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Geophysical Agency in the Anthropocene: Engineering a Road and River to Rocky Mountain National Park

Abstract

Proponents of the Anthropocene epoch posit that human activities now powerfully influence the Earth's governing systems. Many environmental scholars have offered alternative concepts for this new geologic epoch to challenge its outward anthropocentrism and tendency to flatten the diversity of the world's people into a single planetary humanity. But in doing so, these critiques distort a more distributive and systemic understanding of agency. This article suggests that *geophysical agency* offers historians a more useful and precise conceptual term for interpreting connections among human ideas and actions, material systems, and geologic change. One way that human undertakings have functioned geologically has been by moving earth and inscribing asphalt over an extended chronology of the Great Acceleration. Examining 1930s highway construction in Colorado's Big Thompson Canyon offers a window into some of the historical processes that have defined geophysical agency.

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On May 28, 1938, some five hundred Coloradans gathered at the mouth of the Big Thompson Canyon in the foothills of the Rocky Mountains to celebrate the formal dedication of US Highway 34. The modern road traced a ribbon of asphalt through this narrow gorge alongside the Big Thompson River from the low-lying town of Loveland to the high-country reserve of Rocky Mountain National Park. Around 3 p.m., throngs of citizens and dignitaries congregated in front of a raised platform near the banks of the river. On the stage, engineer Charles Vail, chief designer of the road project, and Governor Teller Ammons offered an opening address and asked their audience to consider how this "engineering dream" would draw ever-increasing tourist traffic. Afterward, they led the crowd to a specially constructed gate at the craggy walls of the canyon entrance to close the ceremony. As mountains loomed overhead, Vail and Ammons applied a 3-foot-long key to an equally oversized padlock, suggesting their immense powers to unlock this route for future automobile travel. "When we consider that it took nature thousands of years, maybe hundreds of thousands, to make this beautiful can[y]on," Governor Ammons boasted, "we can realize that we are making progress when we see this fine highway thru [*sic*] the can[y]on."[1]

Ammons's speech during the dedication ceremony reveals a stark judgment. He compared the engineering powers of technocrats and construction laborers, who had erected a paved road within the canyon over mere years, to the erosive powers of geo-fluvial activities that had formed the canyon itself over millennia. From the end of the last Ice Age—the final glaciation period of the Pleistocene epoch—into the present, the Big Thompson River had carved and sculpted its watercourse through the eastern slopes of the Rockies. From 1932 to 1938, however, Vail and the Colorado State Highway Department oversaw road-building crews as they chiseled through layers of granite, gneiss, and other geologic formations to construct the modern highway. Both entities were forces of nature in the governor's mind, and both moved enormous amounts of rock and rubble in the process. By equating these road architects to river effects, Ammons was in essence bragging about a nascent form of human geophysical agency that we might today identify with the concept of the Anthropocene.[2]

Capturing the idea that humans have collectively become a geologic force, atmospheric chemist and Nobel laureate Paul Crutzen proposed that the Earth had entered into a new geologic epoch—the Anthropocene—in a 2000 newsletter for the International Geosphere-Biosphere Programme.[3] In one sense, the Anthropocene calls attention to the unprecedented scale, scope, and degree of anthropogenic impacts on the global environment.[4] Postcolonial scholar Dipesh Chakrabarty asserts that recognizing humans as one of the great forces of nature, in another sense, dissolves the

Figure 1. The 1938 dedication ceremony for the Big Thompson Canyon highway, with Governor Teller Ammons (second from right with key) and engineer Charles Vail (far right). Credit: *Fort Collins Express-Courier*, May 29, 1938. Copyright of *Fort Collins Coloradoan*. Used with permission.

methodological boundaries between human history and Earth history.[5] Ethicist Clive Hamilton and his coauthors claim the Anthropocene demands that scholars also consider the aggregate effects of human activities a "telluric force, changing the functioning of the Earth as much as volcanism [or] tectonics."[6] During the last two centuries, from the start of the thermo-industrial revolution and intensifying over the post-1945 period that historians J. R. McNeill and Peter Engelke have called the "Great Acceleration," human numbers and activities had become one of the major drivers of the Earth's biological, geologic, and chemical cycles.[7]

The Great Acceleration demarcates a stage of the Anthropocene during which the Earth has witnessed a rapid escalation of both human enterprises and global biogeochemical changes. Pivoting around World War II, technological breakthroughs merged with free market–oriented institutions to facilitate this exponential outburst. Socioeconomic trends—like primary energy use, total human population, and motor vehicle numbers—have quickly risen in lockstep with Earth-system trends—such as atmospheric carbon dioxide levels, flood frequency and intensity, and deforestation.[8] By analyzing global data sets, climate scientist Will Steffen and his colleagues observed a critical moment: “In little over two generations—or a single lifetime—humanity (or until very recently a small fraction of it) has become a planetary-scale geological force.”[9] The Great Acceleration of the Anthropocene complicates how environmental humanists understand historical agency: namely, that humans must henceforth be understood as geophysical agents.

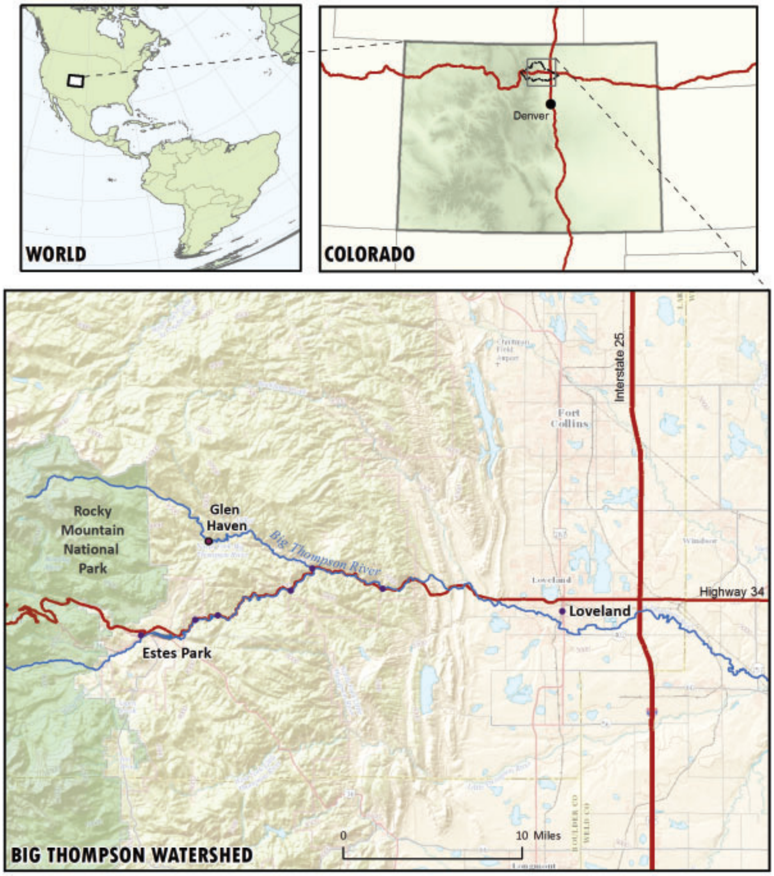
Earth-systems science can offer some guidance in negotiating this novel intellectual terrain. For example, human-induced earthmoving accelerated over the last half of the twentieth century with the construction of highways and other types of physical infrastructure, leaving behind the artifacts that have provided scientists with one plausible geologic boundary for the Anthropocene. Stratigrapher Jan Zalasiewicz and other scholars argue that global spread of modern building practices and technologies, principally defined by layers upon layers of concrete and asphalt, could remain imprinted on the lithosphere for millennia to come.[10] Indeed, landscape modifications for human uses have become so intensive and widespread that geographer Erle Ellis and his coauthors insist that more terrestrial “anthromes” now exist on the planet than biomes.[11] Primarily through industrial agriculture, mine quarrying, and, most important to this article, road building, Earth-systems scientists estimate that human undertakings during the Great Acceleration have removed, relocated, or repurposed more of the Earth’s crust than *all* other material forces.[12]

Criticisms of the Anthropocene point out that not all humans reached this earthmoving status. The cultural anthropologist Alf Hornborg contends that a different name, the “Technocene,” better acknowledges how radically variable powers to command modern technologies have inscribed social inequities across the planet. Only a small portion of the world’s people, Hornborg stresses, has possessed the industrial machines that have wrought most global changes.[13] From a Marxist perspective, human ecologist Andreas Malm observes how uneven class differences have been overshadowed by an undifferentiated humanity. Malm asserts that a more fitting label could be the “Capitalocene,” assigning culpability for planetary distress to neoliberal capitalism.[14] The environmental historian Timothy LeCain, from a neo-materialist stance, takes issue with the blatant anthropocentrism of the Anthropocene concept, arguing that it tends to reinforce the sharp modernist distinctions between humans and nature, which in many ways has justified modern environmental destruction. LeCain argues that a more reasonable term might be the “Carbocene,” as it would better recognize the powerful role of burning hydrocarbon-based fossil fuels whose consequences humans rarely comprehended, much less fully controlled.[15] All these critiques offer important perspectives on the problem of understanding the sources of Earth-systems transformations, yet neither coal nor capital, artifice nor *anthropos* alone resulted in the advent of modern humans as mass earthmovers. While none of these authors suggests a monocausal explanation for the Anthropocene, the terms that each of them favors nonetheless tend to shift agency from humans to another of the key forces at hand: technology, capitalism, or hydrocarbons.

One way in which we might ensure a more systemic historical approach, similar to Earth-system dynamics, is to frame humans as earthmovers focusing on the complex interactions of all these factors as they played out in a specific place and time.[16] Upon closer examination, the origins of certain geologic transformations appears to begin slightly earlier than the standard Great Acceleration chronology. During the 1930s highway construction in Colorado's Big Thompson Canyon, geophysical agency emerged from the entanglement of concentrated capital, technological machinery, fossil fuels, human labor, and a certain engineering mentality. Highway planners conceived of this New Deal roadway project both as a means to employ Americans during the Great Depression and to encourage automobile tourism through the convenience of modern transportation infrastructure. These New Deal work-relief programs relied on massive injections of federal monies that assisted in generating automobile-oriented landscapes. By modifying the existing geologic materials within the gorge, road-building crews not only erected a substantial thoroughfare between the canyon walls, but to this end they altered the form and function of the Big Thompson River. To accomplish this feat, highway engineers used a hydrocarbon energy regime in order to augment the biophysical corporeality of construction labor. Workers' bodies merged almost seamlessly with the fossil fuel–driven mechanical power of shovelers, bulldozers, and jackhammers, enabling them to become something akin to a geophysical force of nature.[17]

THE NEW DEAL AND NATURE

In a 1932 issue of *Colorado Highways*, Frederic Everett, the president of the American Association of State Highway Officials, emphasized the reciprocity between public roads and private cars. "Every dollar spent in road betterment makes the car worth more," Everett wrote. "The automobile industry is the largest industry, employing, in one way or another, one-tenth of the nation's workmen. It is large because it serves a public demand and because the United States is building roads."[18] In a similar piece, the leader of the American Road Builders' Association, W. R. Smith, advised that the profusion "of public money must be maintained at proper working efficiency . . . to reduce the cost of transportation as well as to facilitate the speed and comfort of travel."[19] Like many state engineering magazines,



Credit: Geospatial Centroid (2017)
Base Map: USGS National Map

Figure 2. Map of Big Thompson River and US Highway 34 in relation to the state of Colorado and the world. Credit: Chrissy Esposito and Sophia Linn, Geospatial Centroid, Colorado State University, 2017.

Colorado Highways lobbied the national administration for increased financial support during the global economic downturn of the 1930s in order to construct new highways or renovate existing ones. As these publicists believed, the viability of engineering roads would only expand with further capital investment, laying the critical groundwork for the Great Acceleration to come.[20]

In the midst of the Great Depression, the US government looked for ways to make these calls to action a reality and to put Americans back to work. In 1933, when recently elected President Franklin Roosevelt stepped into office, a quarter of the entire American workforce, some 13 million laborers, were jobless, and another quarter were seriously underemployed. Additionally, General Motors executives and other corporate elites lobbied federal policymakers to prime the economic pump with federal subsidies instead of social welfare spending. Without government intervention, Interior Secretary Harold Ickes worried that petroleum overproduction would tumble out of balance with industry demand, hurling "more and yet more oil upon an already glutted market."[21] Roosevelt, in concert with Congress, sought to provide assistance to both companies and citizens through a series of federal programs. New Deal legislation was partly composed of bureaucratic schemes for massive technological systems—such as large dam works or extensive road systems—meant to rearrange the material world in order to reinvigorate industrial capitalism.[22]

With the passage of the National Industrial Recovery Act (NIRA) in June 1933, Congress allocated a whopping $3.3 billion to bankroll earthmoving projects such as bridge construction, flood control, harbor improvement, and other types of infrastructure development. From this lump sum, NIRA included provisions that apportioned "not less than four-hundred million dollars, to be expended" toward the "Construction, repair, and improvement of public highways and park ways."[23] These funds were to work in conjunction with the Federal Aid Highway Act of 1921, which stipulated that the national legislature would match state governments, through gasoline and vehicle taxes, for highway construction. These funds would be administered to individual states through the Bureau of Public Roads.[24]

In Colorado, state highway engineer Charles Vail wanted to put federal dollars to work through road building. Governor William Adams found Vail, a two-time graduate of the University of Illinois and a skilled railroad civil engineer, well suited for the position and appointed him to the job in November 1930. Vail, an ambitious and hardheaded director, would be later characterized by an associate as "blunt, undiplomatic, tough as leather," and someone who "never dodged a fight or an issue."[25] He was also a classic technocrat who believed that technical expertise and the rational application of engineering could overcome any material obstacle. Vail used his domineering personality and equally domineering technical skills to his advantage, convincing the Colorado legislature to raise matching funds for the construction of new highways. By the time Vail was finished, he had grabbed a considerable share of federal dollars through NIRA—$6,874,530 to be exact—all of it matched by the state of Colorado to total nearly $14 million for road production.[26]

Using these funds, Vail and the Colorado State Highway Department decided that carving modern highways into the Rocky Mountains would be a sound Depression era investment. They

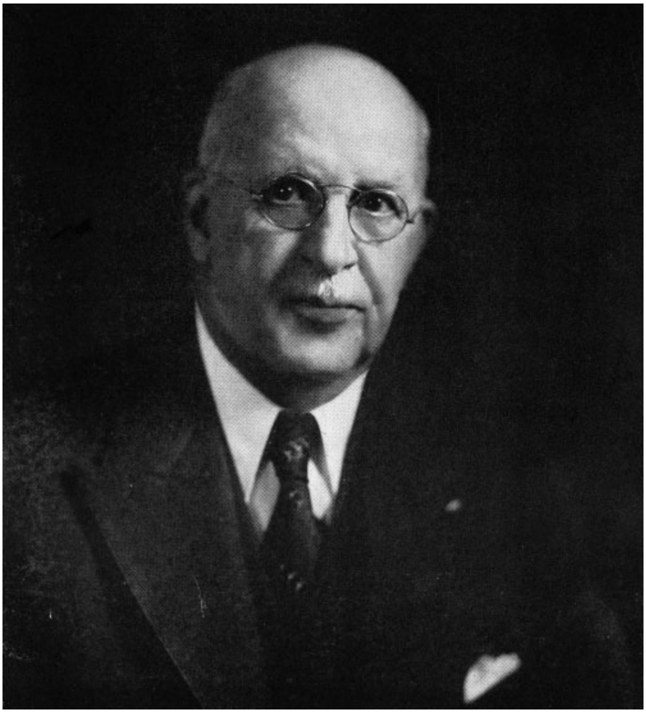


Figure 3. Charles Vail, the chief highway engineer of the Colorado State Highway Department from 1930 to 1945, orchestrated the rapid expansion of highways in Colorado on the cusp of the Great Acceleration. Credit: *Rocky Mountain Contractor*, January 12, 1938. Gemmill Library, University of Colorado-Boulder. Copyright of Associated Construction Publications. Used with permission.

developed a highway plan that would construct six major expressways leading into the Rockies, including one proposal to revamp a dilapidated gravel road within the Big Thompson Canyon. Back in the early 1900s, local business interests had financed the construction of a single-lane dirt roadway to connect Front Range cities to their high-country hinterlands. State officials upgraded the road in the following decades—mainly by widening and reinforcing—to expedite travel to the eastern entrance of the newly established wildlife preserve, Rocky Mountain National Park, founded in 1915. Yet traveling along the route still took considerable time and effort as motorists navigated the difficult features. Piloting bumpy roads, steering through hairpin curves, and honking warnings at blind bends, all made the passage uneasy for drivers and passengers alike.[27] When finished, the proposed 25-mile stretch of road—renamed US Highway 34—would place sightseers going to the national park site, as one newspaper bragged, at the intersection of "the entire Rocky Mountain playground."[28]

THE ENGINEER AND EXPERTISE

Vail developed an almost legendary reputation within Colorado during his tenure. Politicians and businessmen called him the "highway dictator" and alleged he "ruled like a czar."[29] Engineering colleagues addressed Vail solely as "Chief" or "Boss." Speaking to the eightfold expansion of Colorado highways under his lengthy reign, one contemporary even remarked that "Chas. D. Vail was an institution."[30] The individual notoriety that Vail had established owed much to the international systems of engineering knowledge that had begun to develop between the nineteenth and twentieth centuries. During this time, engineering as a standardized male-dominated profession began its rapid transition toward university-trained education. It was believed the more expertise that men attained, the more technical authority they achieved and the more command they possessed over people and nature. This engineering paradigm underlay highway building on the verge of the Great Acceleration.[31]

Demand for the engineer's trade swelled during the latter parts of the nineteenth century as it became synonymous with economic progress. Railroads, canals, and mines—all symbols of geophysical prowess—moved immense tracts of earth and demanded sophisticated engineering if they were to succeed technically, economically, and socially. With this mounting interest came a gradual shift in engineering education away from the experiential apprentice-based learning as pioneered by the railroads toward more formalized college-based instruction and professional standards. The growth in American engineering schools—supported by the Morrill Land-Grant Act of 1862—reflected this trend: only two university engineering programs in 1840 escalated to 70 engineering departments by 1870, 89 by 1900, and 139 by 1934.[32] Membership in professional societies, which frequently upheld the educational standards for civil engineers and others, expanded across much of the Western world as well. In the United States, about 250 members in 1870 increased to 5,300 affiliates by 1910; in England, 1,600 enlarged to 8,850; in Germany, 3,550 skyrocketed to 9,800; and in France, 1,000 swelled to 7,000.[33] The individuals who formed these associations traveled to national and, occasionally, international conferences to share ideas and instruction.[34] Vail was a member of the American Society of Civil Engineers since 1900, an organization that already featured 341 affiliates from five different continents only ten years later, and was surely influenced by this global technocratic revolution.[35]

Born in 1868, in Lone Tree, Illinois, Vail became one of the first generation of college-educated engineers.[36] After graduating from the University of Illinois in 1891, Vail reinforced his newfound knowledge through work experiences with railroad companies: the Union Pacific in Wyoming and Utah, the Mexican International, and the

Chicago, Milwaukee, and St. Paul. After switching to public waterworks construction in Montana and Canada for a short time, Vail finally made Denver, Colorado, his permanent home in 1908. He was appointed as engineer for the public utilities commission in 1917 by the state government. Vail held the position until 1930 when he became chief highway engineer for the Colorado State Highway Department, a commanding role he would hold until his death.[37]

Vail's graduate work, in particular, offers an understanding of what he perceived as both possibilities and constraints when building US Highway 34. While supervising the Big Thompson Canyon route in 1936, Vail finished a master's degree in civil engineering at his alma mater. Then sixty-eight years old, he completed a thesis, suitably entitled "Highway Location in the Foothills of the Rocky Mountains in a Cloudburst Area."[38] The study detailed a pending scheme for highway construction within Colorado's Clear Creek Canyon between Golden and Idaho Springs, located about 75 miles directly south of the Big Thompson Canyon. Although the thesis did not include any details about US Highway 34, the similarities in topography and hydrology between the constructed and proposed roads within these two canyons provides useful insights into Vail's thinking.

In the thesis, Vail showed that he was well aware that recurring floods periodically overwhelmed the Big Thompson Canyon and other mountain gorges along Colorado's Front Range. Vail described these geo-fluvial forces in his introduction: "In the foothills region, generally during the summer months, moisture-laden air suddenly deflected upward by the mountains, frequently results in torrential precipitation or cloudburst conditions. The storm-water runoff becomes concentrated quickly in the can[y]on-bound creeks, which, because of steep grades, become raging torrents possessing tremendous erosive power."[39] Vail was also cognizant of the impacts that modern transportation infrastructure could have on floods, observing that road-building "procedure[s] will necessitate the encroachment upon the creek channel in many places by varying amounts."[40] Nonetheless, Vail remained confident that the "flood menace," as he often called it, could be eluded with technological fixes. Vail reasoned that "it i[s] obvious that the highway plan must provide extensive and adequate bank protection" with "very substantial walls or riprap [to] be constructed to protect the fill. Otherwise it is inevitable that the highway will be frequently and at times very materially damaged by floods."[41] Vail continued that "highway location in cloudburst areas present distinct problems which must be solved if disaster and loss of life are to be avoided."[42] Although inundations may occur, Vail believed that technology would mitigate the problem.

Economics guided road production for Vail. "Modern highway construction based on careful analysis of the various possible locations with special attention to their relative advantages and disadvantages from engineering and economic points of view is imperative," Vail wrote.[43] Within this vein, he dedicated much of his thesis to maximizing "traffic volume," which entailed using statistical data to determine how to get as many cars as feasible onto the road. Regardless of how these rivers coursed through their canyons, straight and wide lanes proved the most economical for increasing automobile capacity and speed. "The principal item of [driver] cost in this case," Vail argued, "would appear to be the loss of time due to the reduced speed at curves."[44] In this process, Vail distilled dynamic geo-fluvial systems down to schematic representations: the planning of roads became an exercise of technical abstractions. Instead of following the contours of the preexisting landscape, Vail and other highway engineers often sought the most economic routes, that is, the most direct ones. These expressways worked for spurring on capitalist growth by accelerating the movement of people and goods.

ENERGY REGIMES AND EARTHMOVERS

While civil engineers with similar education and experience received average salaries of over $4,000 annually (about $1.90 an hour) during the 1930s, Vail himself would not touch the wooden handle of any shovel or the steel clutch of any bulldozer at all. Rather, construction laborers and industrial machinery sputtered and roared, clanked and grinded—more or less merging together into a geophysical force.[45] For road production tasks, Vail and the engineering firms recruited between fifty and two hundred men at a time. Most of the workers were local Coloradans, especially common laborers, although the construction companies brought in a few out-of-staters, including one group from Texas, to run specialized machinery. At least half of all laborers were taken from unemployment "relief rolls." The construction project paid $0.50 an hour to unskilled laborers, or "linemen," who shoveled rocks and raked concrete; intermediate laborers, who handled jackhammers and drove trucks powered by diesel-fuel engines, earned $0.70 an hour; and skilled laborers received $1.10 an hour for operating bulldozers, shovelers, and other heavy equipment. The workers' pay scale reveals a paradox central to industrial America's mineral-based, fossil fuel economy that reinforced the value of technical skill over physical toil: the more bodily energy one had to exert on the job, the less monetary compensation one actually received.[46]

The wage differences that confronted these road workers were the by-products of a relatively novel energy regime. Each time construction laborers drilled into the canyon rock, power-shoveled a heaping pile of dirt, or hauled off truckload after truckload of rubble, they tapped into the energy sources of borrowed time. In the deep past, hundreds of million years ago, dead organic matter—phytoplankton, plant leaves, and animal excrement—collected in the oxygen-deprived recesses of swamps and the ocean. Encased in layers of sediments over time, pressure and heat gradually transformed these mixtures of peat and sludge into the substances that humans would later come to know as coal and oil. Dispersed across the planet, these subterranean stores of hydrocarbons offered dense reserves of solar energy captured from eons prior. State engineers and private contractors, in effect, assembled blue-collar workers to channel past geologic processes in order to become geophysical agents in the present.[47]

This finite supply of fossilized fuels had long been useless to humans while an ancient-organic energy regime dominated societies. Human and animal muscles did most of people's work—with power derived from the caloric intake of plants and animals, all of which ultimately procured that energy from the sun. Domesticated agriculture allowed human societies to amass larger reserves of energy in the form of foodstuffs such as cereal grains and pork flesh. Trade networks between Old and New Worlds opened up new items of caloric energy to be exploited. The burning of organic matter was equally important for humans. Domesticated fire offered light for dark places, flames to fend off predators, warmth against the cold, heat for cooking palatable meals, and eventually, combustion for an energy revolution.[48]

Only when people figured out how to capture hydrocarbons for mechanized power did the resource become more accessible. Building off the Savery and Newcomen devices, Scottish inventor James Watt built a steam engine in the eighteenth century that more effectively burned fossil fuels, which, in part, stimulated Western industrialization and its ever-expanding appetite for coal. Nearly a hundred years later, French engineer Jean Lenoir and German designer Nikolaus Otto similarly established oil's place in the global economy with technical innovations that produced the petroleum-powered internal combustion engine.[49] Relying on these works, American industrialist Benjamin Holt resolved a common problem during the early twentieth century after witnessing how heavy tractors often sank into California's soft farmlands. In 1904 Holt replaced the machinery's standard gasoline-driven wheels with a belted crawler track, to which one commentator remarked, "If that don't look like a monster caterpillar." Some twenty years later, the Holt Manufacturing Company merged with one of its competitors to form the Caterpillar Tractor Company. At about this same time, Caterpillar turned its focus toward selling earthmoving products and began exporting them for state, colonial, and military projects throughout the world.[50]

The Colorado State Highway Department became just one of many beneficiaries of these road production technologies. Construction crews working on US Highway 34 at any one time utilized an army of industrial machines: one to three bulldozers of Caterpillar Sixty, Forty, or Thirty models; one to three tractors of various Caterpillar varieties; one to three power shovels (with 1- to 1½-cubic-yard-size buckets); five to six 1½-ton dump trucks; three to four 5-ton dump trucks; two to ten jackhammers; one to four air compressors; one to two 2-sack concrete mixers; one 12-foot-wide grader attachment; and one to two steamrollers. Engineers within the Colorado State Highway Department at times anthropomorphized these machines, blurring, at least rhetorically, the lines between humans and technology. Referring to excavation work by a gasoline-driven shoveler, technocrat D. S. Moore stated that high-quality fill "material requires *handpicking* to remove large rocks."[51] In reality, it was these construction technologies—powered by fossil fuels—that paved the way for modern highways.[52]

The adoption of hydrocarbon sources was both liberating and enslaving. Its embrace shattered the energy bottleneck that had limited human activities for centuries. The mass production of automobiles and highways, supporting a greater freedom in transit, would have been an almost impossible task without oil. Even so, the utilization of hydrocarbon energy also meant that people went to even greater lengths to fuel the boom. The petroleum wells in Pennsylvania, Texas, Oklahoma, and California, many of which were enveloped within John D. Rockefeller's gargantuan oil conglomerate, the Standard Oil Company, attest to the growing reliance of the United States on fossil fuels.[53] In 1900 American oil fields generated 174,000 barrels of crude petroleum a day. By the mid-1930s, with highway projects like the Big Thompson Canyon route underway, US wells had surpassed the daily production rate of 3 million barrels. Meanwhile, a subsidiary company of Standard Oil had first secured overseas hydrocarbon access within the Persian Gulf. Increasingly embroiled in the Middle East, American petroleum extraction continued to soar during the Great Acceleration: over six million barrels per day in the mid-1950s and over eight million barrels per day by the mid-1970s.[54]

The amount of work that was accomplished by fossil fuel technologies compared to human labor alongside the Big Thompson River demonstrates the revolutionary difference in an ancient-organic versus modern-hydrocarbon energy regime. A healthy middle-age adult male steadily contributed 0.1 horsepower of energy toward construction-related activities, such as raking or shoveling, and supplied 1.2 horsepower in short periodic bursts. In contrast, a Caterpillar Sixty tractor, which received its namesake for its 60-horsepower engine, provided a potential 600-fold increase in energy output in relation to one highway laborer. Barring mechanical breakdowns, this heavy equipment faltered only when diesel supplies ran short and maintained an exponentially higher work rate. As an illustration, it would have taken six hours for a hundred men to accomplish the same amount of hard-rock excavation as it took a single hour for a lone Caterpillar bulldozer. This fundamental revolution in energy systems allowed some humans to become a geophysical force. Instead of struggling against geologic features as in times past, construction laborers used powerful hydrocarbons to move them almost effortlessly.[55]

The entrenchment of an energy regime based on coal and oil (and eventually natural gas) proved to be a defining step in transforming humans into a geologic entity. In order to prepare the Big Thompson Canyon for a modern transportation corridor, road-building crews and their fossil fuel–driven equipment excavated a total of at least 372,397.2 cubic yards of earth.[56] To place this figure into perspective, the cumulative amount of rock, gravel, and dirt weighed some 465,500 tons and could have filled around 115 Olympic-size swimming pools. A newspaper columnist boasted about what "has taken the Big Thompson River centuries to [c]ut into the unyielding granite" now conceded to "the new ribbon of highway" in only a few short years.[57] Humans as earthmovers takes on deeper significance when generalized to a planetary scale. Geographer Dov Nir has noted that for every half mile of newly constructed motorway, it produces, on average, 450 to 500 tons of erosion. Nir also estimated that mineral extraction in all forms had moved more terrain by 1980 than did the material processes of wind, water, and ice.[58] It is thus reasonable to assume, given the rapid growth of highways over the Great Acceleration, that road production likely—if not certainly—paralleled this trend.

THE ROAD AND RIVER

During the early morning hours of November 6, 1936, construction laborer Earl Gainsforth jackhammered into the solid rock of the Big Thompson Canyon. Gainsforth's duty, with the help of his fellow "relief roll" comrades, was to grade a smooth path into the daunting Colorado landscape for the future asphalt expressway. At 7:10 a.m., Gainsforth directed his jackhammer, driven by a diesel-powered air compressor, toward an area that, unbeknownst to him, contained "a charge of dynamite which had evidently failed to discharge in [a] previous blast." When his machine struck the envelope of nitroglycerin, it exploded, projecting chunks of rubble onto the ground and into the Big Thompson River. As the dust and debris settled, Gainsforth writhed in agony. "The shot hit him in the face," a supervisor observed, "and destroyed one eye and injured the other."[59]

The accident reveals one intimate moment in the collision of humans and hydrocarbons, of money and machines, of the entanglements responsible for "geophysical agency." Each stage of building highway infrastructure—often instigated by some combination of mountain geology, hydrocarbon technology, and engineering ego—required alterations to the Big Thompson River to accommodate US Highway 34. These types of earthmoving activities gave Vail and Ammons good reason to believe in their collective telluric status. And yet as Gainsforth's mishap demonstrates, these geophysical powers were far more tenuous than the engineer or governor assumed. Highway workers such as Gainsforth paid the social costs of the new motorway with pain-stricken bodies, but they could never fully pacify the river as engineers desired. In fact, most phases of construction had the opposite effect. While the unstable alliance of capital, labor, technology, and fossil fuels flattered engineers' illusions of geologic power, the modern road was actually transforming the mountain river into a more powerful agent. Accelerating cars on highways, in other words, held the unintended consequence of accelerating waters.[60]

The Colorado State Highway Department commenced "Federal Aid Project No. 9-R" on paper in 1932 by announcing the invitation for construction bids from private contracting firms. When the project finally got moving in 1933 from a large dose of New Deal monies, Vail and other state engineers would oversee hired companies as they built the newly integrated portion of US Highway 34 in smaller sections, usually in 1- to 3-mile segments, from Loveland to Estes Park. After weighing the submitted options, Vail chose five construction businesses to complete respective sections of highway in the Big Thompson Canyon: Hamilton & Gleason, Sacra & Watts, Lowdermilk Brothers, and Gordon Construction, all from Denver, as well as W. A. Colt & Sons of Lyons, Colorado. Injecting these private companies with public support, the preliminary estimated cost to craft the highway was a sizable $700,000.[61]

Before construction crews completed any serious work, highway engineers had surveyed the proposed route and acquired rights-of-way. While Vail and his engineers at times conformed to topographic features, they nonetheless chose the straightest possible lines within the canyon. By eliminating sharp curves and difficult grades, the engineers sought to aid future motorists by making greater driving speed, safety, and comfort possible. Their motivations also likely matched those of a 1934 civil engineering textbook: "The economist demands the straightest road that can possibly be secured," reflecting the reality that a straight stretch of road typically required less material and was faster and easier to build than one with curves.[62] These technocrats largely disregarded, though, where the road transected homes and river, imposing significant modifications to both human property and stream hydrology.[63] One substantial challenge for the Colorado State Highway Department lay in obtaining parcels owned

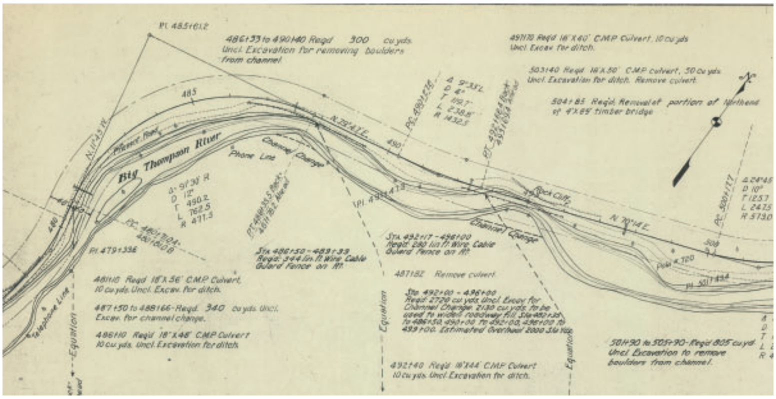


Figure 4. Construction plans for a short section for US Highway 34 between Estes Park and Loveland. Note the intended "channel change" to Big Thompson River, twice. Credit: Colorado Department of Transportation, Denver.

by private citizens—mostly a scattered collection of plots inhabited by motels and cabins. For example, Walter Lawson, a permanent canyon resident, became upset when he discovered that highway plans would destroy a ditch he had built to irrigate a small acreage of pastureland for his cows. When Lawson wrote a letter to Vail about his concern, the unsympathetic highway engineer bluntly responded, "We are not interested in the cattle industry of the State; we are interested in building highways. That is our one and only business."[64] Vail and his highway department were relentless in their road-building crusade, acquiring properties and removing at least eleven buildings to advance toward construction.[65]

Once highway engineers surveyed the area and secured easements, the next task involved "Clearing and Grubbing" the upcoming transportation corridor to prepare it for grading. Sweat dripped down the brows of construction workers as they removed all debris that would inhibit a smooth motorway, getting rid of old fences and taking away large boulders that stood within the right-of-way. As crews labored, they also cleared away what one report dismissively referred to as "Scattered Pine, Cedar, and Cottonwood Trees and Small Brush" alongside the Big Thompson River. While this indiscriminate removal of streamside vegetation apparently warranted only passing mention by the engineers, it resulted in significant alterations to the features of the canyon watercourse that enhanced the power and pace of geofluvial processes. The elimination of riverside plants contributed to increased stream flows as less water would be absorbed by the vegetation. This critical riparian flora had previously provided buffer zones to check flood height and velocity, helping to mitigate raging

Figures 5a and 5b. The Big Thompson Canyon route ca. 1910 (left) and ca. 1940 (right) at the gorge's mouth. Note the channel constriction of the Big Thompson River due to the massive amounts of earth moved to construct US Highway 34. Credit: Fort Collins Museum of Discovery Archives.

mountain river currents. The streamside vegetation had helped to anchor soil in place, improving channel stability and limiting erosion. The crews eventually covered these areas with riprap to slow erosion, yet this also inhibited most riverfront plants from growing again.[66]

Once obstructions were removed, construction companies transitioned to the next task of grading the landscape to provide a solid foundation for the paved highway. The initial phase involved "Drilling and Shooting," or blasting away at the impeding geologic features. Laborers drilled holes into the rock at key intervals along the mountainside and placed dynamite in these spaces. When workers ignited the charges, debris flew everywhere with little control. Some jetted toward the ground. Some soared into vacation houses. Some smashed into workers' bodies, as Earl Gainsforth discovered. Some cascaded down into the Big Thompson River. D. S. Moore, a resident engineer on the project, reported, "During the necessary shooting, some of the material has dropped over the shoulder and into the river. . . . I have had the contractor clean up the channel [but] . . . it is very difficult to get the shovel into the river." Although Moore maintained that "the flow of water will not be in any way impaired by this condition," the engineer ignored the fact that accumulating construction debris next to the river would inevitably concentrate stream flow.[67]

In the secondary "Excavation" phase of the grading process, construction teams with mechanized bulldozers, shovelers, steamrollers, and dump trucks moved into the thoroughfare to create a firm, level substructure before paving. Unloading gravel and moving dirt with the machinery, workers built large embankments to shield the road from the river and enlarged a route that was two to three times wider than that of the original dirt path. While this broad road design permitted two or more lanes for more vehicles, the groundwork altered the form of the river by constricting it in numerous sections. In several cases, the topography of the canyon forced engineers to make channel changes to the Big Thompson River. What technocrats like Vail and regional engineer A. B. Collins labeled as "channel improvements" often entailed straightening out natural bends in the stream. Instead of the twisting and turning that functioned to slow down river current, construction workers realigned the watercourse in some twenty-seven junctures throughout the canyon. By modifying river form—constricting and straightening—highway engineers thus altered river function, increasing its hydraulic power and velocity.[68]

The nearer the construction crews inched toward completion, the more frantically they labored to meet engineers' demanding deadlines: installing 8,107 linear feet total of corrugated-metal culvert pipes, pouring 5,453 cubic yards of concrete, reinforcing with 718 tons of steel, erecting 6 major cement bridges, and steamrolling some 440,000 square feet of terrain.[69] All these steps were meant to prepare the firm roadbed for the final stage of supposed technological mastery: "oil surfacing." Hydrocarbons reinforced hydrocarbons as highway workers operated large gasoline-fueled trucks to apply a sticky "oil" substance manufactured as a by-product during fuel refining, known as asphalt. Standard Oil of Indiana (Amoco) supplied this petroleum derivative—over 2.5 million gallons in 1933 alone—to the Colorado State Highway Department for applications on their expressways. When construction workers sprayed asphalt onto the road surface, it mixed with dirt and gravel, hardening over hours. Oil surfacing delivered a more durable highway for motorist travel, but it also provided a surface that was more impermeable to water infiltration than even a compacted dirt and gravel road. Instead of a majority of rainfall percolating down into the soil, most rainwater now collected on the pavement. This newly erected impervious surfacing contributed to runoff concentration and overland flow, both of which strengthened the movement of the Big Thompson River. Asphalt paving, while facilitating convenient and dust-free auto tourism, further expedited fluvial accumulation and speed.[70]

After nearly seven years, from late 1932 to mid-1938, road builders had finished the Big Thompson Canyon route. Although Vail and the

Colorado State Highway Department overshot their initial budget (by nearly two times the original plan) for a final cost of $1.3 million, local Coloradans celebrated this engineering accomplishment. "Mr. Vail has helped these migratory Americans to enjoy the wonders of Colorado," one engineering journal commended, "first, by his *epochal* work in improving Denver's mountain parks, and, second, by his direction of the highway improvement program that makes the Silver State more accessible to visitors who travel by automobile."[71] On Memorial Day weekend in May 1938, Governor Ammons and Vail directed the formal dedication ceremony to "unlock" US Highway 34 at the mouth of the canyon near Loveland. The following day, on May 29, around twenty thousand people gathered in Estes Park for a parade and festivities. Among the string of floats that passed by, Rocky Mountain National Park provided one that depicted the evolution of the tourist, praising the benefits of new automotive travel for the national park. Vail's work was undeniably epochal. It epitomized the heightened geophysical agency of humans manipulating the powers of nature in the emerging epoch of the Anthropocene.[72]

CONCLUSION

The canyon bottom—occupied by highway and stream—was shaped by a complex network of forces that, when amassed, resulted in giving the geophysical environment unprecedented new levels of power and agency. The Big Thompson River relied on water, solar heat, and gravity to erode its course through the mountains while the Colorado State Highway Department depended on huge sums of state money, human labor, industrial machinery, fossil fuels, and a certain engineering logic to do much the same. But instead of building a thoroughfare that would complement the topographic and geologic realities within the Big Thompson Canyon, Vail and other highway engineers believed they could shape a malleable environment to conform to their anthropogenic road infrastructure. In large part, the hydrocarbon energy derived from petroleum—providing the mechanical power for dump trucks, bulldozers, and jackhammers—gave them reason to believe in their geomorphic abilities. These technocrats constructed an automobile highway that they thought would provide both smooth transportation for tourists and withstand the forces of nature. Ironically, though, the engineers' drive to create the former undermined the latter once 12 inches of rainfall arrived one summer night in 1976. Delayed destruction struck the canyon when the Big Thompson Flood, an inundation that was exacerbated by the modern roadway, took 144 human lives.[73]

The consequences of the Big Thompson Canyon road were particularly dramatic, yet its construction reflected a much larger scale of road building and geomorphic transformation. Engineers not only altered the geophysical features in a new highway to allow motorists to step on their automobile accelerators, but projects like this also set an earlier foundation—in roads, cars, and oil consumption in an aggregated sense—for the Great Acceleration. In the state of Colorado, the entire amount of paved highways increased from 343 miles in 1930, to 3,640 in 1950, to 8,821 by 1970. The total in the United States escalated from 86,515 miles in 1930, to 267,645 in 1950, and to 455,915 by 1970.[74] The number of highways constructed worldwide has continued to climb as almost half of all roads by 1990 would be paved.[75] Today, this network of paved roadways has risen to over 11.2 million miles and, if connected end to end, would circle the Earth some 450 times.[76] This road-building explosion, beginning in earnest over the interwar years with the Italian autostrada, German autobahn, and American highway systems, demonstrates the unequal international distribution of concrete and asphalt as a geologic marker for the Anthropocene's Great Acceleration.[77]

George Perkins Marsh, in his famous 1864 book *Man and Nature*, remarked that "human action must rank among geological influences."[78] But as Hornborg, Malm, and LeCain have suggested, unified human action was not totally responsible for the changes to the Earth's governing systems. They ask us instead to focus on the forces of new industrial technologies, capitalist economic relations, or the nonhuman power of material things like coal and oil. In reality, the case of the Big Thompson Canyon reveals a complex interplay of all of these factors more akin to theorist Bruno Latour's networks of human and nonhuman actors.[79] Caterpillar machinery, New Deal capital, and Rockefeller petroleum allowed Vail and his road-building cohort to achieve the status of geologic agents. Rather than proposing yet another name for a designating a new geologic epoch—for the "Anthropo-techno-capitalo-carbo-cene" just sounds bad—perhaps environmental humanists might do better to adopt the simpler and more flexible concept of "geophysical agency." A novel phenomenon emerged when humans became mass earthmovers, demonstrating the entangled reality of culture, political economy, technology, and environment while still meeting Dipesh Chakrabarty's call "to scale up our imagination of the human."[80] Narrating geophysical agency, then, assists scholars in explaining particular, yet shifting, arrangements of causality at the same time acknowledging how they contribute to large-scale, even global, patterns.

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Notes

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