, we have attempted to analyze human and extra-human natures as part of a dialectical relation. In focusing on central Appalachia, we constructed an artificial boundary around a region in order to emphasize events occurring in a place and the conditions of the world-economy so as to highlight the material processes that generate exhaustion and transformation in the energy sector more broadly. In doing so, many aspects of the socio-ecological relations of the coalfields remain outside the scope of this article. Further research on the informal economies, subsistence practices, and reproductive aspects of coal communities is needed to highlight the struggles of resistance and resilience among the peoples of the coalfields and in what ways they contribute to capitalist socio-ecological processes.

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