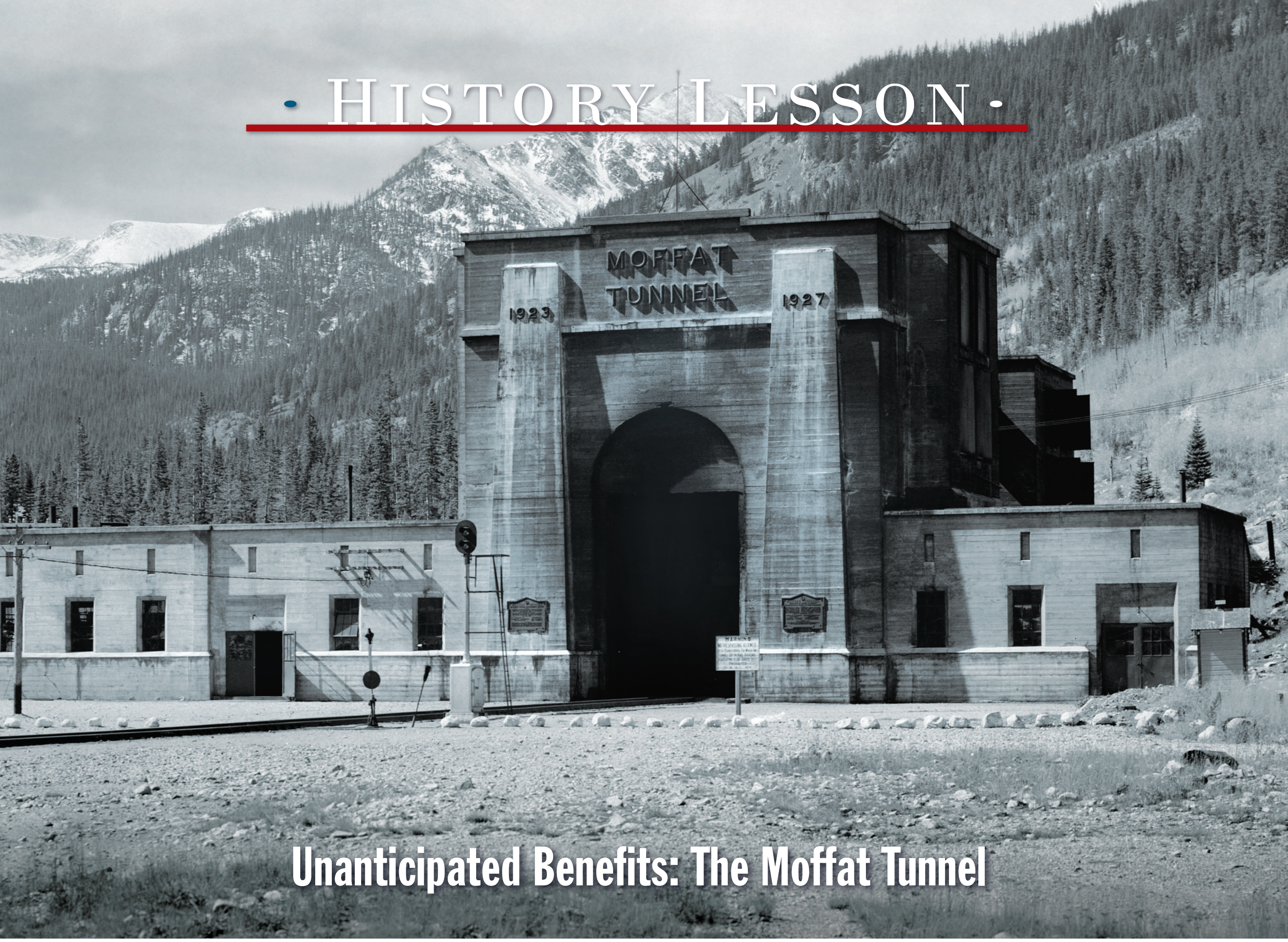

Unanticipated Benefits: The Moffat Tunnel

EVER SINCE THE FOUNDING of the city of Denver in the mid-19th century, people have been drawn to the Rocky Mountains that tower above it. Some of the city's founders dreamed of gold or silver. Others dreamed of steel as they planned to link the isolated metropolis to the coasts via the transcontinental railroad.

"Though many spent fortunes in pursuit of this goal, none lived to see it attained," wrote Steven F. Mehls in his 1982 article, "Westward from Denver: The Obsession of David Moffat," (Railway & Locomotive Historical Society, *Railroad History*, No. 146, pages 29–40.) "The magnitude of the task was not at all clear at the outset."

Indeed, no one dreamed bigger or struggled against longer odds than David Halliday Moffat, who dreamed of a rail connection through the Rockies into Utah. Though he never saw it completed, his vision led to the creation of a monumental tunnel 9,000 ft above sea level and a secondary tunnel that brought water from the mountains to the city.

Though Denver had prospered by the mineral wealth in the mountains, its leaders were desperate to connect it to the developing transcontinental rail system to ensure the city could keep pace with its rivals, Cheyenne, Wyoming, and Pueblo, Colorado. To the north, Cheyenne, was on Union Pacific's route linking Chicago to San Francisco. To the south of Denver, Pueblo was connected to Santa Fe, New Mexico, and Los Angeles.

The east portal of the Moffat Tunnel through the Rocky Mountains included a ventilating plant, railroad tracks, power lines, and bronze dedication plaques.

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"Denver had spur routes to both cities, but it did not have its own western route," explains Jared Orsi, Ph.D., an associate professor of history at Colorado State University. For Denver to join the party, it would require a route straight through the continental divide that straddled the Rocky Mountains.

Moffat arrived in Denver in 1860 at the age of 20. He opened a bookstore, became a successful businessman, and before long was, according to Mehls, "a full-fledged member of Denver's inner circle of business and financial leaders."

Moffat would make his fortune in banking and mining, but according to the book *The Moffat Tunnel: A Brief History* (Charles Albi and Kenton Forrest, Golden, Colorado: Colorado Railroad Museum, 1978), Moffat had been dreaming of a route through the mountains since at least 1881. Still, it took another 21 years before he announced plans to build a railroad from Denver to Salt Lake City. He was 63 years old—it was then or never.

Moffat incorporated the Denver, Northwestern and Pacific Railway (DNW&P) in 1902 and two years later built an initial line through Rollinsville, Colorado. The Rollins Pass was considered a fairly sophisticated

David Halliday Moffat was a bookstore owner, banker, capitalist—and prescient railroad builder.

undertaking at the time, requiring 30 tunnels and looping under itself as it traveled up the continental divide to a summit at 11,600 ft before dropping down to Middle Park, one of Colorado's famed mountain basins.

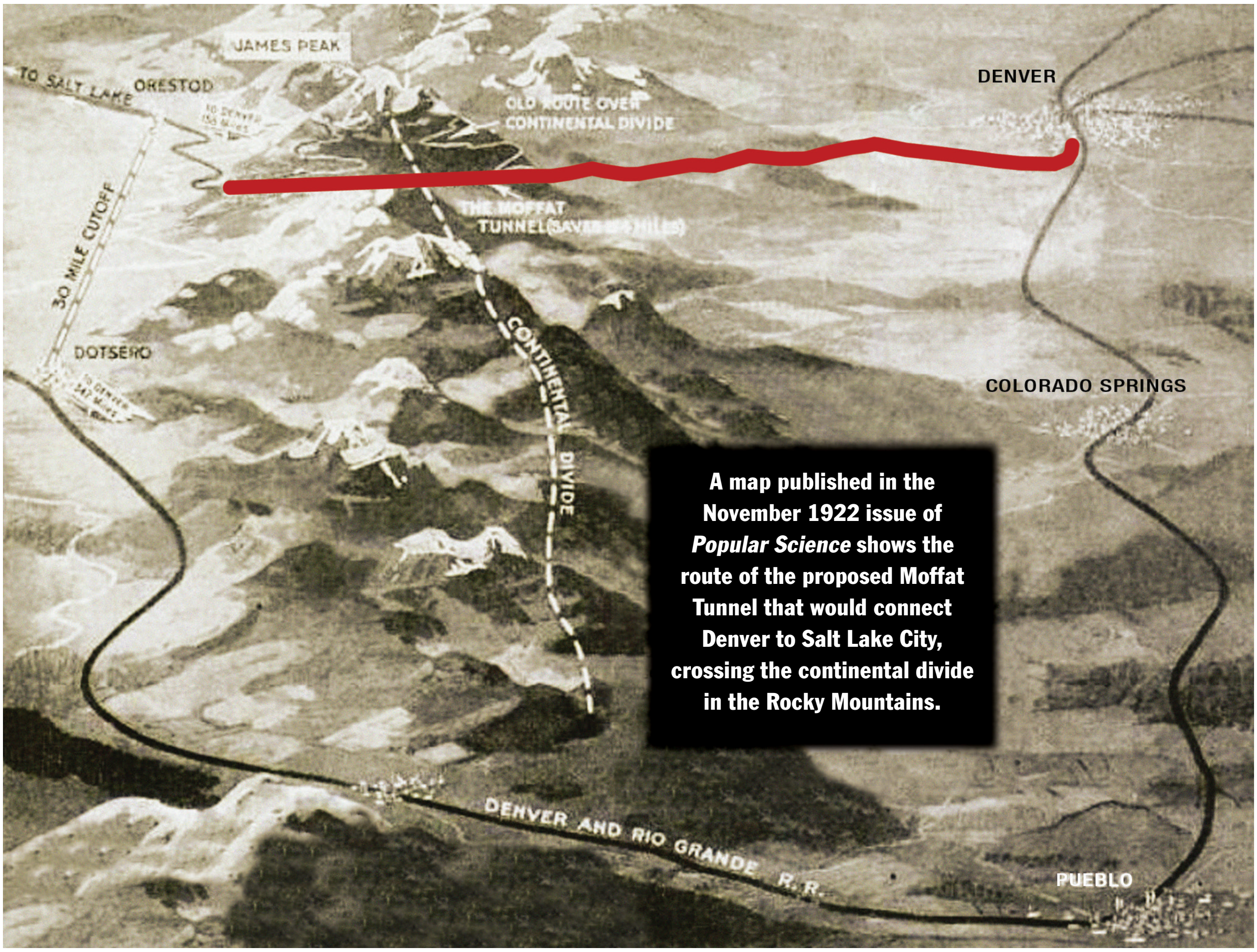
This final stretch over the mountain was meant to be a temporary route, a way to bring in revenue to fund a more ambitious and efficient line through the continental divide and on to Salt Lake City.

But the steep grade, which at some points reached 4.5 percent, and the many switchbacks made the rail route incredibly slow. Additionally, the line constantly had to be cleared of snow in the winter—a process that, according to Mehls, chewed up nearly half the company's revenues.

Tourists from Denver made the so-called Moffat Road a popular one-day excursion—traveling the line was billed as taking a trip to the "top of the world"—but it was not a cost-effective way to move freight or passengers to the coast. Traffic never picked up, even when the DNW&P reached the coal fields at Oak Creek, Colorado, in 1906. Within a few years, Moffat's wealth had dwindled to practically nothing, and he died broke in 1911 while on a trip to New York City to raise more funds.

Under new ownership, the railroad extended by roughly 40 mi to Craig, Colorado, in 1913 and later, during World War I, transported coal from northwest Colorado. But it fell into receivership twice before 1920; it simply could not overcome its economic challenges.

Denver boosters, led by William G. Evans, tried to sell bonds through the years to jump-start construction of a tunnel, but they couldn't win state support because other cities in Colorado didn't want Denver to gain such a significant economic advantage. It took a flood that devastated Pueblo in 1921 to create the conditions for a pivotal compromise. In 1922 a law was



A map published in the November 1922 issue of *Popular Science* shows the route of the proposed Moffat Tunnel that would connect Denver to Salt Lake City, crossing the continental divide in the Rocky Mountains.

DENVER PUBLIC LIBRARY, WESTERN HISTORY COLLECTION, H-123, *TOP*; WIKIMEDIA COMMONS/*POPULAR SCIENCE*, *BOTTOM* passed authorizing state funds be used both to help rebuild Pueblo and to build the tunnel.

A year later, after an initial $6.72-million bond was issued, the newly constituted Moffat Tunnel Improvement District began construction on the tunnel.

According to a December 1923 *Scientific American* article by Theodore Merrill Fisher ("Colorado's Six-Mile Tunnel Under the Rockies"), the Moffat Tunnel was planned to run a little more than 6 mi beneath James Peak, a little south of the winding Moffat Road. The west portal, near the headwaters of the Fraser River, was 9,100 ft above sea level; the east portal was at 9,200 ft. The tunnel eliminated 23 mi of track and reduced the road's maximum climb by 2,400 ft. The tunnel was planned for a width of 16 ft and a height of 20 ft. The 2 percent grade of its alignment meant only one locomotive would be needed to haul freight through the tunnel, instead of the eight needed to crest the nearby Corona Summit.

It was, for its time, a monumental effort—the longest such tunnel in the western hemisphere. According to George F. Paul in another article for *Scientific American*, this one in April 1926 ("The Six-Mile Moffat Tunnel"), a total of 522,500 cu yd of rock was excavated from the site. A power station was built at South Boulder Creek—on the east side of the continental divide—to supply 250 volts of electricity for driving the mucking machines, electric locomotive, and blowers. Additionally, wrote Paul, "A ventilating plant has been set up at each portal capable of delivering close to 25,000 cubic feet of free air per minute to the various headings."

To speed up the tunneling work, engineers turned to a method known as the "pioneer" bore—or pilot bore—first deployed 20 years earlier on the Simplon Tunnel linking Switzerland and Italy. The method, according to Fisher, called for drilling a small, auxiliary tunnel that paralleled the main tunnel. In this case the auxiliary or pioneer bore would be 8 ft square, with cross cuts every 1,500 ft connecting it to the main tunnel.

"Where under the usual method work on the main bore is restricted to simultaneous drilling from the two ends," wrote Fisher, "the faster progress of the 'pioneer bore'—due to its much smaller diameter—permits cross cuts to be run out from it to the line of the main bore and double headings along the latter started from each of them." According to Fisher's account, the pioneer bore shaved at least a year off the time it took to bore the tunnel.

"A special air-hoist has been devised for switching the muck cars," wrote Paul. "By means of the hoist, muck cars are picked up and switched laterally. This operation gets rid of all the delays and derailments that might otherwise be encountered. The operating cylinder is suspended from a little trolley that runs on a steel bar."

According to Paul's account, while a drill crew was working in one tunnel, the muckers would work in the other; then the workers would shift places. The mucking machine featured an "apron, scoop and endless belt conveyor." Four workers could "load a car of fifty cubic feet capacity in about two minutes. This means that something like fifty tons of material can be handled in two hours."

While the pioneer tunnel was a crucial innovation, engineers faced plenty of difficulty. During the initial surveys of the tunneling site, geologists had badly underestimated the amount of soft, unstable rock that existed on the west end of the planned tunnel route—part of the Ranch Creek Fault zone.

According to the website drgw.net, which covers the history of Colorado railroads, instead of finding solid rock, workers found "a horrid mess of shattered rock and flowing water, crossing three different fault lines over its length."

"The extremely bad rock in the west portal area resulted from tremendous underground pressure," wrote Albi and Forrest. The 12 by 12 in. timbers couldn't handle the stress and began to give way. "Even the tunnel floor began to buckle and swell upward," they wrote. "Eventually, the timbering was replaced by steel supports, but the result was that costs exceeded the original estimates."

While the east side appeared more stable, it had its own trouble: flooding. In 1925, according to drgw.net, "just past the apex of the tunnel, the eastern pioneer tunnel struck a fissure in the rock. Unlike the ones before, this one was directly connected to a glacial lake sitting 1500 feet above the tunnel. Flooding ensued, setting back operations by weeks."

A February 1926 tunnel flood happened so fast that, as Albi and Forrest put it, "men were forced to abandon their machinery and run for their lives. Since work had passed the apex, the tunnel soon filled with water and mud. Huge centrifugal pumps were rushed to the scene, and the water was almost entirely drained."

To make matters worse, a blizzard cut power to the east portal, reflooding the tunnel. "The flow of water eventually ceased, but the mud hardened, and several thousand feet of the tunnel had to be re-excavated," they wrote.

Still, the challenging conditions did yield a crucial breakthrough, courtesy of mining engineer George Lewis, who had been appointed general manager on the project. He developed the Lewis Traveling Cantilever Girder, a device that, as Albi and Forrest explained, "excavated the top of the tunnel heading and then supported the tunnel roof while the bore was enlarged beneath." The girder, they wrote, "proved to be the salvation of the tunnel project and was the major engineering development to come from it."

That same year, according to Albi and Forrest, six men were killed when 125 tons of rock fell from the roof of the tunnel. In all, 28 died building the tunnel.

The tunnel opened to great fanfare in 1928; what had been a two- or three-hour trip along the Moffat Road now took roughly 20 or 30 minutes. In all, according to ASCE, the project cost $18 million; $15.47 million was raised through four bonds, and the remainder through concession profits.

Unfortunately, says Orsi, the Moffat Tunnel opened just as automobile and air travel were becoming economically important and culturally popular. "[A] feat that would have been huge between 1880 and World War I is now almost immediately rendered less necessary," says Orsi. "Mail and freight and people are now increasingly traveling by automobile and airplane. It doesn't have the huge impact on

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The Lewis Traveling Cantilever Girder comprised a series of trusses that supported the arched ceiling of the tunnel before the lining was installed. It traveled along the tunnel axis and was typically located above the upper bench excavation, slightly ahead of the main excavation, which was mucked by large electric-powered shovels.

Denver that it might have earlier and that was originally envisioned by people like Moffat."

As it turned out, the tunnel's real legacy wasn't about hauling passengers or even freight. It was transporting water. Most of Colorado's water resources are on the Western Slope—including, of course, the Colorado River. Yet most residents, and therefore the greatest demand for water, are on the eastern side of the Front Range.

As early as the 1920s, Orsi says, Denver visionaries were interested in bringing water across the continental divide. Water usage from the South Platte River, Denver's principal river, was already approaching capacity, and water officials had begun building reservoirs along the Front Range. And civic leaders realized that the growing city would require even more water.

According to a history of the Denver water system, even in the planning for the tunnel, "The Denver Water Board had recognized that [the] pioneer bore could be reconfigured to convey water from the Fraser River on the Western Slope into the South Platte system on the Front Range." (*A Ditch in Time: The City, the West, and Water*, by Patricia Nelson Limerick with Jason L. Hanson, Golden: Fulcrum Publishing, 2012.)

Supporters of the waterline encountered difficulty raising money for the project until two calamities changed their fortunes. One, the long period of drought and dust storms known as the Dust Bowl hit the Great Plains states in the 1930s, leading to mass migration westward. There was growing concern by then, Orsi says, that Denver was running out of water or at least running low enough that its economic growth would be severely curtailed if a solution wasn't found.

The other came as a result of the Great Depression. The federal government established the Public Works Administration (PWA) to fund infrastructure projects across the country and put young people back to work. George Bull, an engineer with Colorado ties, led the PWA's regional office and helped get the Moffat Tunnel water project moving.

The conversion of the pioneer bore tunnel for water delivery was completed in 1936. After another water diversion tunnel was built in 1939, Denver's water system began an unprecedented boom. The Moffat Tunnel was the first of a wide collection of tunnels and reservoirs built across the Front Range over the course of several decades, all designed to transport water back and forth across the mountains from high-elevation sources to growing population centers.

Starting in the 1950s and 1960s, environmental concerns began to stall many water projects nationwide. Two notable Colorado water projects were among those blocked. In the 1950s, Congress rejected a proposed dam inside the Dinosaur National Monument, and in the 1970s, Denver Water, the city's water utility, attempted to build the Two Forks Dam in the South Platte River, a project eventually scuttled by the Environmental Protection Agency in 1990. Since then, says Orsi, "There has been very little major reservoir construction and transmountain diversion in Colorado."

But that may be changing. As the population along the Front Range continues to grow, large-scale water infrastructure projects that were politically inconceivable for decades are becoming possibilities. "Little has happened yet, but projects are being considered with increased seriousness," says Orsi.

Meanwhile, the Moffat Tunnel was designated a national historic civil engineering landmark in ASCE's Historic Civil Engineering Landmark Program in 1979. And along with the water tunnel, the rail tunnel is still in use. It's the highest point in the nation on Amtrak's system. It still hauls coal. In the winter months it ferries skiers from downtown Denver to a ski resort called Winter Park. All thanks to Moffat, who, as Albi and Forrest note, set in motion a legacy even he could not have fully imagined. —T.R. WITCHER

Witcher

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