Science in Context **22**(3), 487–507 (2009). Copyright © Cambridge University Press
doi:10.1017/S026988970999010X Printed in the United Kingdom

Professionals on the Peak

Catherine Nisbett Becker

University of Chicago

Argument

The administration of mountain expeditions from the ground created special managerial problems. The Harvard College Observatory's Boyden Expeditions of 1887–1890 sent men and materiel to three sites: Pike's Peak, Colorado; Mount Wilson, California; and Chosica, Peru. Their goal was to test sites in order to find a suitable site for a permanent Boyden station to conduct astrophysical work in service of Harvard's preexisting projects. The logistical difficulties of living on the mountainside combined with the organizational difficulties of administrating a station at a distance. The men who lived on the mountain were professionally vulnerable, and often cut off from their home observatory both by the weather conditions at their own altitude and local politics on the ground below them. Only when an unbroken line of communication could be established between the mountain station and the Harvard Observatory could the astronomers on both ends work together to create a successful expedition.

In 1887, money from the Uriah Boyden bequest was transferred from its trustees to the President and Fellows of Harvard College, and the Harvard Corporation became living representatives of the late Boyden's wishes. Boyden had been an eccentric amateur astronomer, and his wishes were that some person or institution would establish an observatory for "conducting astronomical observations at such a height as to be free, so far as possible, from the injurious effects due to the atmosphere" (Pickering 1887, 8). Edward Pickering was, at the time, Director of the Harvard College Observatory (HCO). During his forty-two year tenure, the HCO was transformed from a small- to large-scale observatory. Where it had been structured to focus on the individual research projects of astronomers on the small staff, it became a rich, famous, centrally controlled enterprise with a disciplined, coordinated staff, whose efforts spanned two continents. Pickering was delighted to win the Boyden money, a victory representing over seven years of his efforts. Though the Corporation officially controlled the money, the $230,000 bequest was a substantial contribution to the HCO endowment. And since a high-altitude station could offer access to dimmer stars than could be photographed from Cambridge, Massachusetts, it would almost certainly help further Pickering's research program for the HCO. This money, however, differed from other HCO funds in that it placed demands on the Observatory that could not be met at the home institution. Nothing could transform Cambridge into a mountain, and so Pickering had

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

to do what he had been reluctant to do under other circumstances: send expeditions. Eventually, the HCO must establish and maintain a permanent remote station. Though Pickering was drawn to the opportunity to collect data under better atmospheric circumstances, he was less thrilled about the logistical difficulties that maintaining a remote station would involve. This paper will look at the first part of that effort, the Boyden expeditions to test sites for possible occupation by a later permanent institution (Backwell 1898; Bond 1848 and 1980; Bailey 1931; Barker 1890; Gingerich 1993; Holden [1897] 1980; Jones and Boyd 1971; Plotkin 1978, 1984, and 1993; Rothberg 1990).

Pickering had earlier considered the problems and benefits of mountain observatories in an 1883 article for the Appalachian Mountain Club magazine (Pickering 1883, 99–106). He himself was an avid mountaineer and founding member of the Club. His goals for a Boyden station were more specific than his suggestions in that article, however. The article only warned that continuous operating costs would swallow the bulk of any permanent mountain observatory budget, and so an investor would have to take care that the program of observation demanded the altitude and could not be done from sea level. For the Boyden department, he wanted any permanent station to contribute to the HCO's preexisting program of regular observations. By the late 1880s, the Observatory was engaged in a long-term and ambitious dual plan of photometry and spectroscopy using relatively new photographic techniques. Both schemes were imagined as comprehensive surveys of the sky, ideally including the stars of both the northern and southern hemispheres. This was the first such large-scale survey of its kind. For the Harvard Photometry, Pickering aimed to create a new photometric catalogue of stars, using both visual and photographic data. The goal was to reclassify even stars that had been previously examined in order to avoid reinscribing errors from past efforts. The spectroscopic program, endowed by the widow of the late Henry Draper as a memorial to him, was intended to create not only an independent stellar classification system, but also a photographic survey of all stars down to initially the fourth and then the ninth magnitude. They intended to publish a multivolume catalogue of stellar spectra. If the auxiliary station were well located – if the clarity of the air revealed dimmer stars or if the location offered access to southern stars – the computers at Harvard could use more stars to hone their classification systems, eliminate sampling error, and publish more data. The more data, the more complete the survey, and the more valuable their catalogues would be.

Pickering commissioned three expeditions between 1887 and 1890, to Colorado, southern California, and northern Peru, to test sites for a permanent Boyden station. Site selection would depend on local meteorological conditions, specifically the clarity of the atmosphere. Astronomers recognized clear sky when they saw it, but yearly weather patterns over American mountains were not well catalogued – and over Peruvian mountains not at all – and the vocabulary of "good seeing" was not standardized. Reports from tourist mountain climbers usually had to do with how much they saw of the ground below rather than the sky above. However, though the

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

weather was one of the main factors in site testing, the quality of the air alone would not determine the success of an expedition.

These expeditions were difficult at every management and logistical level. For Pickering, the expeditions were his first attempts to manage men from afar, and his chain of command was sometimes convoluted. The expeditions were plagued by the myriad of problems endemic to control at a distance (Law 1986). But negotiating distance up the mountain proved to be more complicated than distance along the ground; horizontal and vertical distances from Cambridge created different managerial problems, different methods of control. Control over labor in Cambridge meant supervision. The system of rewards and penalties at the HCO was based on completing directed work – completion that was verified immediately, with blame for shortfalls assigned instantly. Though Pickering delegated some authority and responsibility to middle-managers, he largely controlled the production process in Cambridge. Circumstances naturally arose that delayed work at Harvard – sometimes instruments failed or deadlines were postponed – but within limits, faithful employees could expect periodic pay raises, promotion, and authorial credit in the *Annals of the Harvard College Observatory*. Unsatisfactory performance was grounds for dismissal (Nisbett 2007, 164–169). The standards and expectations were never so certain, however, when men left the Observatory for the field.[1] Control over the expedition was negotiated on many fronts: between Pickering and his collaborators at other institutions, between these parties and the men in the field, and ultimately, between Pickering and the Corporation at Harvard, which controlled the money. Local contacts could help or hinder the astronomers on the peak, and local configurations of support or resistance were crucial factors in determining the success or failure of an expedition's efforts. Over the course of the expeditions, control at a distance came to mean clear, constant, and honest communication. A steady flow of information allowed Pickering to make choices about what his men should do in the field in the same way that supervision allowed him to make decisions in Cambridge. Creating a transparent communication network depended on getting rid of all the barriers, physical and metaphorical, between the mountain station and the HCO. The logistics of climbing the mountain, hauling up equipment and supplies, and maintaining supply lines was difficult enough, but communications proved to be far more trying than anyone expected. For Pickering, a successful expedition would be one that could evaluate the meteorological and logistical conditions of a place with the least cost and the least inconvenience. If it were an inappropriate site, a successful expedition would find out quickly, and leave efficiently, with a minimum of time and money wasted.

Men on the mountain were particularly vulnerable to the ill effects of management problems. They lived in tents, in shacks, in paper houses; they carried their water

[1] It was always men whom Pickering sent on expeditions. Ruth Bailey was the only woman on any of the three expeditions, and she accompanied her husband, Solon Bailey. He paid all of Ruth's expenses out of his observatory salary.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

up the mountain from distant towns; they had no control over the environment they were sent to observe. They were sent not only into remote areas, but into unfamiliar roles. When the weather was good, they were astronomers. When the weather was bad, they were very expensive meteorologists. At sea level they were experts, while near the summit they were yet another uncontrolled variable. Sending expeditions required Pickering to face the unease of paying for astronomers whose expertise was sometimes useless, and trust that they were always doing all they could to advance the interests of the HCO. The astronomers, likewise, had to trust their contract labor, on whom they depended to live and work. When they tried to be honest and clear with Pickering, they had to trust that their clarity and honesty would not be lost in transit to Cambridge. Each step removed from Harvard complicated the transparency of the operation, and increased the cost of miscommunication.

Though Pike's Peak was near both Colorado Springs and Denver, though Mount Wilson looked down on Pasadena, and though on a clear day Lima, Peru, could be seen from Mount Harvard, the mountain was a place so near and yet so far. Creating an unbroken line of communication from the HCO to the peak would determine the success or failure of the expeditions.

Colorado

In 1887 Pickering sent the first expedition to the relatively nearby Colorado Rockies, and canvassed various men for their opinions of the meteorological conditions. Two of Pickering's new correspondents – F. H. Loud and Adolphus W. Greely – made possible an affordable expedition to Pike's Peak in addition to smaller meteorological stations throughout the state. They were able to chart the meteorological landscape of Colorado, which meant gaining Harvard's first systematic experience with mountain weather. They learned that not all mountains offered the same sky, and that none of the mountains in Colorado offered the Boyden Department a good investment. The expedition failed because the more information was gained about mountain weather and the conditions necessary for good seeing,[2] the more Colorado mountains were excluded as possible permanent sites. However, the practice of contracting with local experts and coordinating volunteers became a model for future expeditions.

Keeping local meteorological records was one of the normal functions of observatories, but deep study of meteorology was new to the Harvard astronomers (Friedman 1989, 44). Fortunately, in Colorado they depended on local expertise: the Signal Service predicted weather for the military, and civilian meteorological associations collected weather data for farmers (Bradford 2001, 32–55). There was little popular interest in meteorology. The state had only been admitted to the

[2] "Good seeing" is a technical term for the clarity of the sky.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

Union in 1876, and the citizenry was more interested in the 1858 gold rush and the resulting mining boom (Downing and Smith 1995; Leonard et al. 2003; Wyckoff 1999, 42–100). Loud, a professor at Colorado College and an officer of the year-old Meteorological Association, sensed an opportunity to build interest in the state's meteorological program with Harvard's involvement. He suggested three high-altitude stations besides the well-known Pike's Peak: Alma, near Mt. Lincoln and Mt. Bross; Silverton, in the west; and the summer station at Seven Lakes, near Bald Mountain. Despite Pike's Peak's accessibility and convenience – it was already a tourist attraction – he was hopeful that Harvard might settle on Bald Mountain, where a cooperative agreement with Colorado College could help support a "very young and feeble institution." Colorado College might even be persuaded to finance the venture, he said, while leaving "the entire direction and control to Harvard, subject only to our right to be associated in the work in that distant day when there can be a science-making astronomical department here" (Loud to Pickering, 21 March 1887). Pickering was cautiously grateful for the offer, and wrote to Loud: "It would give me much pleasure to assist the Colorado Meteorological Society in any way which could be at the same time serviceable to the Boyden project" (Pickering to Loud, 30 March 1887). His own plan included two stations, one at 11,000 feet, and one as much higher as possible, perhaps 14,000 feet, which might not be habitable during severe weather. The Boyden Fund would provide instruments, infrastructure, and labor to establish the stations. Colorado would presumably furnish volunteer labor, training, and enthusiasm; the results would be returned to Harvard for publication.

Unfortunately for Loud, the Signal Service's established high-altitude station on Pike's Peak proved too tempting for Pickering (Smith 1993, 91–103). Political gaffes and budget cuts had forced the Signal Service to cut back its weather service, and Greely, the Chief Signal Officer in Washington, was less committed to the station than his predecessors. But in March, when Pickering expressed interest in the area, Greely offered to keep it open for another year. Greely would keep one man there if Pickering would supply the other two, and when Pickering's men left, the station would be closed. In any event, it would only be kept open for one extra year (Greely to Pickering, 14 March 1887). Pickering accepted, and arranged that the Boyden Fund would supply self-registering barometers and thermometers for Pike's Peak and either Denver or Colorado Springs (for low-altitude comparison), with the Signal Service providing the labor to take measurements. Greely gave the average annual expenses of the Peak station as $615, most of which ($434.10) went for fuel. The arrangement was convenient and fairly inexpensive (Pickering to Greely, 25 March 1887; Greely to Pickering, 6 and 20 April 1887.)

Pickering's decision deeply disappointed Loud, who did not see how he could turn an alliance between the Signal Service and Harvard into a sustainable Coloradoan enthusiasm for meteorology. Pickering was not concerned with sustaining that enthusiasm, but did take on Loud as a middle-manager for Harvard's other operations in Colorado. He recruited and supervised volunteer meteorological observers from

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

around the state and supplied them with a small set of instruments. Loud's amateur meteorologists cost the Boyden Fund little or nothing and provided him an opportunity to rouse interest from both Coloradoans and Pickering in meteorology. Furthermore, it gave the Boyden Department a more extensive survey of the sky above the Rocky Mountains. Loud spent his vacations touring the sites, each time going a little farther, recruiting a few more people, surveying more sites. A volunteer was only required to record, daily or a few times a day, whether he saw clouds around a nearby peak. He estimated the cloudiness, recorded rain, and perhaps took measurements with instruments provided by the Boyden Department.

Everyone involved operated in a virtuous circle of gift-giving. Greely maintained his man on the Peak as a favor to Pickering. Pickering published the Signal Service's data from Pike's Peak as a favor to Greely, and published the Bulletin of the Colorado Association as a favor to Loud. Loud recruited people to do favors for Harvard. That cycle ended, though, when Pickering, the lynchpin, decided to pull out. In one sense, the expedition had been enormously fruitful. The data they collected gave the astronomers a far better idea of what made for good seeing. They learned that altitude was not nearly so important as humidity or temperature stability. Stars were distorted at both the bottom and the top of the mountain – valleys created seas of warm air that falling cold air from the mountain disturbed, creating a turbulent surface of waves and eddies in the air, while the gusts of wind at the top of the mountain condensed water out of cold air. Although dry air could often be found higher on the mountain, above the point that fog normally reached, it was often better to situate the telescope in a partially protected midpoint. The data helped the astronomers to begin to develop a standard vocabulary for the suitability of different sites, which helped them to compare different mountains. But nowhere in Colorado was it clear enough to fulfill the terms of the Boyden bequest, and the longer Pickering received data, the more definite became his plan to leave.

Because he was not making a long-term investment in Colorado, Pickering did not worry much about what were, to him, small breakdowns in the chain of command. He prioritized efficiency and economy, but did not try to manage the men working on the Boyden project in any detailed way. He trusted that the Signal Service men would faithfully execute their duties, and that Loud would spend money wisely and efficiently collect reliable data from volunteers. It did not always work smoothly. Dissension grew between Loud and the Signal Service men, because Loud thought their negligence was driving Pickering from Colorado. Loud coordinated with the men on Pike's Peak, but had no authority over them. When he had a complaint against a Mr. Schneider of the Signal Service, Loud wrote to Pickering in Cambridge. Pickering wrote to Greely in Washington asking that something be done. Greely wrote the Signal Service men in Colorado to replace Mr. Schneider, and wrote back to Pickering that the problem had been resolved. Pickering, finally, wrote back to Loud at Pike's Peak. It was not a model of managerial efficiency (Pickering to Loud, 31 January 1888; Pickering to Greely, 31 January and 15 February 1888).

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

Setting boundaries to Loud's work and authority also proved problematic, and Loud's missteps could be expensive. Loud's ambition was a blessing – it was the reason that so much data was collected in a limited time. But he wanted Harvard invested in Colorado, and spending the money from Boyden was one way to do that. When Loud hired Mr. Curtis at Seven Lakes, he modeled the expenditure on Pike's Peak (Loud to Pickering, 11 October 1887). But Pickering did not need the station and did not want to pay an observer when a volunteer would suffice. He did not want to offend Loud, but he had to clarify that Loud had limited flexibility in using his judgment with the Boyden money (Pickering to Loud, 27 October 1887).[3] Luckily Curtis broke off the arrangement first, to the relief of all three parties (Loud to Pickering, 2 November 1887).

By April 1888, the Signal Service was itching to leave Pike's Peak, and the citizenry of Colorado had had little luck producing a plan for civilian ownership. Pickering lost all interest in remaining in Colorado (Pickering to Loud, 14 April 1888). Later that month, Pickering asked Loud to compile a statement of all observations, clerical work, and instruments maintained by the Boyden Fund, in preparation for an efficient withdrawal (Pickering to Loud, 30 April 1888). As a last ditch effort, Loud wrote to Pickering that "I think we are *beginning* to realize something of your intention" (Loud to Pickering, 23 April 1888; emphasis in original). Pickering was not interested. He offered to publish the results of the Meteorological Association's Bulletin for a time, but his offer of ten dollars a month would not meet their expenses of twenty-five. They eventually made other arrangements. Pickering removed funding and instruments from Colorado, closing the stations one by one.

California

Where Colorado's managerial circumstances were inconvenient, California's were disastrous. Yet the sky over Wilson's Peak, in the southern California desert, was exceptionally clear. M. M. Bovard, President of the University of Southern California (USC), had just come into $50,000 for the purposes of building an observatory, and Pickering jumped at the chance to help him spend it. Bovard was a scientific layman, and asked Pickering's advice on the basics of founding an observatory. The HCO was in a unique position to aid USC, since under the terms of the Boyden bequest, Pickering could send his own astronomers to Mount Wilson to test the atmosphere and scout for sites. When USC had chosen theirs, Pickering could choose another Wilson site for the Boyden station. Whereas in Colorado, where it was not worth the time or money to overcome serious inconveniences, the clarity of the sky over Mount Wilson made those concerns urgent. However, the Boyden Department never had the opportunity to settle

[3] Pickering's monthly expenses were $7.50 per observer on Mt. Lincoln, and $10.00 for Mr. Powless' work at Alma, although Powless' inspection of three mountain stations brought the total to $63.00.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

on Wilson's Peak. Eventually, confusion over the title to the land on the peak presented a last, decisive barrier; but, the expedition was a failure long before, because relations and communications between managers and laborers fell apart at every level. Mount Wilson was large enough to support at least two observatories, but fighting over the mountain, and with the mountain, became a proxy for fights over managerial control.

In 1888, after receiving a $50,000 donation from wealthy E. F. Spence of Los Angeles, Bovard approached Pickering for advice on building a large telescope to rival the University of California's 36-inch Lick refractor. Pickering advised him to take advantage of the clear sky around Pasadena by building an innovative 24-inch photographic doublet (designed by Pickering), but Bovard was unimpressed. He was not about to squander a chance to beat their northern rivals by wasting money on a smaller telescope. Nevertheless, Pickering proposed a mutually-beneficial collaboration between the HCO and USC. Harvard would provide personnel and a large telescope to test the atmosphere on Mount Wilson; USC would pay the transportation costs of the instruments, and the men's housing and board. The results would be shared by the two institutions, and the HCO would recommend a site on Mount Wilson for the Spence Observatory. Since the HCO was interested in photographic rather than visual work, its needs were different, and after Bovard had settled on a site for the Spence, Pickering might choose to settle the Boyden station elsewhere on the mountain. Bovard seemed to agree to this arrangement, but it never materialized as it had been planned on paper (Pickering to Bovard, 9 June 1888; Bovard to Pickering, 1 October 1888; William to Bovard, 30 July 1888).

Pickering chose his younger brother, William, to head the Boyden Department (though he retained most of the control over the expeditions) and William began by taking over operations in California. He traveled west during the winter of 1888–89 with three assistants: Solon Bailey, Robert Black, and Edward King. They took a short detour to observe the total solar eclipse of January 1st in Willows, California, and afterwards, William left the assistants to pack the instruments and ship them to Pasadena (Jones and Boyd 1971, 257). Bailey went on to Peru, and William went ahead to meet Dr. Bovard.

William arrived to find that no preparations had been made for the astronomers. The road to the summit of Mount Wilson, the housing, and the instrument sheds had not been built. When Pickering heard of it, he assumed that Bovard had made a mistake, but Bovard took no blame. He resented the assumption that he had committed to anything. Pickering replied that he would not have sent the expedition, including the expensive 13-inch telescope, if he had not been assured of USC's support. "I learn, however, that your understanding of the matter seems to be different" (Pickering to Bovard, 26 March 1889). Bovard shot back that he had not agreed, and if he had known the terms they would have been unacceptable. He accused the astronomers of working solely for the HCO's interests, which he considered distinct from USC's, and said he would not use the Spence money for a Harvard project. "I am not as you will see obligated at all, but I do think you will render us a valuable service, and

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

I would like to look over the matter over [sic] completely and pay you a reasonable cash payment to assist you in the expense" (Bovard to Pickering, 22 April 1889). The slippage in who was assisting whom confounded Pickering. Bovard seemed to object to astronomers practicing astronomy while testing meteorological conditions, but Pickering balked at the idea of three qualified astronomers on salary traveling to a distant mountain at the expense of the Boyden Fund to do nothing but measure cloud cover. He tried to explain what was involved in testing a site – not one or two nights with small instruments, but long-term, systematic observations with an instrument comparable to the one Bovard wanted. This was the service Pickering had contracted his men to do, and "reasonable compliance" with the agreement would cost USC, at minimum, $1,500.00, according to Pickering (Pickering to Bovard, 13 May 1889). Bovard disagreed, the stalemate deepened, Bovard became distrustful. He wrote that he was trying to arrive at a "just conclusion" but that "so many reports have come to us representing that you are doing the work paying for it and the University of Southern California has no interest in it" (Bovard to Pickering, 11 July 1889). Pickering tried to explain the mutual benefit of the cooperation, and pleaded for financial support – he was spending $250 per month on the expedition (Pickering to Bovard, 22 July 1889, 29 April 1890). Bovard was convinced that he had been hoodwinked.

Pickering was far from Pasadena, and with a two-week mail delay, it is perhaps not surprising that he could not solve such difficulties from where he was. But his manager on the ground was no better. When William arrived in Pasadena to find no road and no dwelling, he was nonplussed, and began negotiating with Bovard and other citizens of Pasadena, Sierra Madre, and Los Angeles to take a financial interest in the new observatory. His loyalties were divided: his fundraising would benefit both the Spence and the Boyden station, but those were the terms of the cooperation. William was certain that he had convinced Bovard to buy a 24-inch photographic doublet in addition to a refractor four inches larger than the Lick's. He reported that the citizenry of Pasadena had shown much interest in the project, and in February he reported that he had been promised $150 from Pasadena, $100 from Sierra Madre, and that Bovard would supply the difference to preserve the collaboration (William to Pickering, 19 and 26 January, 21 February 1889). This money never materialized, Bovard never commissioned the 24-inch, and problems kept arising for the Harvard team. The money would have been seriously insufficient in any event. The 40-inch lens was commissioned, and was built by the Clarks, but was eventually bought and installed at the Yerkes Observatory outside of Chicago. Harvard eventually commissioned the Clarks to build the 24-inch photographic doublet for use in Arequipa, Peru, with a $50,000 gift from Catherine Wolf Bruce of New York. The trail to the summit was in poor condition, which meant that the 13-inch telescope could not be transported to the station safely, and as early as January, William noticed that there might be trouble with the title to the land (William to Pickering, 20 January 1889). William's attitude was always sunny, but he wrote to Pickering, "the local papers are full of sharp notes about the observatory" (William to Pickering, 1 February 1889).

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

His optimism sometimes bordered on delusional. William's wife, Anne, reported that USC had offered William a job, and Pickering urged his brother to consider it. William wrote that he would:

> It is pretty certain that I have got to receive a larger income than I get at Cambridge, somehow. If they offer me enough to support my family properly I think I shall accept. . . . I have just seen Dr. Bovard & he asked me how I would feel about taking the Directorship. I told him I would do so if there was sufficient salary . . . . (William to Pickering, 4 February 1889)

It is unlikely that this offer was ever made. Given Bovard's growing antipathy to Harvard, and the fact that Bovard never mentioned it to Pickering, it is far more probable that William's report was a ploy for a higher salary at Harvard.[4] Pickering, though, had no reliable source of information outside of William, and he was dazzled by the possibility of an association with the new Spence Observatory. The sky was clear and steady, and he believed that the Boyden Department could have two observing stations, in the northern and southern hemispheres. His brother's directorship made this a virtual certainty. He wrote, "Wilson would be the observing station of Harvard, and Harvard the computing station of Wilson" (Pickering to William, 20 January 1889).

In the summer of 1889, William returned to Cambridge, and the California expedition continued to report to him. The expedition was suddenly expensive, but it would have been far more expensive to recall men and materiel without any results, so the men made do with ad hoc plans and severe economy. William left before winter set in, and never worked on the Peak, so he was unsympathetic to the difficulties the men had living and working on a barren mountain. After completing the buildings and training a local boy, Arthur Carter, to assist Robert Black, Edward King traveled home in early fall. Carter and Black were left on the mountain. It was a difficult year.

Even before winter set in, Black complained of tourists. The men worked at night and slept during the day, and morning tourists interfered with the work. William suggested that they open the station to the public in the afternoon, after sleeping but before night work (William to King, 18 May 1889). Ten months later Black had posted a notice declaring the station private property and had reinforced it with barbed wire, and still the tourists were getting "worse and worse. . . . This morning a party of them came around the building when we were asleep, tried to pry open the door and windows, climbed the dome, and hammered the tin, and climaxed the affair by moving the slides of the sunshine recorders down, and piling them on top of each other" (Black to William, 3 May 1890). The bedraggled astronomers had become another attraction on the Peak. Yet these irritations paled when winter

[4] In fact, throughout his tenure with the Boyden Department, he argued that he was more valuable than his salary indicated.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

weather began in October. The astronomers had made do with canvas construction instead of sturdier structures, and the nights became uncomfortably cold (Black to William, 7 October 1889). Winter began in full in December, and the sleet and snow covered all instruments with ice, making them unusable until thawed. Many broke under the strain. The men were virtually trapped on the mountain by severe storms (Black to William, 23 December 1889). Black was caught in one such storm and was laid up at sea-level with a bad cold for weeks, leaving young Carter on the mountain alone, which in turn wore him down. On February 20th, he wrote, "We are virtually snowed in. It has been with great difficulty that we could even get to the cabin for our meals" (Black to William, 20 February 1890). A few days later, he reported, "I haven't seen a star out for two weeks, and the prospect just now is most unfavorable. The Obs. is a complete mass of ice. The fog is so dense that one can hardly see 50 yards" (Black to William, 26 February 1890). The winter was one of the severest on record.

William and Black did not have the same understanding of the expedition's aims. If they were exploring the quality of the sky over Wilson's Peak, then these interruptions in astronomical work added to that store of data. But if the expedition was astronomical, then every delay was serious – and expensive. Pickering did not yet have enough information to found a Boyden station, but USC had already decided to build on Mount Wilson, which required astronomical not meteorological testing. For Black, the expedition was meteorological; for Pickering, it was there to serve the HCO's other astronomical projects. William, meanwhile, intended to use the data from Mount Wilson to benefit his own work on Mars, and measured the success of the expedition solely in terms of his own advances. Black did not know that his work would be judged without reference to the weather he was there to observe, and William was concerned with making a name for himself and did not explain it.

William had two sources of information about California: the weekly status reports from Black and the newspapers from Pasadena. The steady flow of Black's letters was interrupted when Black was sick, or when storms prevented him from leaving the mountain. Newspapers were sent only sporadically – William suspected that newspaper offices failed to send them on purpose because of the icy relations between Harvard and the people of Pasadena. William constantly asked for more information, but letters were held up, were less complete than he expected, or had bad news of delays in the work. William was frustrated and disappointed with these setbacks, but wrapped in the comforts of Cambridge, with fixed schedules and many employees, he was unsympathetic to his mountaineers' special situation. He complained and criticized, and eventually facetiously told Black that he understood "that you both need sleep, & on account of tourists may even have to sleep occasionally a few hours towards morning on clear nights, after several nights work, but I do not understand breaks of a fortnight with nothing done, or why only a single object was taken during another fortnight when you had plenty of clear weather" (William to Black, 20 June 1890). Black flared.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

> I am practically working all the time for the obs'y except when I am asleep. . . . I have been on Wilson's Peak one year last April. During that time I have not been able to attend a concert, lecture, church or theater. I have not been away farther than Los Angeles (and that means *never* for pleasure) but once . . . . I am practically excluded from the world. (Black to William, 27 June 1890; emphasis in original)

He offered to resign. William was unmoved. He alienated Carter by scolding him for taking more than his allotted vacation when Carter was ill (William to Carter, 14 and 31 July 1890). Black and Carter retaliated by restricting themselves to their contracted hours – Carter seven and Black twelve (Black to William, 7 August 1890). After closing the station, William passively told Black to stay in California if he wanted, but the meaning was clear to Black – he had been fired (Black to William, 26 September 1890).

Pickering and Bovard were not the only two people arguing over ownership of the mountain. The difficulty of establishing ownership of the peak created the last, intractable barrier to Harvard's Wilson station. Like the problems with communication and confusion, problems with ownership affected every level of the expedition. A. G. Strain, the expedition's landlord, was one of at least three claimants to the land. He ran a small hotel, and the HCO contracted with him to provide room and board to the expedition. Animosity developed between Black and Strain after King left, and deepened until both felt cheated and misused. Black eventually left Strain to board with a rival claimant, which made Strain's blood boil. At the time, Strain was involved in at least one lawsuit over the ownership of his land. With the situation deteriorating, Pickering sent his assistant, J. Rayner Edmands, to California to sort it out. Edmands was to see if anything could be done about Bovard, Black, Strain, Carter, or the Peak, and he was instructed to finesse hurt feelings and settle the situation amicably, even at a financial loss (Pickering to Edmands, 28 July 1890). He arrived in the middle of July, 1890, during a heat wave, and sided with Black. Life at the camp was very difficult, and Edmands thought that Strain had been overcharging (Edmands to Pickering, 29 July 1890). Nevertheless, he was on a diplomat's mission and offered Strain a financial settlement. His visit confirmed that the station had become a managerial disaster area, which Pickering decided to close. Edmands left Black in charge of shutting it down, selling what he could, and shipping the rest back east. Settling expenses took longer than expected, and by January 13, 1891, Black still had not closed the account. By that time, his health had failed (Black to William, 31 January 1891).

The attempt to own the peak lasted longer than the station itself, but even that had to be abandoned. By July 1889, Pickering was making motions to purchase land, and he told Bovard, as he had been advised to do by his lawyer. He contracted two lawyers to help, but it was more complicated than buying and selling: as interest in Wilson's Peak rose, the number of claimants proliferated. Pickering tried to pass a bill in Congress naming USC and Harvard as proper owners, but the name of the university was misprinted. The University of California, Bovard's chief rival, was named the beneficiary instead. An already icy relationship turned arctic on May 19, 1890, when

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

Bovard wrote to Pickering: "That you have been deceiving us from the beginning is now plain" (Bovard to Pickering, 19 May 1890). Bovard would not write to Pickering again, though both Pickerings tried to placate him (Pickering to Bovard, 27 and 31 May 1890). By May 1889, Pickering estimated that USC owed the Boyden Fund $4,000. With the failure of the bill in Congress, Pickering withdrew all plans to settle in California. He could control neither the men nor the mountain (Hoar to Balch, 21 December 1889, 4 June 1890; Balch to Henry Cabot Lodge, 16 December 1889; Pickering to Balch, 2, 17, and 20 September, 22 November 1889, 27 March, 27 May 1890).

Peru

The South America expedition ran concurrently with the Mount Wilson expedition. Pickering hoped to send Bailey to either Peru or Chile. Access to stars in the southern hemisphere was more valuable than even a clearer sky in the northern hemisphere since it would allow Harvard to render its photometric and spectroscopic surveys more complete. Indeed, even if he had to found a small observing station somewhere at sea level without the aid of the Boyden Fund, Pickering was dedicated to settling within view of southern stars. Yet although conducting work in South America was expensive and logistically difficult because of the great distance to Cambridge, the expedition did not suffer from managerial confusion or conflicting interests. The troubles of the other two expeditions were roughly five-fold. First, there were problems with the weather. In Colorado it was disappointing; in California bad weather was destructive. Second, there were communication problems between the HCO and outside associates. These communication problems interfered with forming clear goals and standards of successful mountain work, problems of horizontal distance. Without a support system in place on the ground, men on the peak were effectively cut off from the home institution. Third, there were problems of communication between managers and their own employees. In Colorado and California, neither Pickering nor William ever adjusted to the lack of direct oversight. Fourth, there were systemic breakdowns of communication, such as when storms kept Black from sending letters or when letters were lost in the mail. And finally, there was lack of clarity about the aims of the expedition, whether astronomical, meteorological, or institutional. On the expedition to Peru, on the other hand, Bailey's clarity eliminated the problems or at least limited their effect. As with the Colorado expedition, when Bailey decided to settle on Mount Harvard, near Chosica, Peru, the weather was disappointing, but elsewhere in the country he found more promising places. Like Mount Wilson, life on the mountain was difficult; however, communication and hierarchy never broke down between Bailey and Pickering, and Bailey always tried to advance what he believed were the best interests of the HCO. Bailey's interpretation never seemed to clash with Pickering's. Pickering himself seemed to change his expectations in the context of foreign administration. He was usually diplomatic with his employees, but in this case, Pickering gave exceptional latitude to Bailey in dealing with local problems. And perhaps most importantly, Peruvian local

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

interests did not inhibit the progress of the expedition, but rather gave the astronomers assistance that they asked for, and generally allowed them to do their work.

Bailey, with his wife and son, left San Francisco on Saturday, February 2, 1889, aboard the *San José* steamer of the Pacific mail. Bailey's brother, Marshall, left Cambridge at about the same time, and met up with the family in Panama. The group arrived at the port of Callao about four weeks after their initial departure, and proceeded to Lima. Armed with letters of introduction, they canvassed local gentlemen in Lima about the meteorological condition of the country, and the most favorable site for their station. Mr. Cilley, President of the Oroya Railway, and Dr. Antonio Raimondi, who had written a definitive book on Peru, recommended Chosica or Matucana above the Rimac Valley (Raimondi 1874). Ralph Abercrombie, an English meteorologist, recommended a site in the Atacama Desert. Years before Bailey arrived, the Peruvian government had tried to establish a national observatory, and the commission had decided on the vicinity of Jauja. Bailey was disappointed to find however that no systematic meteorological data had been kept on different parts of the country (Bailey 1895, 9). After three days of gathering suggestions, Bailey and Marshall left Lima to explore the area around Chosica. On March 11th, accompanied by an Indian guide, they reached the summit of what they would eventually call Mount Harvard (Bailey 1889, 27). The summit was eight miles from Chosica, and four thousand feet higher.

Bailey's goal was to find a proper site for the temporary station, which he hoped to place along the railroad, for easy access and communication. The government was happy to help. When they traveled to Lima, the Bailey brothers were invited to have an audience with the President of the Republic, General Cáceres. Their meeting was an encouraging one, with Cáceres offering any help that the expedition needed (Bailey 1895, 9–10). When the family returned to Chosica, Mrs. Bailey stayed at the hotel to take meteorological observations, which she would continue to do in various places throughout the expedition. Bailey and his brother explored Matucana, further inland. The road proved perilous, and the tumultuous relationship between the government and the railroad authorities made it unlikely that the trains would run farther than Chosica for some time. Transportation of food and water, not to mention the valuable astronomical instruments, would be dangerous. Along the Oroya Valley, mountains cut off the horizon to the south. Bailey was faced with the decision to leave the area and explore further or to settle in Chosica immediately. Given the uncertainty of the former, he chose the latter. Pickering agreed with his "expedient" decision (Pickering to Bailey, 26 April 1889).

Bailey returned to Chosica wishing to begin immediately, but finding a site proved difficult:

> As soon as it became known that it was desired to find the most suitable elevation near Choisca for an astronomical site, various *cholos*[5] came to us with stories of fine localities

[5] A *cholo* is a pejorative term for a poor group of mixed-race Indians, although it is likely that Bailey only meant to be descriptive.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

> convenient to food and water. Several of these were investigated with the conviction that either the *cholos* were woefully ignorant of what we wanted, or more probably that they invented their descriptions, hoping to win money in the capacity of guides. From all these points I returned wearied with climbing and angry with my guide for what seemed to me deception. (Bailey 1895, 17)

Nowhere seemed as advantageous as the mountain he had visited on his first trip, so he chose that site to set up the station. He employed almost a dozen men to repair the road to the summit, and left his brother in charge. The path was finished in three weeks, while on April 1st, Bailey started to make plans to bring the equipment up. Unable to do astronomical work (the instruments were dismantled awaiting their trip up the mountain), Bailey carried on with the meteorological work, and even arranged for a railroad employee to telegraph the weather in Matucana when Bailey read the same in Chosica so that he could have a comparative record of the sky.

On April 15th, Bailey sent up the first installment of freight by mule. A second load went up the next day, and a day after that, Bailey ascended the mountain himself. He later wrote, "The fact that the nearest human being was miles away gave me a peculiar sense of proprietorship in the exhibition of nature" (Bailey 1895, 18). The solitude proved to be a mixed blessing. The last load arrived on May 7th, making nearly eighty mule loads in all. Two days later, the entire Bailey family came to the peak, and that night Bailey made his first photographic plate, a trail on the pole star with the Bache telescope.

Regular work began in earnest at the end of May, nearly four months after leaving San Francisco. Pickering was impressed. He began to allow Bailey more leeway in the management of the station, praising him on his thrift, giving him some latitude in routine work. When Bailey left California, he had a journal of notes for the expedition – fifty-five pages of instructions for communicating observations with Cambridge ("Notes, etc., relating to the Peruvian expedition, 1888–9"). Later, Pickering relaxed a bit, and he asked Bailey to use his discretion in completing the assigned work, only asking that Bailey communicate those choices so that nothing was lost in translation (Pickering to Bailey, 16 March, 5 April, 17 July 1889). Only these tasks of communication were rigid: Pickering asked Bailey to keep a journal, to write regularly and fully to Cambridge, and to photograph "all objects of interest as proposed, especially of the places under consideration for observing stations, and of the horizon seen from them" (Pickering to Bailey, 5 April 1889). Ideally, with these considerations, Pickering would be able to understand the progress of the expedition as if he were there. Bailey obliged. After the station was running on a regular schedule, Bailey tried to operate it as efficiently as possible to get the most out of every clear sky. By the end of the summer, he sent his first batch of plates back to Cambridge, to Pickering's delight:

> Two boxes of plates arrived last night and . . . I take this occasion to congratulate you on your success. . . . I have . . . been impressed with the skill you and your brother have shown

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

> in overcoming the various obstacles in Peru and on the Isthmus. Also at the rapidity with which the work is progressing. . . . I am desirous that you should all be as comfortable as possible at your station and I hope that you would go to any reasonable expense to attain this end. (Pickering to Bailey, 4 August 1889)

Bailey replied that they had "certainly endeavored to finish the work as rapidly as possible" (Bailey to EC Pickering, 11 September 1889).

The expedition was still an expedition, a long journey to an unfamiliar environment. Bailey and his family, their two servants Francisco and Vincenta, and a young Peruvian assistant, Elias Vieyra, spent long nights and hot days isolated on the mountain face. By noon it was too hot to walk outside, and their primary amusement was lawn-tennis. It was difficult to find servants who were happy to stay for any length of time before Francisco and Vincenta arrived, and because it was not possible to inspect the food before it was brought up, the party was often disappointed. Things taken for granted even in the town below were difficult to come by above, and water delivery – because it was used both for the household and for developing photographic plates – proved a constant irritation:

> The mountain furnished neither water nor food. These were brought daily from Chosica eight miles away and nearly four thousand feet below. Considerable difficulty was at first experienced in finding a trustworthy man to act as a muleteer. Those first obtained were drunken or lazy, so that we were repeatedly disappointed by the non-arrival of our day's water and provisions. Although we intended to keep several days' supply in advance, this was not always practicable, and several times we were for hours without water, and with none too luxurious a diet. (Bailey 1895, 21–2)

It was a lonely existence. Frustrations with local help, and with the brash manners and mistakes of their assistant Vieyra, were only magnified under the isolation. The family lived in a paper house and their entire energies revolved around maximizing astronomical output.

In this, Bailey profited from the other expeditions' experiences. Where they had problems with the weather, he used the information gained in Colorado to place the station to maximize good seeing. He was also able to plan around Chosica's marked wet and dry seasons to solve another problem that marked the other expeditions, the lack of clarity about the goals. While the weather was good, he believed that his party was in Peru to do astronomical work. Otherwise, it was his job to make the most of the unusable time. In anticipation of the cloudy season, Pickering advised him to work late into the night, making long-exposure photographs in the eastern sky, and making longer series with the meridian photometer in order to avoid a gap in the results (Pickering to Bailey, 28 August 1889). The observatory depended on steady observations for its routine work, and the uniquely stable and predictable situation on Mt. Harvard facilitated those goals.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

In late October 1889, clouds began to interfere with the work nightly, and Marshall began planning to explore other sites in Peru. Solon and Marshall Bailey left on November 8 for the south. Only Vieyra and the two servants were left on the mountain to do what they could during the rainy season and to protect the equipment. They suffered terrible weather, and the paper house suffered against the driving rain. Mrs. Bailey and Irving went to Lima, until Mrs. Bailey's health brought them up the mountain again, where she acted as nurse for the members of the party. Meanwhile, the brothers traveled to the Port of Mollendo, to Puno, and to Arequipa, taking a short vacation at their own expense to La Paz, Bolivia, at the end of November.

Bailey's communication with Cambridge was almost entirely one-way while he traveled, because his location constantly changed and was often remote. In lieu of explicit orders, he relied on extrapolations of the instructions he had received before he left, and on his discretion. He was sometimes torn: he wanted to survey as many sites as possible and create a full climatic picture of the Andes, but he also wanted to find a stable place to set up the expensive instruments and continue astronomical work. In some ways, his regrets over settling quickly on Mount Harvard fueled his decision to opt for a fuller meteorological survey:

> Although I am desirous of getting to work with the M[eridian]. P[hotometer]. at once it seems best to stop over, one or both of us at Caldera, for a few days. I do not know just how much you wish to put into this investigation. But of late it has seemed that possibly in the end it might have been better if in the first place I had taken a little more time & investigated the Mollendo R.R. in which case I should have selected Arequipa instead of "Mt. Harvard." The other course however seemed wiser at the time. (Bailey to Pickering, 25 December 1889)

In December, he visited Antofagasta, a nitrate town, on his way to Valparaiso on December 22nd. William wanted the station settled in Valparaiso or Santiago since he heard the society was congenial to living well, and when Bailey's term was up, William would be the new station's director. When Bailey visited Santiago, he found it an attractive site, but the Chilean government already had an ill-equipped national observatory there. Bailey reported, "I could not help feeling that they were ashamed of the condition of things . . . and that an active station near them would not be a source of pure satisfaction to them" (Bailey to William, 13 February 1890). Overall, Bailey found that Pampa Central was the best site for astronomical work, though a dubious place for a permanent station. It was difficult living, and there was no nearby town to furnish the necessities of life cheaply. Over the long term, any astronomical gains would be overwhelmed by the enormous cost of running the station. Arequipa was his recommendation. Though the weather was not quite so good as Pampa Central, Arequipa was a city that furnished easy railroad access to the port at Mollendo – which meant it would be cheaper to maintain. Arequipa had three mountains and

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

an enthusiastic populace. A local gentleman, Juan L. de Romaña, with instruments lent him from the Boyden Department, agreed to take measurements of the sky. Arequipans were thrilled at the opportunity to have regular measurements taken on modern instruments, and published the results in the daily papers (*La Bolsa* 1890, 2). It freed Bailey to make the most of the inhospitable Pampa in order to complete some meridian photometer work in January and February while Vieyra made the best of the rainy season on Mt. Harvard. On March 5th, this phase of the expedition was over, Bailey had given all the information he could, and returned to Mt. Harvard to await the Director's decision.

In May, Pickering wrote to Bailey to tell him that Arequipa had been chosen as the site for the permanent station (Pickering to Bailey, 9 May 1890). Bailey was pleased that a decision had been made and after consultation, decided to stay on Mount Harvard to continue work until the beginning of October (Bailey to EC Pickering, 31 May 1890).

All was not perfect. Bailey faced constant frustrations with Vieyra, who was a proud young man and did not easily admit mistakes. Bailey's wife admitted that she would not go through these two years again for anything. But these aggravations seem normal when seven people live together in isolation, removed from the comforts of settled, urban life. They depended completely on the *aguador* who at times failed to bring their water. Their contact with the United States was limited to month-old letters. Yet the confusion, chaos, and bad feelings that characterized the other two expeditions were nowhere seen here.

By November 20th, Bailey and his family had left Mount Harvard behind and rented a house in Arequipa. They left Vieyra in Lima and waited for William to come take charge of the Boyden Department in Peru. Pickering held out faint hope that the Mount Wilson land troubles could work out, but he had one successful expedition to his credit.

Conclusion

The key difference between the successful and the unsuccessful expeditions was that the latter were plagued by conflicting interests on the ground, which had the effect of removing the men doing the work from the decisions that shaped the aims of that work. The mountain asserted itself because it was a natural barrier to the men's participation in their man-made institutions. On a map, the expeditions were never far from civilized society; in practice they existed in a world apart. The mountain was a problem that had to be overcome in order to preserve good relations, good management, good communications, good work. In Colorado and California, communication between Pickering and his men on the peaks broke down as it was filtered through layers of

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

conflict on the ground. Their ability to act as scientists, and consequently their identity as astronomers, was threatened by their managers' inconsistent expectations.

And so it was that Harvard did not settle on Pike's Peak, on Mount Wilson, or even on Mount Harvard. Arequipa, Peru, was a well-established city in a mountainous region, but it was not the kind of site that the Harvard men had originally gone looking for. It fulfilled the terms of the grant insofar as the sky was far clearer than Cambridge because of its high altitude, about 7,800 feet above sea level. However, those who lived and worked there could easily ride into town and get the things they needed (or pick up things they needed shipped from the United States), and when they did subcontract for services, they were not at the mercy of a single, unreliable *aguador*. When William arrived with his family and his assistants to take over the Boyden Department in Arequipa, he bought land, built a large house and instrument sheds, and installed running water. He would not live with the hardship the mountaineers had. The Arequipan people wholeheartedly embraced the station, called it their own observatory, and participated in its success in the way that the Boston elite participated in the HCO's. Most importantly, after a few fits and starts, the station became an integrated part of the HCO's data production process. The astronomers in Arequipa took photographs and sent them back to Cambridge so that they could be analyzed and processed by the corps of women computers. In this way, they acted almost like their counterparts in Massachusetts who took photographs at night and handed them over to the computers for daytime analysis. The Arequipa station was a logistical compromise that erased many of the most expensive and inconvenient effects of the other three sites' remote locations while still maintaining the potential for good work.

That was not all. A good location did not obviate the problems of management at a distance. Until it was closed in 1927, Bailey, one of Pickering's most trusted employees, was most often the director of the Arequipa station. But Bailey was not always there, and Pickering had to trust someone else to run Harvard's expensive auxiliary. Through the trials of the expeditions, he had grown wary of untested middle-managers with whom he had irregular contact. So along with conveniently situating the Boyden station, he also tried to lessen the chances that any person could, intentionally or not, sabotage the finely tuned operation. Aside from special, optional projects, the Boyden assistants found their authority in the core HCO projects diminished. They took photographic plates, checked them for quality, and shipped them back home, where the computers did the data processing that Pickering considered more important. Those privileged functions of the spectral or photometric projects always took place in Cambridge, under Pickering's direct supervision. If communication was cut off for a time, for whatever reason, the impact on the HCO would not be fatal. In the end, the operations of the station could be summarized once a year in several typewritten pages, remarking on how many photographic plates had been taken of which regions of the sky, and how much money had been spent doing it. None of those pages complained about the conditions of living in the mountains.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

References

Backwell, Henry Brown. 1898. "Harvard Women's Work as Astronomers." *Woman's Journal* (9 April): 116.

Bailey, Solon I. 1895. "History of the Expedition." *Annals of the Astronomical Observatory of Harvard College* 34:1–48.

Bailey, Solon I. 1889. "Journal of the South American Expedition by S. I. Bailey, with some notes by M. H. Bailey, and journal by Elias Viegra." Unpublished mss. Records of the Harvard College Observatory, Harvard University Archives.

Bailey, Solon I. 1931. *The History and Work of the Harvard Observatory, 1839 to 1927; an outline of the origin, development, and researches of the American observatory of Harvard College together with brief biographies of its leading members*. New York: McGraw-Hill.

Barker, Daniel W. 1890. *History of the Harvard College Observatory during the Period 1840–1890*. Cambridge, MA.

La Bolsa. 1890. "Observatorio meteorológico." October 31:2.

Bond, William Cranch. 1848. *Description of the Observatory at Cambridge, Massachusetts*. Boston: The Academy.

Bond, William Cranch. 1980. *History and Description of the Astronomical Observatory of Harvard College and Results for Astronomical Observations Made at the Observatory of Harvard College*. New York: Arno Press.

Bradford, Marlene. 2001. *Scanning the Skies: A History of Tornado Forecasting*. Norman: University of Oklahoma Press.

Downing, Sybil and Robert E. Smith. 1995. *Tom Patterson: Colorado Crusader for Change*. Niwot: University Press of Colorado.

Friedman, Robert Marc. 1989. *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology*. Ithaca: Cornell University Press.

Gingerich, Owen. 1993. "Two Astronomical Jewels from Peru, 1889–1927." In *Mundialización de la ciencia y cultura nacional: actas del Congreso Internacional «Ciencia, Descubrimiento y Mundo Colonial»*, edited by Antonio Lafuente, Alberto Elena, and María Luisa Ortega, 707–713. Aranjuez and Madrid: Doce Calles.

Holden, Edward S. [1897] 1980. *Memorials of William Cranch Bond, Director of the Harvard College Observatory, 1840–1859, and of His Son, George Phillips Bond, Director of the Harvard College Observatory, 1859–1865*. New York: Lemcke & Beuchner.

Jones, Bessie Zaban and Lyle Gifford Boyd. 1971. *The Harvard College Observatory: the first four directorships, 1839–1919*. Cambridge, MA: Belknap Press.

Law, John. 1986. "On the methods of long-distance control: vessels, navigation and the Portuguese route to India." In *Power, Action and Belief: A New Sociology of Knowledge?*, edited by John Law, 234–263. London: Routledge & Keegan Paul.

Leonard, Stephen J., Thomas, J. Noel, and Donald L. Walker, Jr. 2003. *Honest John Shafroth: A Colorado Reformer*. Denver: Colorado Historical Society.

Nisbett, Catherine Elaine. 2007. "Business Practice: The Rise of American Astrophysics, 1859–1919." Ph.D. diss., Princeton University. "Notes, etc., relating to the Peruvian expedition, 1888–9." Records of the Harvard College Observatory, Harvard University Archives.

Pickering, Edward Charles. 1883. "Mountain Observatories." *Appalachia* 3 (April):99–106.

Pickering, Edward Charles. 1887. *Forty-Second Annual Report of the Director of the Astronomical Observatory of Harvard College*. Cambridge, MA: Harvard University Press.

Pickering, Edward Charles. 1914. *Sixty-Eighth Annual Report of the Director of the Astronomical Observatory of Harvard College*. Cambridge, MA: Harvard University Press.

Plotkin, Howard. 1978. "Edward C. Pickering, the Henry Draper Memorial, and the Beginnings of Astrophysics in America." *Annals of Science 35*:365–377.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press

Plotkin, Howard. 1984. "Harvard College Observatory." In *The General History of Astronomy, vol. 4A, Astrophysics and Twentieth Century Astronomy to 1950*, edited by Owen Gingerich, 122–124. Cambridge: Cambridge University Press.

Plotkin, Howard. 1993. "Harvard College Observatory's Boyden Station in Peru: Origin and Formative Years, 1879–1898." In *Mundialización de la ciencia y cultura nacional: actas del Congreso Internacional «Ciencia, Descubrimiento y Mundo Colonial»*, edited by Antonio Lafuente, Alberto Elena, and María Luisa Ortega, 689–705. Aranjuez and Madrid: Doce Calles.

Raimondi, Antonio. 1874. *El Perú: Itinerarios de Viajes, vol. 1*. Lima: Banco Italiano de Lima.

Rothberg, Marc. 1990. "Patronage of Harvard College Observatory, 1839–1851." *Journal for the History of Astronomy* 21(1)February:37–46.

Smith, Phyllis. 1993. *Weather Pioneers: The Signal Corps Station at Pike's Peak*. Athens: Swallow Press.

Wyckoff, William. 1999. *Creating Colorado: The Making of a Western American Landscape 1860–1940*. New Haven: Yale University Press.

Correspondence (All records are located in Director's Correspondence, Records of the Harvard College Observatory, Harvard University Archives).

File II: Letters from Robert Black (Box 2), M.M. Bovard (Box 2), J.R. Edmands (Box 5), A.W. Greely (Box 6), George F. Hoar and F.V. Balch (Box 7), F.H. Loud (Box 9).

Solon I. Bailey to Edward C. Pickering and William H. Pickering: "Arequipa to Cambridge, 1888–1891," "Arequipa to Cambridge, 1889–91."

Edward C. Pickering to Black, Bovard, Edmands, A.W. Greely, and Loud: Letterbooks A-7, A-8, A-9, and A-10.

Edward C. Pickering to William H. Pickering: Letterbook B-4.

Edward C. Pickering to Solon I. Bailey: "Cambridge to Arequipa: 1889–91."

William H. Pickering to Bovard, E.S. King, Black, and A.N. Carter: Letterbook E-1.

William H. Pickering to Edward C. Pickering: File II, Box 11.

https://doi.org/10.1017/S026988970999010X Published online by Cambridge University Press