HIGH PEAKS, DIRTY SNOW

THE WINTER DUST storms in Colorado's San Juan Mountains have their own, somewhat predictable schedule. The rare ones blow in before Christmas. More often, the first grit arrives in February, followed sporadically by storms appearing throughout spring and occasionally even in June. Since they began documenting the storms several years ago, scientists have recorded up to eight dust storms per year among the mining towns of Telluride, Silverton and Ouray.

Most people, even those who live in snow country, think of snow as purely white. Close observers may have noticed a soft bluish tint when the snow lies in shadow. Yet digging pits into the snowpack in the San Juan Mountains reveals something that is rather like an angel-food cake layered with chocolate.

The "chocolate," of course, is the dust, and it's more than a mere oddity. Research conducted during the past several years has traced much of the dust to nearby deserts of the American Southwest. Some evidence already collected suggests that the relocation of the dust is not natural, but rather the result of disturbances of fragile desert soils in Arizona and New Mexico. Scientists studying sediments in high mountain lakes seek to determine whether such dust storms existed centuries ago, before livestock herding, four-wheeling and massive road building began in the Southwest. The working hypothesis is that today's dust is something new.

What is clear is that the changing climate—warmer, with earlier springs—is causing the mountain snow to melt more rapidly across the West. Peak runoff in springtime occurs three to four weeks earlier than it has in the recent past. New research in the San Juans points to the dust storms as causing additional acceleration of the melting, by about a month.

Not every mountain snowpack is subjected to dust from nearby deserts. But many western ranges—the Tetons in Wyoming, the Sawtooth in Idaho and the Wasatch in Utah, among others—are subject to the dust-on-snow phenomenon, which poses intriguing and troubling questions.

The Albedo Factor

The seed for dust-on-snow research was planted one June day in 1999. Tom Painter, now forty-one and an assistant professor at the University of Utah, was on a hike, accompanied by his father, Richard J. Painter, who was then a mathematics professor. They were out to summit South Maroon Peak, a 14,156-foot peak located near Aspen, Colorado. Pausing next to a patch of snow that morning, Tom scraped away the top layer, which had accumulated dirt, leaving a gleaming white layer next to the dirtier snow.

That afternoon, returning from the summit, they revisited the idle experiment. There was a sharp difference between the two sections of snow. "The clean snow had still melted but the dark snow was melting a lot faster, and you could see the difference from a long way off," Tom Painter remembers.

By Allen Best

Every child who has used black buttons to make the eyes of a snowman would know the principle, if not its name. Albedo is the extent to which a surface will reflect heat, i.e., solar energy. A darker surface will absorb the solar radiation, causing snow to melt faster and the button eyes to disappear. In this case, the albedo of the clean snow left it standing two to three inches above the darker, dirtier snow.

But from where, asked the elder Painter, did the dust come? His son, the budding snow scientist, four years into his training, couldn't be certain.

Several years later, a Ph.D. in geography then tucked into his resume, Tom Painter was ready to chase that question. By then he was associated with the National Snow and Ice Data Center at the University of Colorado, and he began fishing around for places to study the dust-on-snow phenomenon. He was driven by curiosity, pure and simple. Only later, after he had begun his research, did he fully realize the potentially significant role of this vagrant dust in the hydrology of the mountain snowpack—and the further role it may play in causing the planet's warming to accelerate.

Mountain Laboratory

Colorado's San Juan Mountains are a dazzling spectacle of contortion. Located in the state's southwest corner, they are not a simple range, but rather a jumble of ups and downs across 10,000 square miles. In this jumble are two caldera, remnants of the mountain-building volcanoes of 20 to 40 million years ago. The volcanism injected bodies of silver and gold near the surface that led to the creation of mining-supply towns named Creede, Lake City and, surrounded by a wall of 13,000-foot peaks, Silverton.

Silverton, elevation 9,300 feet, is a place of gaily painted Victorian homes and storefronts, with streets broad enough to turn around trains of ore-bearing mules. The last mine, the Sunnyside, closed in the early 1990s, but evidence of mining is everywhere, from trams strung up hillsides to

Senator Beck Basin is unusual because it has few disturbances from either mining or motorized recreation.

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the local cemetery, which contains the graves of 117 people who died in snow avalanches and another 143 miners who died of silicosis, more commonly called rock lung. The focal point of summer days is the midday arrival of the old smoke-belching steam-engine trains from Durango bearing tourists, who briefly inundate the shops and restaurants before vanishing. Winters are quieter yet. Sometimes, during major storms, avalanches thunder down across Highway 550, which provides the only access into the town, isolating the 500-plus year-round residents for up to a week at a time.

The snowpack is notoriously unstable. Because of the far-inland location and high elevation, the San Juan snow tends toward dryness—what skiers fondly call powder. The storms delivering powdery snow are often interspersed with long periods of sunny days and clear nights. These temperature swings cause what scientists call near-surface faceting, a weakening of the snow that makes it less able to support subsequent snowfalls. The result is a greater propensity of snowslides on slopes of thirty degrees or more. Yet the magic of the snow is such that tiny, remote Silverton boasts two ski areas: one, a beginner area called Kendall Mountain, and the second an experts-only, take-your-avalanche-beacon-and-shovel area called Silverton Mountain. Silverton attracts serious snow lovers and risk takers.

In 2002 the town attracted one more person for whom summer is something to be patiently suffered. The son of a veteran of the fabled Tenth Mountain Division, Chris Landry grew up in Whitefish, Montana, and Carbondale, Colorado—which is to say that he grew up skiing. In the late 1970s and early '80s, he took skiing to extreme levels, although "extreme skier" was not a way that young men then identified themselves. But what else would you call somebody who was the first to ski off the top of Colorado's Pyramid Peak? Even in summer, its scoured gullies tolerate few mistakes. It was, and is, a place where if you fall, you die. In addition, he skied a new route on Washington's Mount Rainier.

Later, as skiers are wont to do, he became deeply interested in avalanches. One of his jobs was helping forecast avalanches for a marble-mining operation in Colorado. He also noticed dust storms in the Aspen area. One winter in 1999, he saw a wall of red sweeping across the Roaring Fork Valley, limiting visibility to two miles. He believes that the life-claiming avalanches that followed about a month later at Aspen were the result of dust that had settled on the snow, creating an unstable surface for the next snow layer. He intensified his study of snow at Montana State University, where he got a master's degree in snow studies.

Landry scouted out Silverton as the location for a new organization, the Center for Snow and Avalanche Studies. Scientists, most of them based in big cities or at universities, need a mountain field site for their research, he reasoned. He applied to the U.S. Forest Service for a special-use permit for a high-mountain site—a place called Senator Beck Basin, after a nineteenth-century politician from Kentucky.

The basin is located near or above the timberline, roughly equidistant between Silverton, Ouray and Telluride, the latter now transformed as a major ski resort that claims as part-time residents the actor Tom Cruise, Gulf War hero Norman Schwarzkopf and diplomat Richard Holbrooke. The basin begins at a little more than 11,000 feet, extending to 13,321-foot Trico Peak. From that summit on a clear day you can look out onto the canyon country of Utah as it sweeps southward toward Arizona's Monument Valley and the Grand Canyon.

Closer in, there are mines in every direction. But Senator Beck Basin itself had little mining. As such, there are no active roads to draw sightseeing four-wheelers, no easy paths for the ATVs, no logical routes for snowmobiles. It's accessible, but only to those who invest sweat to get there. In this bowl Landry saw a pristine area in which to establish baseline data from which change in a mountain ecosystem could be measured.

Near Silverton, researchers set up a weather station used for predicting avalanches.

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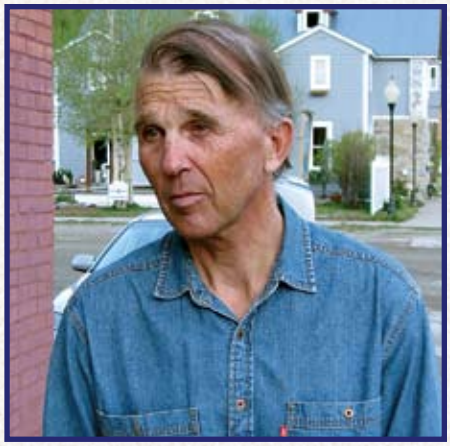

Silverton, above left, has not been overly commercialized, making it a good base for snow student Chris Landry, above.

He also saw himself as an on-site assistant to scientists, helping them in their studies to better understand the mountain environment.

His first scientist was Tom Painter. Growing up in Colorado, Painter had skied since he was a toddler. He dropped out of college at one point, spending a winter at Utah's Snowbird ski area with the spurious purpose of establishing residency to study bioengineering in Utah. Later, he was good enough to join a competitive ski tour. He was good, but not the best—a realization that drove him back to school, a career of snow studies, and eventually to the San Juans. "I'm interested in dirty snow, and you've got it," he told his contact in Silverton. Not entirely by coincidence, he was soon paired with his one-time hero, Chris Landry, whose exploits he had read about in ski magazines as a child.

Painter visited the basin chosen by Landry in February 2003, just two days after a dust storm. As he skied to the above-treeline study site, he noticed the color of the snow. It was pink.

Origins of Dust

To conduct their experiments in Senator Beck Basin, Landry and his assistants take periodic measurements—sometimes daily—that scientists, working in labs far away, wouldn't normally have access to. Painter visits Silverton once a month, first driving to 11,018-foot Red Mountain Pass, and once there, putting on skis. For the 1,000- to 2,000-foot climb to the study sites he attaches to the bottom of his skis long strips, commonly called skins, that provide traction for uphill movement in snow. Seal skins were originally used, although most people now use fibrous plastic materials. They were useful even in mid-June, when Painter paid his last visit of the season to the basin; snow remained to depths of twenty feet in places.

At the test site, Painter, Landry and their assistants spend the day measuring the snow, the dust and the melting. The more direct rays of spring and early summer amplify the melting of darker snow.

But while the pivotal story is how the dust accelerates melting—by anywhere from eight to thirty-two days, depending upon location—equally interesting is the question that Tom Painter's father asked in 1999: where does the dust come from?

To a small extent, some of the dust is from nearby locations. Other studies trace it to dust-bearing storms in northwest China. But the majority of the dust in the San Juans seems to originate on the Colorado Plateau, a desert area riven by the Colorado River some 200 to 300 miles away.

This sourcing is accomplished in two ways. First, dust storms can be seen by satellite images in fifteen-minute sequences. Storms in Arizona closely jibe with dust deposition in Colorado's mountains. More compelling evidence comes from study of the dust particles themselves. The tiny pieces of rock plucked from the mountain snow bear chemical isotopes that can be traced to the isotopes found in the bedrock of particular regions of the world. Jason Neff, a biogeochemist with the Geological Science Department at the University of Colorado–Boulder, says the isotopes tell the story of the dust.

"With that information, we can say very definitely it's not local," he says. "It's not from wood-burning, it's not road dust and it's not stuff flying off ridges from near the sample sites. It's traveling into the state and being deposited on the snowpack."

Scientists cannot currently pinpoint the precise source of the dust—for example, a location twenty miles outside Flagstaff, Arizona. But Neff and other scientists believe that relatively little of this dust originates from dry river beds or lakes, called playas. Rather, most of the dust is the result of soil disturbances.

Neff participated in a study in Canyonlands National Park that found a progressive loss of surface soil in areas that have been grazed, as compared to areas not populated by livestock. "One hundred years of grazing in the American Southwest, at least in that particular place in Utah, has

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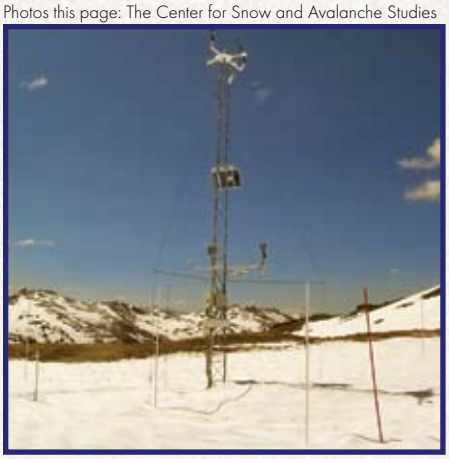

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led to a pretty large loss of soils," he says.

A study Neff is conducting in the San Juans may confirm that Painter's dust comes from disturbed landscapes. He is studying core sediments taken from above-timberline lakes, including the atmospheric dust that has been deposited. One goal is to determine whether there have been major changes since the nineteenth-century arrival of settlers. "We actually had a lot more grazing 100 years ago than we do now, although we now have more cars, home construction and recreational use," he says.

Jayne Belnap has also studied changes in the deserts of the Southwest from her base in Moab, Utah. A soil scientist with the U.S. Geological Survey, she used advanced equipment to simulate the effect of wind in the desert. The goal was to see what sticks and what flies. What she has found is that most desert soils will stay put, if they haven't been disturbed.

Few deserts are naturally dusty, Belnap says. In the Southwest, the story is largely one of disturbances—from livestock grazing, from recreational vehicles and from home construction. "Anything that has a compressional force. It doesn't matter whether it's a hoof, a bike, an ATV or a tank—anything will disturb that surface," she says. This, she adds for emphasis, is not normal.

The dust-on-snow concern is not just pertinent to the San Juan Mountains. Some of the storms that have dusted Senator Beck Basin near Silverton have also deposited layers of dirt in mountain ranges closer to Denver, some 300 miles away. These dust "events," says Landry, can be as intense as those in the San Juans, or more so.

Jeff Dozier, a professor of snow hydrology at the University of California, Santa Barbara, says Painter's study is important far beyond Colorado. Conditions similar to those of the San Juans exist in other areas of the nation, and the world. All together, about a billion people depend on melt from snow or glaciers for their water supply.

"In considering future climate changes, we often focus on warmer temperatures," says Dozier. "In the high alpine zone, however, snow is more sensitive to the amount of solar radiation absorbed than it is to the air temperature. For this reason, a change in the amount of dust from the desert—perhaps caused by drier conditions there—is probably more important to the San Juan snow than a change in temperature."

Ripple Effect

Mountains supply three-quarters of the West's water, mostly in the form of snow. As such, mountains can be seen as high-elevation reservoirs. Of, if you prefer, they are like the water towers of a small town. In the case of the San Juans, the melted snow becomes rivers: the Uncompahgre and Dolores, the Animas and San Juan, all of which deliver water to the Colorado River, the lifeblood of 35 million people.

Whether the changing climate, spurred in places by dust on snow, will upset the apple cart of water in the West is something being talked about frequently. Barely a week goes by without a conference being held in Salt Lake City, Boise, Denver or Phoenix devoted to the subject of water and climate change. With a new liveliness, the argument for more storage is being advanced, meaning more dams, although not necessarily in the style of the behemoths erected in the 1960s.

Researchers study the snowpack during a spring trip above the treeline in the Senator Beck Basin, above and right.

Dust on snow may not be a direct result of climate change, but it has the potential to accelerate global warming through the albedo effect. Climate models show the Southwest becoming drier, with what is now considered drought becoming a perennial feature: the new average. Increased drought could potentially yield more dust, which in turn would cause more early melting. Snowless mountains will, all things being equal, absorb more solar radiation, and hotter soils and rocks will delay the onset of winter even more. But that's just speculation at this point, although it's a question that Painter, or some other scientist, may tackle.

Endless questions—that's what Painter sees in front of him. He likens it to entering one room, hoping to find absolute truth, but instead discovering he must pass through yet another door, and then another—too many doors to open in one life. But that's what keeps him going, the quest to open new doors. His ultimate goal, like that of any scientist, is to find the evidence supporting a paradigm shift, causing us to see the world differently.

In a way, he already has. You've heard the old expression "as pure as the driven snow"? From the studies in Colorado's San Juans, you now know that it isn't all that pure. FM

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