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Astronomers at Altitude

Mountain Geography and the Cultivation of Scientific Legitimacy

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In August 1909, American astronomer William Wallace Campbell, Director of the Lick Observatory, left his home near the summit of Mount Hamilton in California's Diablo Mountains and travelled with a small expedition party to Mount Whitney in the Sierra Nevada Range. His purpose was to observe the planet Mars with spectroscopic instruments, that would allow him to settle a simmering debate over whether the Martian atmosphere contained any measurable amount of water vapour and, thus, whether the red planet might be habitable.[1] To achieve his goal, Campbell had determined that measurements were needed from 'the highest point of land in the United States', where the density of Earth's own atmosphere would be lowest and therefore least disruptive to the very sensitive processes required to assess the composition of the red planet's atmosphere.[2]

Starting from the village of Lone Pine, Campbell and his group travelled by carriage and horseback up the slopes of Mount Whitney to a base camp at 10,300 feet. After two days spent adjusting to the effects of altitude, they continued their ascent on pack animals, despite the fact that 'the weather for two days past had been threatening' and that they suffered snowstorms above 12,000 feet.[3] After a difficult final ascent, they reached the 14,000-foot summit, where a shelter had been constructed specifically for the expedition's purposes. According to Campbell, their arrival at the mountain's peak could hardly have been more dramatic, for just as 'Director Abbot opened the door to receive us there were two violent discharges of lightning, near enough to be felt by most members of the party.'[4]

After setting up a temporary observatory and adjusting instruments in continuing bad weather, the astronomers welcomed a clearing of the skies that provided atmospheric conditions that were 'as perfect for our purposes as could be wished' for the next two nights. On his third and final day of astronomical observations at the summit, Campbell reported

> the sky was absolutely clear; the wind was from the fair-weather quarter; the humidity was low; and the sky was remarkably blue. On occulting the Sun behind the roof of the shelter one could look up to the very edge of the Sun with no recognisable decrease in blueness. I had never seen so pure a sky before.[5]

Campbell exposed numerous spectrographic plates of the moon and Mars, capturing what he considered conclusive proof that the Martian atmosphere was virtually dry.[6] He published his findings in a widely circulated *Lick Observatory Bulletin*.

Within the American astronomical community, the Mount Whitney expedition was considered as a success. In reporting that the Martian atmosphere contained less water vapour than could be perceived by modern instruments, Campbell had contributed pivotal data to a larger debate over the possibility of advanced life existing on Mars.[7] Campbell felt that his expedition had settled the issue by taking unimpeachable data from a much higher altitude than 'at all the observatories where the Martian spectrum had previously been investigated'.[8] Although Campbell's opponents at the Lowell Observatory in Flagstaff, Arizona continued to insist on the existence of both water and life on Mars, the Mount Whitney expedition was widely considered the final word on the subject. Most professional astronomers cited Campbell's work as reason to forgo further Mars investigations, and advocates of Martian life never regained their stature, or credibility, within the discipline of astronomy. Although a popular mania for intelligent Martians – which had begun in the 1890s and reached fever pitch by 1907 – continued for several decades, its intensity waned noticeably after 1909.

As this episode indicates, the high-altitude and mountain location of astronomical work became a locus of legitimacy for American astronomers around the turn of the twentieth century. Campbell's description of the alternating sublimities and difficulties of his Mount Whitney expedition displays two themes that emerged in astronomical writing as the first mountaintop observatories were built in the American West in the late 1800s. First, astronomers began to gain prestige among their peers and in the public eye by emphasising the isolation and purity of the remote mountains in which they worked. Thus Campbell's emphasis on the 'perfect', 'remarkable' and 'pure' atmospheric conditions he achieved by virtue of ascending America's highest peak. Second, astronomers strategically emphasised the rugged and challenging characteristics of their mountain locations in order to distinguish themselves from established metropolitan observatories and to cultivate credibility for their claims. Thus Campbell's report details the 'great difficulty' of planning and executing the Mount Whitney expedition in pursuit of scientific knowledge.

These representational manoeuvres will be traced here primarily by examining episodes of research into the planet Mars. Over the two decades that the possibility of advanced Martian life was taken seriously in American astronomy (roughly 1890–1910), a number of prominent astronomers and observatories participated in the discussion. As the timing of the Mars debates generally coincided with a critical period in astronomy's history, which was marked by the building of new observatories, the professionalisation of observatory staff, the emergence of expert specialisations and the transition from planetary to stellar topics, representations of place played a critical role in the establishment of modern American astronomy. In an era of prominent scientific mountaineering, polar exploration and field expeditions, American astronomers' strategic association with mountain geography was not merely a means to gathering new data, but also a means of cultivating legitimacy.

Geographies of science

Recent studies of the 'geography of science' have come to the forefront of scholarship concerned with knowledge production. The classic works in science studies, which focussed on the contingent and situated nature of scientific knowledge, essentially begged a spatial question without addressing it directly.[9] More recently, Livingstone's push for an explicitly geographical approach to the study of science has inspired a substantial body of scholarship.[10] The places in which scientists conduct their work, the pathways and networks along which scientific claims travel and the unique locations in which audiences engage with scientific knowledge have all been shown to have important influences not only on the substance of scientists' work, but also on scientists' ability to gain credibility.[11] The spatial settings in which scientific work is undertaken are no longer viewed 'as passive backdrops, but as vital links in the chain of production, validation and dissemination'.[12] This scholarship helpfully nudges us beyond the problematic constructivist-versus-realist debate over the 'true' nature of 'science' by acknowledging the plural and varied natures of science, scientists, scientific investigation and claims to scientific knowledge, in their many spatial variations.[13]

Livingstone's repeated calls for attention to science's geography have focussed on three major themes: site, region, and circulation.[14] The sites in which scientists work are now acknowledged to have a fundamental impact on the way knowledge claims are constructed and prepared for dissemination. Important recent work on this theme has shown that scientific knowledge is produced in a multiplicity of sites, including not only the controlled laboratory, but also the field, museum, hospital, pub, coffee house, bazaar, ship, body, etc.[15] The micro-geographies affecting each site of science are 'central to the veracity of the knowledge produced', despite the common perception of science as a 'placeless' activity that does not vary by location.[16] On a broader scale, regional geographies influence not only how scientists will approach their work, but also how that work will be received. The role of local scientific societies, for instance, has important regionally-specific effects on the legitimisation of scientific work.[17] Finally, geographies of circulation between sites, regions and audiences are now seen as important determinants of scientific knowledge and its credibility. Because scientific practices are typically separated from witnesses or audiences by some spatial distance, the establishment of trust (and, therefore, legitimacy) usually requires a circulation of knowledge claims. The spatial- and socio-geographic dimensions of this circulation influence the nature of the claims themselves, as well as their reception.[18]

These dimensions have been brought to bear on one of the most complex spatial divisions in the scientific world: the distinction between field and laboratory. Laboratory science is often considered *placeless*, with location said to have no impact on universally replicable findings. Field science, on the other hand, is considered site-specific, in that results cannot be replicated from one place to another, given that local variation itself is typically the topic of study. In legitimacy contests, bench scientists will savagely criticise results that can be produced in only a single site, whereas field scientists will reject investigations that do not show a sophisticated understanding of the uniqueness of the field site in question. Science is practised differently in these two spaces, and legitimacy is therefore cultivated differently.[19] Traditionally, field scientists emphasise 'the heroic quest of the naturalist-explorer', while bench scientists prioritise 'mastery over Nature through the steady, distanced gaze of the scientist'.[20] This fundamental distinction between objective distance and active contact as means of accessing natural reality certainly complicates our understanding of the geography of 'science'. Field scientists and bench scientists must invariably interact, communicate, collaborate and mediate the intricacies of their two worlds.[21]

What of the main concern here, the astronomical observatory? Is an astronomical observatory a field site or a laboratory? An observatory is essentially a controlled space, like a lab, but its scientists pursue observational work rather than experiment. Results and findings are theoretically supposed to be replicable, as in a lab, but the physical location of various observing sites has a significant impact on what types of observations can actually be made successfully. In essence, then, the astronomical observatory is a unique scientific site, in which the elements of field and lab co-mingle with no buffer or border zone between them.[22]

This dual identity can be read most clearly in astronomers' representations of their observatory locations. During the establishment of the first observatories in the American West, astronomers were especially effective in gaining legitimacy by representing their practices as both controlled and heroic, which was possible only by association with the new, high-altitude and mountain observatory sites. It is important to note, however, that although these observatories were located in mountain sites, that fact did not automatically produce this legitimacy. Astronomers, writers and audiences had to engage actively with the representation of astronomy's mountain geography to create the effect of legitimacy. Representations in science have been shown to influence what claims to knowledge can be made, what social networks can be activated, what alliances can be cultivated, what legitimacy can be established and how audiences can be manipulated.[23] In the case of the new American observatories at the end of the nineteenth century, this representational power was mobilised to portray astronomy as a mountain science. Like natural science, geology or even meteorology, American astronomy's reputation at this time became connected to popular enthusiasm for travel, fieldwork and adventuring in remote mountains and at high altitudes.[24]

Astronomy and the American West

Several new observatories were built in the American West at the end of the nineteenth century. They were hailed as great advances for the discipline and for American science, partly because of their large telescopes, professional staffs and commitment to new areas of stellar research. But the profile and status of these observatories were also highly dependent on their physical locations. Those that were in non-urban or mountain locations were automatically taken seriously, even with smaller telescopes and less experienced astronomers. Those closer to metropolitan areas or at lower altitudes, on the other hand, struggled to establish legitimacy, despite having large telescopes and highly trained staff astronomers.

The University of California's Lick Observatory, established in 1888, was the first 'big-science' institution in the United States. Endowed by California businessman, James Lick, the observatory was envisioned from the beginning as a world-class institution that would outshine all other observatories in two regards: first, it would have the most powerful telescope in the world and, second, it would be sited on a mountaintop with excellent conditions.[25] Lick's predilection for a mountain site was influenced by recent enthusiasm among astronomers for the benefits of improved atmospheric steadiness at high altitude, which supposedly 'would amply repay the inconvenience' of transporting materials and asking astronomers to live in difficult and isolated conditions.[26]

Lick himself was involved in the site selection and apparently gave his blessing to the remote peak of Mount Hamilton in the Diablo range, partly because he was enchanted by the fact that he could see its summit from his own home near the south end of San Francisco Bay.[27] At 4,200 feet high, the mountain exceeded Lick's minimum elevation criterion of 4,000 feet. This height and California's reputation for clear skies created the powerful assumption that the site would be ideal for astronomy. No formal evaluation of Mount Hamilton's atmospheric characteristics had been performed, in fact, before the site was officially selected and the County of Santa Clara induced to build an expensive 26-mile road to the mountaintop site.[28] Given the size of Lick's investment and the height of the astronomical community's hopes for its new centrepiece observatory, it was perhaps fortunate that when the site was eventually tested, the atmospheric characteristics were deemed to be very good! Before this determination, however, Mount Hamilton had already received favour, not because of the particulars of its scientific advantages but more because it fit a romanticised notion of the mountain as a proper location for astronomy. As the editor of an astronomical journal remarked: 'One year on the summit of the California mountains affords the opportunities which twelve years of observations in the changeable climates of other states do not furnish.'[29]

Lick's second ambition – to have the world's most powerful telescope at his observatory – was also fulfilled, but this quality was rarely remarked without simultaneous reference to the observatory's mountain location. The Lick Observatory's own director, Edward Holden, issued a widely circulated pamphlet, which through illustrations emphasised the site of the observatory, rather than the observatory's famous telescope.[30] Likewise, the very first volume of the new journal, *Publications of the Astronomical Society of the Pacific*, included this telling quote in its 'news briefs' section,

> Telescopes … 'cannot be formed so as to take away that confusion of rays which arises from the tremors of the atmosphere. The only remedy is a most serene and quiet air, such as may perhaps be found on the tops of the highest mountains above the grosser clouds'. Sir Isaac Newton, in his *Opticks*, AD 1730.[31]

Mobilising the undisputed (and 250-year-old) authority of Newton in support of mountain-based astronomy, the new observatory and new society showed the extent to which geographical location mattered to the new astronomical science. The mountain location of the Lick Observatory was a major component of its status and credibility, quite separate from the observatory's actual work and contributions to research in stellar astronomy.

The second large-scale American observatory, the University of Chicago's Yerkes Observatory, provides another example of the role geography played in establishing credibility for astronomical institutions. Like the Lick Observatory, Yerkes was funded by a philanthropist who wanted his observatory to boast the largest telescope in the world. Much of the drama surrounding the new observatory's planning and construction in the 1890s, in fact, focussed on its attempt to 'lick the Lick' by installing a telescope with a 40-inch lens, which would famously exceed the 36-inch lens of Mount Hamilton's celebrated instrument.[32] The Yerkes Observatory was conceived as a centrepiece of the University of Chicago and of the city of Chicago, both then emerging on the national and international stages.[33]

There was only one problem with the Yerkes Observatory: its location. Given the University of Chicago's desire to maintain a close association with one of its showcase units, a site was selected for the observatory in Lake Geneva, Wisconsin, which was 'then just at the limit of leisurely commuting distance by train' from Chicago.[34] It was also, coincidentally, a 'resort for the choicest people of Chicago', whom the University of Chicago president wanted to lure as donors.[35] Although the site selectors were confident that the Lake Geneva location was fine for astronomical purposes, the observatory's spatial association with the city and the easy life proved to be a constant hindrance.

Observatory director, George Hale, found himself constantly defending the site selection, thus revealing deep concerns about the site's influence on the legitimacy of the observatory. He repeatedly provided technical explanations of the site's atmospheric advantages but also regularly emphasised his observatory's remoteness as a way of perceptually distancing it from urban Chicago.[36] At the dedication of the observatory in 1897, for instance, he thanked attendees for travelling to a site so far 'removed from the neighbourhood of great cities, and from the more populous regions of the United States', though in fact most of them had taken only a short train ride from Chicago.[37]

In these representations, Hale was forced to acknowledge the favouritism usually shown to mountain sites, particularly that of the Lick Observatory. He tried to rebuff this favouritism by arguing that mountain locations were not necessarily a guarantee of good astronomical research and by suggesting that his Lake Geneva institution was every bit as

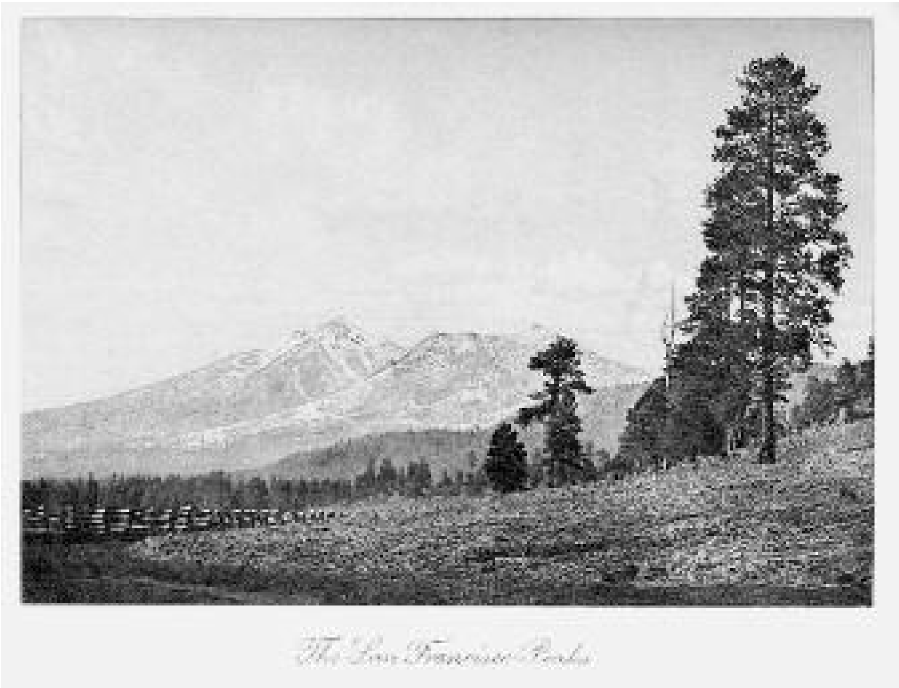

Figure 8.1a First of the two plates which opened Lowell's first astronomical book *Mars* (Boston: Houghton, Mifflin & Company, 1895) shows the San Francisco Mountains, which could be seen from the Lowell Observatory.

credible as the Lick.[38] Despite these efforts, however, Yerkes was persistently dogged by accusations of 'bad seeing'. Even several of Yerkes' own astronomers admitted their site's inferiority to the Mount Hamilton as a matter of fact, and Hale himself soon grew tired of the difficulties of observing at Yerkes.[39] He left Chicago in 1903 to establish a new solar observatory outside Pasadena on Mount Wilson, elevation 5,700 feet. Despite the Yerkes Observatory's massive telescope, its generous funding, its meticulous organisation and its soaring expectations, it never managed to rise above concerns about its location. Yerkes was considered an excellent site by Eastern or Midwestern standards, but could not truly challenge the Western mountain sites for prestige.

By contrast, the Lowell Observatory – more meagrely equipped, funded and staffed than either the Lick or Yerkes Observatories – managed to achieve considerable acclaim by promoting the excellent conditions of its site above Flagstaff, Arizona, elevation 7,000 feet. This small-scale observatory was founded in 1894 by a wealthy amateur astronomer, Percival Lowell, who intended a research programme focussed on visual observations of the planets, specifically Mars. In an era of increasing spectral and stellar work, an observatory dedicated to the visual investigation of a single planet seemed an anachronism. With this

Figure 8.1b Second of the two plates which opened Lowell's first astronomical book *Mars* (Boston: Houghton, Mifflin & Company, 1895) depicts one of the observatory residences almost as a frontier outpost. Together, these images created a strong visual connection between the Lowell Observatory and Western high-mountain landscapes.

singular interest, Lowell could hardly have expected to earn much esteem among professional astronomers and major observatories. He did not help his case by publishing his observations alongside speculative interpretations of the Martian surface as an inhabited landscape (described in more detail in the next section). Lowell's propensity for taking quasi-scientific arguments directly to popular audiences through magazines and lectures seemed to go against every promising trend in American astronomy. In thus antagonising leading American astronomers, Lowell inspired numerous assaults against his own and his observatory's legitimacy.

Lowell, however, managed to establish and maintain significant credibility, especially in the public eye. One of the most important things he did in this regard was to emphasise the remoteness of his observatory's location, the superiority of its altitude, and the excellence of its climate. In his publications, he regularly emphasised that he had investigated climatic conditions in numerous Western sites before selecting high-altitude Flagstaff 'for the purpose of getting as good air as practicable'.[40] He relied on this fact heavily in asserting that his observatory was much more credible than any on the East Coast or in urban areas, lamenting that 'at the present time most observatories are situated where man is greatly handicapped in his own efforts toward the stars' by city smoke, electric lights and other pollutants of atmospheric visibility.[41] He even went so far as to argue that his observatory was on equal footing with the world-class Lick Observatory by virtue of his advantageous location, despite the great difference between their telescope powers and staff experience.[42]

Popular writers and audiences responded enthusiastically to this strategy, regularly commenting on the advantages of Lowell Observatory's high-altitude location when discussing the Mars debates. Although professional astronomers generally did not express any enthusiasm for Lowell's theory-driven methods, his speculative hypothesis and his targeting of popular publications, they often found themselves forced to admit the quality of his location. Simon Newcomb, who never accepted Lowell's theory about the inhabitants of Mars, nonetheless wrote of the Flagstaff observatory, 'Its situation is believed to be one of the best as regards atmospheric conditions.'[43] Such comments indicate the extent to which geographical location had achieved parity with other factors which also defined an astronomer's credibility, such as one's professional rank and the power of one's instrument.

It should be noted that Lowell Observatory is not in the mountains. Rather, it is located on a high mesa. This fact apparently escaped many of Lowell's readers and audiences at the time, however. The observatory was just assumed to be in the mountains by virtue of its reported remoteness, altitude, climate, and general location in 'the West'. A well-known astronomer, for example, referred in a publication to the excellent climate of the 'Arizona Mountains' and lauded Lowell's site on 'Flagstaff Mountain', which does not exist.[44] Lowell and his associates did nothing to correct this frequent mistake. On the contrary, they actively cultivated such a close association with mountains. One of Lowell's small staff described the observatory's location thus: 'It is a trifle short of 7,000 feet above the sea and is ten miles south of the San Francisco Peaks whose highest point is 12,800 feet in elevation.'[45] The San Francisco Peaks so prominently noted in this quote had nothing whatsoever to do with the observatory, but they (and their height) were regularly mentioned in connection with the observatory. Lowell's first book, *Mars*, actually included photographs of the San Francisco Peaks alongside photographs of the observatory buildings, implying that the observatory was in fact in the mountains. [Figs 8.1a and 8.1b] Both Lowell and his most experienced astronomer, William Pickering, were members of the Appalachian Mountain Club and were known for their climbing enthusiasm, which deepened the observatory's connection to mountain landscapes.[46] These mountain representations created by the Lowell Observatory relied on an already-established and widely accepted notion of high mountains as ideal sites for astronomical science. By tapping into this association, Lowell managed to generate significant credibility for himself and his work.

The movement of observatories away from the urban centres of the East Coast was seen as part of the inevitable professionalisation and industrialisation of astronomy, processes that were taking place across the sciences in America as a whole.[47] Amateurs, who had been fully integrated into the discipline in the middle of the nineteenth century, quickly lost their footing in this transitional era.[48] The notable exception of gentleman-amateur Percival Lowell and the success of his Lowell Observatory show the power that representation of place carried within the processes of scientific legitimisation. The new mountain locations for Western observatories were clearly important to the topical and methodological transitions underway in turn-of-the-century American astronomy. However, it was the representation of these mountain locations that proved fundamental to establishing the credibility of observatories and astronomers. This can be seen quite clearly in debates that raged over the planet Mars and its geography.

A sublime view of the red planet

Over the decade and a half spanning the turn of the twentieth century, an extraordinary popular mania developed in the United States around the idea that Mars was inhabited by intelligent beings. Starting in the late 1870s, some European astronomers had reported seeing geometrical patterns on the Martian surface. Despite disagreement among professional American astronomers as to the visibility, existence or meaning of these patterns, popular audiences responded enthusiastically to Percival Lowell's bold interpretation that the lines were most likely a network of irrigation canals. Backed by an impressive map of the so-called 'canals', Lowell asserted that the lines proved the existence of an advanced race of Martian canal-digging engineers.[49] To the chagrin of disciplinary leaders intent on advancing the rational status of astronomy, Lowell's sensational claims were reported widely in newspapers, discussed frequently in general interest magazines, and presented regularly to popular audiences on both sides of the Atlantic.[50] As a result, the term 'canal' became the standard designation for linear features on Mars, though the existence of water was always much in debate. Despite their general lack of interest in planetary astronomy, scientists such as Newcomb of the Nautical Almanac, Hale of Yerkes Observatory, and Campbell and Holden of Lick Observatory responded to Lowell's growing fame by conducting their own Mars research and trying to discredit him. In the process, they hoped to protect the scientific reputation of their discipline by exposing Lowell as an amateur whose claims were unsound, unscientific and based on little more than optical illusion.[51] In the ensuing credibility contest, mountain representations played an important role because much of the manoeuvring over personal, professional and institutional legitimacy centred on the locations of the various observers. Each observer usually insisted on the superiority of his own position while denigrating his opponents' locations. In this rhetoric, high-altitude, remote, isolated, mountain observatories maintained the upper hand, using two primary themes to assert their credibility.

The first theme focussed on the sublime nature of mountains. With increasing altitude, air becomes less dense and contains fewer particles, meaning there are fewer opportunities for air molecules to impede or refract the path of light as it passes through Earth's atmosphere. All other things being equal, distant celestial objects thus appear brighter from high altitude positions than they would from sea level. Furthermore, high altitude sites provide the opportunity to rise above dense cloud-cover and escape the visual distortion caused by water vapour molecules.In one sense, the sublimity was technical. Distance from urban areas also reduces the effects of pollution and heat, both of which impede clear views of the heavens. So the higher and more remote the observatory, the more sublime its conditions for scientific work. Lick Observatory, the first American observatory to see the Martian 'canals', emphasised this theme in its 1892 reports confirming earlier European findings. Though Mars was very low in the northern sky in 1892, Holden reported that the pure atmosphere and large telescope at Lick allowed for numerous observations and sketches of Mars at a time when most other American observatories reported a dismal failure in their attempts to get good views of the red planet.[52] The perfection of Lick's mountain location again became a theme in 1894, when Lick astronomer Campbell tackled the conventional wisdom about water vapour on Mars. In publishing controversial findings that showed little or no water vapour on the red planet, Campbell referred to the 'extremely unfavourable' conditions under which past observations had been made. He then lauded the high altitude of Lick Observatory, 'which eliminates from the problem the absorptive effect of the lower 4,200 feet of the Earth's atmosphere, with all its impurities. Most of the old observations were made from near sea-level.'[53] He thus used representations of the pure and sublime characteristics of the Lick Observatory site to validate his controversial position regarding the science of Mars.

In addition to boasts about the technical perfections of high and dry air, Western astronomers also cultivated legitimacy with colourful descriptions of the sublime vistas their observatories offered of surrounding terrestrial landscapes. From a mountaintop or mesa cliff, the astronomer's view of his home planet was said to be spectacular. A *Scientific American* feature article on the new Lick Observatory typically emphasised the new facility's view of California:

> In speaking of the outlook from Observatory Peak, which is 4,802 feet in height, Professor Holden says: 'It would be difficult to find in the whole world a more magnificent view than can be had from the summit just before sunrise, on one of our August mornings. The eastern sky is saffron and gold, with just a few thin horizontal bars of purple and rosy clouds … The instant the sunbeams touch the horizon the whole panorama of the Sierra Nevada flashes out, 180 miles distant … The Bay of San Francisco looks like a piece of a child's dissecting map, and is lost in the fogs near the city. The buildings of the city seem strangely placed in the midst of all the quiet beauty and the wild strength of the mountains. Then you catch a glimpse of the Pacific in the southwest and of countless minor ranges of mountains and hills that are scattered toward every point of the compass, while, if the atmosphere is especially clear, you can plainly see to the north Mount Shasta, 175 miles distant.'[54]

Not only did this detailed representation garner interest from popular audiences, but it also conferred authority on all claims to clear vision coming from the Lick Observatory. If Holden could see with such clarity beyond the fogs of San Francisco, all the way to majestic Mount Shasta, then Lick Observatory's claims for seeing the surface of Mars could also be trusted.

Percival Lowell used and extended the effectiveness of these themes in his own early publications, when he was trying to establish his new observatory as a legitimate site of scientific knowledge making. He opened nearly every publication with a discussion of the clarity of high-altitude air in Arizona, thus predisposing readers to accept his later claims about having discovering numerous Martian canals.[55] He also successfully repelled attacks by Hale, Newcomb and a number of British skeptics by turning attention away from the content of their critiques and toward the location of their urban observatories.[56] In Lowell's rhetoric, an inability to see the Martian canals was linked to impure or polluted observing sites. His own remarkable ability to see increasing numbers of canals, on the other hand, could be attributed to the purity and sublimity of his own site.

Lowell also deftly emphasised a moral purity associated with sublime mountain locations. Removed from civilisation, he claimed, high-altitude astronomers were free from corrupting influences that would otherwise denigrate the purity of their investigations, observations and intentions. In repetitive yet persuasively eloquent arguments, he contended that proper investigations of Mars could be done only in high, remote places.

> [The astronomer] must abandon cities and forego plains. Only in places raised above and aloof from men can he profitably pursue his search, places where nature never meant him to dwell and admonishes him of the fact by sundry hints of a more or less distressing character … Withdrawn from contact with his kind, he is by that much raised above human prejudice and limitation.[57]

In representations of this type, Lowell effectively tapped into a national enthusiasm for wilderness that was just then emerging in the United States.[58] This enthusiasm was strongly associated with the American West, allowing Lowell to make sweeping generalisations about the inferiority of the East for astronomy: 'Not till we pass beyond the Missouri do the stars shine out as they shone before the white man came.'[59] His skillful responsiveness to popular sentiment allowed Lowell to cultivate large audiences even though professional astronomers rejected many of his arguments about Martian canals and inhabitants. The romantic representation of his scientific exploits in the sublime air of the American High West carried great authority with general audiences.

Heroic explorations of Mars

A second theme that promoted and maintained the legitimacy of high-altitude and mountain observatories represented the ruggedness and physical challenge associated with working in the mountains. Textual descriptions and graphical depictions of snow, ice, bad weather and dangerous terrain reinforced the concept that the best investigations of Mars were being done in wilderness settings. In such representations, the astronomer was painted as a 'heroic and manly figure', confronting mountain wilderness and rising to its challenges in the name of science.

The heroic-astronomer theme had long been tied to mountain observatories in general, not just those that undertook observations of the planet Mars. Director of the Lick Observatory Holden published a monograph in 1896 on 'the conditions of good vision at mountain stations all over the globe', in which he lauded the world's high-altitude observatories. Perhaps most striking about this volume was that it was illustrated with numerous vivid

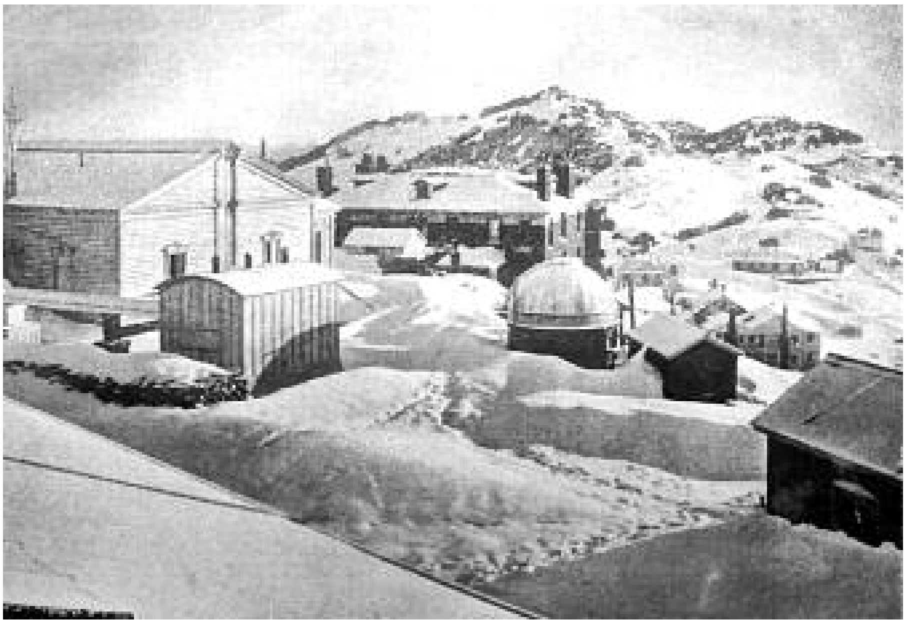

Figure 8.2 Holden's *Mountain Observatories* (Washington, DC: Smithsonian, 1896) featured numerous images that emphasised the climatic challenges and isolation of the world's mountain observatories, including this image of Holden's own Lick Observatory after a snowstorm. Most of Holden's images also appeared as plates in *Publications of the Astronomical Society of the Pacific* between 1893 and 1896.

graphics depicting astronomers and observatory buildings on remote mountaintops [Fig. 8.2].[60] In these images, which Holden had collected from various publications and observatories, astronomers were shown to be every bit as hardy as the seasoned polar and glacial explorers then making headlines throughout Europe and North America. In the most extreme examples of this visual trope, astronomers were depicted as miniscule figures in ominous, vertical landscapes, often in the act of trekking through deep snow or crossing threatening crevasses. Their supposed destinations – summit observatories – were always excluded from the visual frame to accentuate the wildness of the setting [Figs 8.3, 8.4a and 8.4b]. Needless to say, Holden's volume contained not one image of a passive astronomer seated at a telescope. The astronomer-as-heroic-adventurer trope required that astronomers be represented as mountaineers, not as observers. In Holden's book, these dramatic images were accompanied by a textual narrative that recounted the difficulties astronomers had reported while living and working at various high-altitude facilities: violent weather, forest fires, snow-blindness and mountain-sickness, as well as isolation, discomfort and monotony, to name a few. Holden cast these potential negative features in a decidedly positive light that

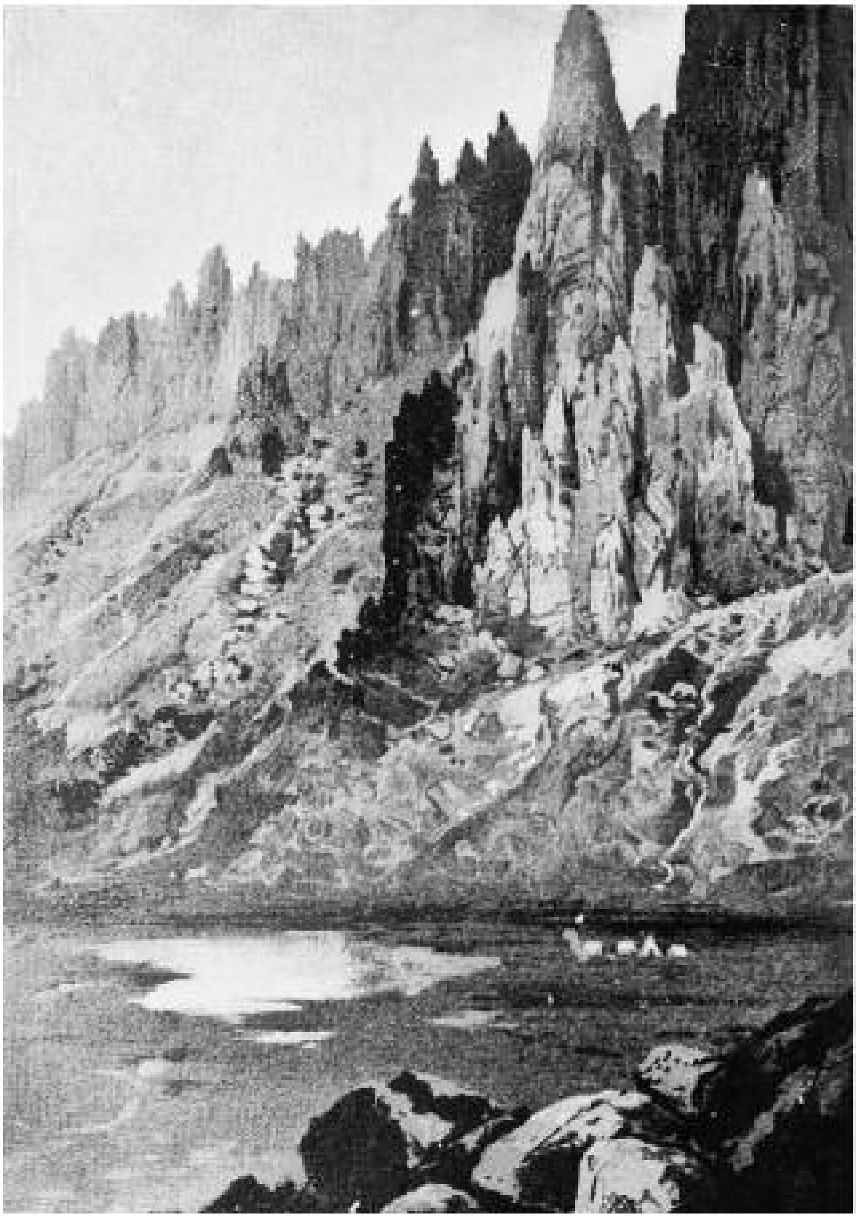

Figure 8.3 The astronomers' 'Mountain Camp' depicted in this image is dwarfed by Mount Whitney, site of Campbell's 1909 expedition to photograph the spectrum of Mars. From Holden's *Mountain Observatories* (Washington, DC: Smithsonian, 1896).

Figure 8.4a The first of two images titled 'On the Way to the Mont Blanc Observatory' in Holden's *Mountain Observatories* (Washington, DC: Smithsonian, 1896). Here astronomers are depicted as fearless mountaineers in an ominous landscape.

embraced the heroic-astronomer persona: 'Devoted men can always be found to undergo necessary hardships in the pursuit of scientific truth.'[61]

The debates over Mars, its canals and its inhabitants trafficked heavily in this type of representation. Most often, the portrait of the heroic-astronomer was evoked implicitly through counter-portraits of urban or sea-level astronomers as unmanly and untrustworthy in terms of their Mars claims. Lowell, for instance, often rhetorically challenged his critics to visit the Lowell Observatory, noting that everyone who had observed from Flagstaff had seen canals on the Martian surface. In such challenges, Lowell implied that only those astronomers who were hardy enough to undertake a westward journey were capable of good scientific vision. No wonder the Eastern astronomers had never seen canals, he suggested – they were not man enough. To discredit his critics at the Lick Observatory, against whom he clearly could not level the same charge, Lowell suggested instead that the men working on Mount Hamilton were not capable of using their powerful telescopes properly in their excellent setting.[62] Lowell's principal attacks on his opponents thus focussed either on their failure to obtain a sublime location or on their failure to meet the challenges of the scientific endeavour in a sublime location. Campbell, at the Lick Observatory, responded in kind, levelling similar criticism of Lowell's own staff. In explaining differences between his spectroscopic results (which found no water vapour on Mars) and those performed at the Lowell

Figure 8.4b The second of two images titled 'On the Way to the Mont Blanc Observatory' in Holden's *Mountain Observatories* (Washington, DC: Smithsonian, 1896). Here astronomers cross a threatening crevasse with seemingly casual ease.

Observatory (which indicated plenty of life-supporting water on Mars), for instance, Campbell argued that the Arizona astronomers probably did not understand fundamental issues related to mountain geography and that their data therefore could not be trusted.[63] Scientific manliness – the ability to confront and ably conquer wilderness challenges in pursuit of knowledge – was thus powerfully mobilised as a means of legitimising various claims regarding the nature of Mars.[64]

Expeditions in search of the red planet

The two dominant, mountain-related, representational tropes in the Mars debates – mountains as sublime scientific sites and mountain astronomy as a difficult, heroic, manly endeavour – found a powerful fusion in the representation of astronomical expeditions. Around the turn of the century, the quest for definitive Mars observations inspired several expeditions: challenging treks through rugged and difficult wilderness conditions in search of perfect, remote, sublime sites of

Figure 8.5 Representations of Harvard College Observatory's astronomical outpost near Arequipa, Peru invariably referred to the formidable Andean mountains surrounding it, as shown in this image. Frontispiece for *Astronomy and Astro-Physics*, New Series 5, No. 105 (May 1892).

science. Though astronomical expeditions were fairly common in the nineteenth century, they were generally aimed at seeing a celestial object or event that would be geometrically invisible from the home location. A solar eclipse that would be visible only in certain areas of the globe, for example, might require an expedition to northern Africa, or East Asia, or India.[65] The new expeditions to observe Mars – though similar in style (and levels of publicity) to these solar eclipse expeditions – were oriented instead around getting a better view, not a unique view.

The first major expedition by an American observatory in this vein was Harvard's investigation of mountain sites in South America during the 1880s. At the same time the vaunted Lick Observatory was being planned and constructed in California, Harvard College Observatory's director, Edward Pickering, obtained funding for a high-altitude, satellite observatory. A much-reported expedition to the Andes Mountains resulted in establishment of a research station near Arequipa, Peru, elevation 8,000 feet.[66] This station, which was originally intended to undertake a programme of photographic mapping of the southern skies, quickly became known for its studies of the Martian surface. The first director, Pickering's brother William (who later moved to the Lowell Observatory), claimed that the perfect atmospheric conditions at Arequipa enticed him to study Mars and its enigmatic markings during the red planet's close approach in 1892. He felt he would otherwise be wasting a glorious opportunity to contribute to knowledge about Mars, given the 'splendid atmosphere' above the Andes at his 'remote and isolated position'.[67]

In reporting his findings about Mars, Pickering regularly mentioned the rugged yet sublime location from which he had made his observations. Photographs of the observatory always showed stunning snow-covered peaks in the background [Fig. 8.5], and the elevations of surrounding peaks were mentioned in nearly every dispatch from the expeditionary station. Pickering himself, an avid mountaineer and member of the Appalachian Mountain Club, undertook multiple ascents of the nearby El Misti volcano, and his successor, Solon Bailey, eventually established a meteorological station on its peak at 19,200 feet. Bailey wrote dramatically of his conquest of the volcano, revealing a powerful entanglement of scientific interest and the romantic pursuit of the heroic. 'El Misti stands alone. At first a sort of awe kept me from considering as possible the establishment of a station on its summit; but always, as I looked upon it, the impulse became stronger and stronger, and finally it could not be resisted.'[68] He wrote excitedly about the 'skill and stamina' required for climbing such a high mountain, reporting, 'the difficulties of the ascents were increased, at heights of 10,000 feet or more, by attacks of *soroche*, a mountain sickness that caused dizziness, faintings, nausea, and sometimes loss of consciousness'.[69] The story of this expedition-within-an-expedition became famously associated with the southern observatory, emphasising the heroism and dangers of astronomical expeditions.

It was not only the Eastern observatories that sent expeditions to high altitude. Even the Western and mountain-based American astronomers went on expeditions strategically designed to improve their credibility in the Mars debates. In the face of increasing criticism of his colourful hypothesis, Lowell conceived a South American expedition of his own in 1907. Appointing well-known eclipse expeditioner David Todd of Amherst as director, Lowell sent a small party from Flagstaff to the Andes Mountains to observe and photograph the surface of Mars. His stated intent was to capture definitive photographic evidence of the Martian canals, thus proving the optical illusion theory incorrect. At the same time, however, Lowell clearly relished the opportunity to create a popular sensation that reflected favourably on the legitimacy of his observatory and its scientists. He cabled the press at every opportunity with news from the expedition and enjoyed the development of a bidding war between several magazines seeking first publication rights to the expedition's findings.[70] Much of the intrigue of the expedition lay in the merger of the two tropes identified above – a heroic search for a sublime site of science.[71]

In answer to the popular furore over Martian canals that Lowell stoked with his 1907 expedition, Campbell plotted his 1909 expedition to Mount Whitney. Just like Lowell's expedition, Campbell's was a carefully planned endeavour meant to settle the life-on-Mars debate by cultivating unimpeachable legitimacy for his scientific claims. Assuming the heroic-astronomer persona quite effectively, Campbell described in his official report a very difficult ascent of the mountain and a painstaking setup of his scientific instruments, made especially arduous by harsh weather. The conditions at the top, however, were said to be sublime, as captured in Campbell's rapturous claim cited above that he 'had never seen so pure a sky before'.[72] These powerful representations of the expedition were critical to the legitimacy of its results, which might otherwise have been seen as extremely limited and inconclusive, given that Campbell observed Mars with the spectroscope on only two nights and reported stormy weather both before and after. The presence of humid air or some other anomaly could have easily tainted results gathered by extremely sensitive equipment over such a short period of time. But Campbell's 1909 results – gathered at the summit of the highest mountain in the continental United States – were received as conclusive and final within the professional ranks. The heroic efforts he had made, the sublime conditions he had attained, and the powerful representations he then created to communicate with his professional colleagues and the wider public ensured a very powerful legitimacy for his scientific claims.

Conclusions

Astronomical expeditions to high mountains became focal points in the turn-of-the-century legitimacy wars over Mars, with popular opinion swinging back and forth in response to expeditionary findings. Astronomers' aggressive and strategic representations of their mountain experiences combined two extremely powerful tropes in support of their claims and reputations. On one level, astronomers succeeded in aligning themselves with popular heroic endeavours like mountaineering and polar exploration. At the same time, however, they relied on a popular reverence for sublime mountains as the foundation for their claims. These expeditions thus merged the instrumental authority of the mobile observatory-laboratory and the personal authority of 'manliness' with the critical geographical authority of high-altitude landscapes.

This acknowledgement, celebration and even embellishment of the site of science raises interesting questions about the nature of the legitimacy Mars astronomers constructed for themselves. By emphasising individual experience and the uniqueness of individual observing locations, mountain-based astronomers actually undermined their profession's claims to universal truth. This paradox perhaps explains some of the lingering difficulty in separating amateurs from professionals before the second decade of the twentieth century, a difficulty that allowed Percival Lowell to establish a powerful credibility for himself and his claims that Mars was inhabited. Only when American astronomy had largely abandoned its sea-level and urban sites later in the twentieth century, fully relocating to the mountains, did the geographical uniqueness of individual sites begin to lose relevance. Only then could instrumental superiority and professional standing re-emerge as primary variables in the legitimacy equation. In the era of Mars debates and the popular canal craze, however, a metropolitan-versus-mountain dichotomy provided the critical means of differentiating among the credibility of observatories, astronomers and hypotheses. The higher, the more remote, the more rugged and the more sublime, the better.

75 Turrill, *Plant Life*.

76 W. Turrill, 'Some problems of plant range and distribution', *Journal of Ecology* 39 (1951), p. 206; Turrill, *Plant Life*, p. 213.

77 A.G. Tansley, 'Editor's preface', in Turrill, *Plant Life*, p. viii; Turrill, 'Plant range', p. 206. That such a mix depended on the geographical location and undefined form of the Balkan peninsula was a driving argument also among European and American geopoliticians of the time; see for example F. Kovacs, *The Untamed Balkans,* New York, 1941.

78 Turrill, 'A contribution to the botany of Athos', *The Plant Life of the Balkan Peninsula: a Phytogeographical Study*, p. 208.

79 Turrill, 'Plant range', p. 215.

80 Cameron and Mattless, *op.cit.*

81 A. Hill, 'A botanist on the Holy Mountain', *Blackwood's Magazine* 236 (1934), p. 81.

82 Turrill, 'Botany of Athos', p. 202; Hill, *op.cit.*, p. 81.

83 *ibid.*, p. 83.

84 G. Speake, *Mount Athos: Renewal in Paradise,* New Haven and London, 2002, p. 34.

85 B. Latour, 'How to be iconophilic in art, science, and religion?', in A Slaton (Ed.), *Picturing Science, Producing Art,* New York and London, 1998, p. 433.

86 Latour, 'Iconophilic', p. 422.

87 Y.F. Tuan, 'Introduction: cosmos versus hearth', in P. Adams, S. Hoelscher and K. Till (Eds.), *Textures of Place,* Minneapolis, 2001, p. 320.

88 Bachelard, *op.cit.*, p. 151.

Endnotes for chapter 8

1 A spectroscope records the wavelengths of light reflected or emitted from a celestial body. Because different chemical elements produce different spectral signatures in reflected solar light, an observer on Earth can determine and characterise – by virtue of the exaggeration or dullness of various wavelengths captured by the spectroscope – the existence and composition of an atmosphere. Because the effects of Earth's own atmosphere must always be accounted for, spectroscopic studies often involve the comparison of two or more celestial bodies, which allows for any common anomalies to be discounted as due to Earth's atmosphere.

2 W. Campbell, 'The spectrum of Mars as observed by the Crocker expedition to Mt. Whitney', *Lick Observatory Bulletin* 169 (1909), p. 149.

3 *ibid.*, 152.

4 *ibid.*, 152.

5 *ibid.*, 152.

6 Campbell's plates showed the spectra of the Moon and Mars to be identical. Because they were observed at virtually the same time, under the same atmospheric conditions, this finding indicated that Mars must have an extremely thin atmosphere, or none at all, just like the Moon.

7 Campbell did not conclusively reject the possibility that Mars had water vapour, but clearly stated that the new data 'put the burden of proof' on those who claimed this to be true. Campbell, *op.cit.*, p. 155. For a discussion of Campbell's role in the controversial history of Mars spectroscopy, see D. DeVorkin, 'W.W. Campbell's Spectroscopic study of the Martian atmosphere', *Quarterly Journal of the Royal Astronomical Society* 18 (1977), p. 37–53. For a more detailed discussion of the Mount Whitney expedition, see D. Osterbruck, 'To climb the highest mountain: W.W. Campbell's 1909 Mars Expedition to Mount Whitney', *Journal for the History of Astronomy* 20 (1989), pp. 77–97.

8 Campbell, *op.cit.*, p. 153.

9 Early work in science studies showed that the emergence and institutionalisation of experimental science, for example, was dependent on the gathering of 'witnesses' who could vouch for the legitimacy of experimental observations and phenomena. S. Shapin, 'The house of experiment in seventeenth-century England', *Isis* 79 (1988), p. 373–404; S. Shapin and S. Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life*, Princeton, 1985. Furthermore, the uniquely local laboratory sites in which witnesses were typically assembled are now understood to have reflected and replicated social geographies of privilege. S. Schaffer, 'Physics laboratories and the Victorian country house', in C. Smith and J. Agar (Eds.), *Making Space for Science: Territorial Themes in the Shaping of Knowledge*, New York, 1998, pp. 149–80; G. Gooday, 'The premisses of premises: spatial issues in the historical construction of laboratory credibility', in *ibid.*, pp. 216–245. This spatial expression of a social geography importantly allowed for the cultivation of 'trust' in the truth of scientific claims, even among those who had not witnessed the reported empirical phenomena in person. Ophir and Shapin helpfully suggest that the 'irremediably local dimension' of scientific knowledge should be seen not as a damaging

critique but as a methodological point of entry. A. Ophir and S. Shapin, 'The place of knowledge: a methodological survey', *Science in Context* 4 (1991), p. 4. See also Livingstone's summary work on this theme: *Putting Science in its Place: Geographies of Scientific Knowledge*, Chicago, 2003. Despite these early acknowledgements of spatial influences in the practice of science, the 'geographical turn' in this literature is just now coming into full swing.

10 Arguing 'Scientific notions like discovery, the challenge to authority, natural knowledge and so on both produce and are produced by geography,' Livingstone called for attention to 'the role of the spatial setting in the production of experimental knowledge, the significance of the uneven distribution of scientific information, the diffusion tracks along which scientific ideas and their associated instrumental gadgetry migrate, the management of laboratory space, the power relations exhibited in the transmission of scientific lore from specialist space to public place, the political geography and social topography of scientific subcultures, and the institutionalisation and policing of the sites in which the reproduction of scientific cultures is effected.' D. Livingstone, 'Geography, tradition and the scientific revolution: an interpretative essay', *Transactions of the Institute of British Geographers* 15 (1990), p. 338; D. Livingstone, 'The spaces of knowledge: contributions towards a historical geography of science', *Environment and Planning D: Society and Space* 13 (1995), p. 16.

11 For an overview of spatial approaches to the study of science, see R. Powell, 'Geographies of science: histories, localities, practices, futures', *Progress in Human Geography* 31 (2007), pp. 309–29, and S. Shapin, 'Placing the view from nowhere: historical and sociological problems in the location of science', *Transactions of the Institute of British Geographers* 23 (1998) pp. 5–12. See also Smith and Agar, *op.cit.*, for a collection of early work in this vein, and M. Bourguet et al., *Instruments, Travel and Science: Itineraries of Precision From the Seventeenth to the Twentieth Century*, London, 2002, for more recent treatments.

12 N. Thrift et al., 'The geography of truth', *Environment and Planning D: Society and Space* 13 (1995), p. 2.

13 The constructivist critique of science has usefully focussed our attention on the relationship between knowledge and power. B. Latour and S. Woolgar, *Laboratory Life: The Construction of Scientific Facts*, Princeton, New Jersey, 1986; D. Haraway, 'Teddy bear patriarchy: taxidermy in the Garden of Eden, New York City, 1908–1936', in *The Haraway Reader*, New York, 2004, pp. 151–98; F. Driver, 'Geography's empire: histories of geographical knowledge', *Environment and Planning D: Society and Space* 10 (1992), pp. 23–40. But it has also often tended to obscure the ways that individuals engage with real phenomena in unique places and reach conclusions with some hesitation. For a discussion of the ultimate failure of an antirealist stance, see K. Bassett, 'Whatever happened to the philosophy of science?: some comments on Barnes', *Environment and Planning A* 25 (1994), pp. 337–42. For a discussion of the problem of treating science as a monolithic entity, see D. Pedynowski, 'Science(s) – which, when and whose? Probing the metanarrative of scientific knowledge in the social construction of nature', *Progress in Human Geography* 27 (2003), pp. 735–52.

14 These themes, first outlined in 'The spaces of knowledge', are fully elaborated in Livingstone, *Putting Science in Its Place*.

15 For an overview of these contributions, see S. Naylor, 'Introduction: historical geographies of science – places, contexts, cartographies', *British Journal for the History of Science* 38 (2005), pp. 1–12. Anne Secord's oft-cited 'Science in the pub: artisan botanists in early nineteenth-century Lancashire', *History of Science* 32 (1994), pp. 269–315, laid the foundation for much of this work.

16 Naylor, *op.cit.*, p. 6.

17 D.A. Finnegan, 'Natural history societies in late Victorian Scotland and the pursuit of local civic science', *British Journal for the History of Science* 38 (2005), pp. 53–72.

18 L. Dritsas, 'From Lake Nyassa to Philadelphia: A Geography of the Zambesi Expedition, 1858–64', *British Journal for the History of Science* 38 (2005), pp. 35–52; D. Livingstone, 'Science, text and space: thoughts on the geography of reading', *Transactions of the Institute of British Geographers* 30 (2005), pp. 391–401; J. Topham, 'A view from the industrial age', *Isis* 95 (2004), pp. 431–42. Although these geographical themes have become commonplace in the history-of-science literature, historical geographers are just beginning to apply them to their own discipline. For a review of their relevance for geographers, see C. Withers, 'History and philosophy of geography, 2002–2003: Geography in its place', *Progress in Human Geography* 1 (2005), pp. 64–72. See also a recent special issue of the *Journal of Historical Geography*, which takes up many of these ideas. D. Lambert, et al. (Eds.) *Special Issue: Historical Geographies of the Sea*, *Journal of Historical Geography* 32 (2006).

19 See R. Kohler, *Landscapes and Labscapes: Exploring the Lab–Field Border in Biology*, Chicago, 2002, for his theorisation of a border zone between field and lab that operates much like a cultural border zone. Kohler argues that the negotiation of fundamental differences between the two spatial spheres – like the acceptance of amateurs and the emphasis on physical action in the field, both of which would be considered unacceptable in a lab setting – gave rise to new and vibrant sciences like ecology, which tries to integrate elements from both sides of the border. See also T. Gieryn, *Cultural Boundaries of Science: Credibility on the Line*, Chicago, 1999.

20 F. Driver, 'Making space', *Ecumene* 1 (1994), pp. 386–90.

21 For a collection of essays that explore the role of fieldwork in bringing different types of science together, see H. Kuklick and R.E. Kohler (Eds.) 'Science in the field', *Osiris* 11 (1996). See especially the article by McCook

for views on the complicated intertwining of reputations and legitimacy among scientists working in different sites and with different standards.

22 I am indebted to Margaret Pilkington's review of Kohler for noting that his neat distinction between lab and field is perhaps insufficient in contemporary contexts, as a more relevant distinction has emerged between observational and experimental practice. M. Pilkington, 'The ecologist's very own ecotone: exploring the lab–field border', *Journal of Biogeography* 31 (2004), p. 516.

23 For a collection of now-classic approaches to representation in science, see M. Lynch and S. Woolgar, *Representation in Scientific Practice*, Cambridge, MA, 1990.

24 On the representation of naturalists as world travellers, see Dritsas, *op.cit.* On the shifting portrayals of geological science as heroic, manly, and sporting, see B. Hevly, 'The heroic science of glacier motion', *Osiris* 11 (1996), pp. 66–86. On the popularity of meteorological science among audiences that associated high-altitude ballooning with adventure and spectacle, see J. Tucker, 'Voyages of discovery on oceans of air: scientific observation and the image of science in an age of "Balloonacy"', *Osiris* 11 (1996), pp. 144–76.

25 D. Osterbruck *et al.*, *Eye on the Sky: Lick Observatory's First Century*, Berkeley, 1988.

26 E.C. Pickering, 'Mountain observatories', *Appalachia* 3 (1883), p. 100.

27 Osterbruck *et al.*, *op.cit.*

28 The road was built in 1876, but an official test of 'seeing' conditions was not conducted until 1879. E. Holden, 'The Lick Observatory', *The Sidereal Messenger* 7 (1888), p. 47–65.

29 'The Lick Observatory', *The Sidereal Messenger* 4 (1885), p. 49.

30 E. Holden, *A Brief Account of the Lick Observatory of the University of California*, Sacramento, 1895. Of the pamphlet's fifteen images, four of the first six depicted the mountaintop site – as remote, overgrown, menacing, or sublime. The pamphlet contained only one image, near the end, of the great equatorial telescope, then the largest in the world.

31 'Mountain Observatories', *Publications of the Astronomical Society of the Pacific* 1 (1889), p. 123. The Astronomical Society of the Pacific and its journal were founded in 1889, one year after the Lick Observatory opened. Lick's director Holden was its first president, and all of the Lick astronomers were members.

32 D. Osterbruck, *Yerkes Observatory, 1892–1950*, Chicago, 1997.

33 Yerkes Observatory's first director, George Hale, used the occasion of Chicago's coming-out party – the 1893 World's Fair – to organise the first international astronomical congress ever held in the United States. The Yerkes Observatory, which was still in the planning stages at that time, featured prominently at the congress and showcased the promise of American astronomy and of the University of Chicago. Osterbruck, *Yerkes Observatory*.

34 *ibid.*, p. 15.

35 *ibid.*, p. 16.

36 Hale publicised the fact that he had sent a questionnaire to many prominent astronomers and reprinted their verbatim responses to questions he had asked about the effects on astronomical research of proximity to urban areas, to lakes and to railroads. He thus relied on the stature and credibility of others to support his view that Lake Geneva posed no major detriment to the observations planned for the new observatory. Interestingly, however, Hale's transcription of questionnaire responses includes the following comment by Simon Newcomb (then considered the leading American astronomer): 'To be of the greatest benefit to science the telescope should be mounted at some such point as Mt. Hamilton, California; Arequipa, Peru; or the Peak of Teneriffe.' G. Hale, 'The Yerkes Observatory of the University of Chicago: 1. Selection of the Site', *Astrophysical Journal* 5 (1897), p. 177.

37 G. Hale, 'The aim of the Yerkes Observatory', *Astrophysical Journal* 6 (1897), pp. 310–21.

38 Hale tried in vain to convince readers that 'notwithstanding a widespread impression to the contrary, the excellent atmospheric conditions enjoyed at the Lick Observatory do not seem to be common to all mountain summits'. Hale, 'The Yerkes Observatory', p. 168. He also drew attention to his colleague Edward Barnard's experience conducting nebula observations at both Yerkes and Lick, reporting that 'Professor Barnard has found that the best nights here are fully as good as the best nights at the Lick Observatory … and he assures me that he now sees [certain nebulae] better than he could see them with the Lick telescope.' Hale, 'The Aim of the Yerkes Observatory', p. 317.

39 Sherburne Burnham, a respected double-star observer at Lick who had also performed the official atmospheric testing for Lick Observatory in 1879, wrote in 1900, 'There is probably no place in the world, where an observatory has been established, which can compare favourably with Mount Hamilton', cited in Osterbruck, 'Yerkes Observatory', p. 30. Hale announced the establishment of his new mountain observatory in G. Hale, 'The development of a new observatory', *Publications of the Astronomical Society of the Pacific* 17 (1905), pp. 41–52.

40 P. Lowell, *Mars*, Boston, 1895, p. v.

41 P. Lowell, 'New photographs of Mars: taken by the astronomical expedition to the Andes and now first published', *Century Magazine* 75 (1907), p. 303.

42 According to Lowell, 'A steady atmosphere is essential to the study of planetary detail: size of instrument being a very secondary matter.' Lowell, *Mars*, p. v.

43 S. Newcomb, 'Astronomy', in D. Wallace, *et al*. (Eds.), *The New Volumes of the Encyclopaedia Britannica: Constituting in Combination with the Existing Volumes of the Ninth*

Edition the Tenth Edition of that Work, and also Supplying a New, Distinctive, and Independent Library of Reference Dealing with Recent Events and Developments, Edinburgh, 1902, p. 728.

44 C. Flammarion, 'Recent observations of Mars', *Scientific American* 74 (1896), p. 133.

45 A. Douglass, 'The Lowell Observatory and its work', *Popular Astronomy* 2 (1895), p. 395.

46 D. Strauss, 'Percival Lowell, W.H. Pickering and the founding of the Lowell Observatory', *Annals of Science* 51 (1994), pp. 37–58.

47 J. Lankford, *American Astronomy: Community, Careers, and Power, 1859–1940*, Chicago, 1997.

48 When the professionalisation of astronomy began in the mid-nineteenth century, amateurs were seen as a major asset. It was widely accepted and often commented that the tasks of observation were best performed by amateurs, while theoretical work or work requiring advanced instrumentation was better done by professionals. By the end of the nineteenth century, however, the two groups were in conflict. Amateurs were trying to organise their own societies, push their own agendas, and garner public interest through popular publications, rather than disciplinary journals. In a debate over telescope size, amateurs began arguing that their small telescopes were actually better than the professional observatories' large telescopes. As a result, the peaceful coexistence between amateurs and professionals had largely come to an end by the first decade of the twentieth century. Professionals forwent the benefits of amateur labour for the higher goal of establishing the legitimacy of astronomy among American sciences. Though amateurs continued to be involved in astronomy (as they still are to this day), they were no longer in a position to drive new developments in the discipline. J. Lankford, 'Amateurs versus professionals: the controversy over telescope size in late Victorian science', *Isis* 72 (1981), pp. 11–28; J. Lankford, 'Amateurs and astrophysics: a neglected aspect in the development of a scientific specialty', *Social Studies of Science* 11 (1981), pp. 275–303; M. Rothernberg, 'Organization and control: professionals and amateurs in American astronomy, 1899–1918', *Social Studies of Science* 11 (1981), pp. 305–25.

49 For a discussion of the geometrical maps that emerged as dominant representations of Mars, see M. Lane, 'Mapping the Mars canal mania: cartographic projection and the creation of a popular icon', *Imago Mundi* 58 (2006), pp. 198–211.

50 For a discussion of the ways that geographical narratives were embedded in astronomers' representations of Mars as an inhabited world, see M. Lane, 'Geographers of Mars: cartographic inscription and exploration narrative in late Victorian representations of the Red Planet', *Isis* 96 (2005), pp. 477–506.

51 Strauss, 'Percival Lowell'; W. Hoyt, *Lowell and Mars*, Tucson, Arizona, 1976; Lankford, *American Astronomy*. For extended treatments of the early debates over life on Mars, see S. Dick, *The Biological Universe: The Twentieth-Century Extraterrestrial Life Debate and the Limits of Science*, Cambridge, 1996; M. Crowe, *The Extraterrestrial Life Debate 1750–1900: The Idea of a Plurality of Worlds from Kant to Lowell*, Cambridge, 1986; K. Guthke, *The Last Frontier: Imagining Other Worlds, from the Copernican Revolution to Modern Science Fiction*, trans. H. Atkins, Ithaca, 1983; W. Sheehan, *Planets and Perception*, Tucson, AZ., 1988.

52 E. Holden, 'What we really know about Mars', *The Forum* 14 (1892), pp. 359–68. It should be noted that most of this article was an attempt to defuse the popular sensation over Martian inhabitants. Holden insisted that the only question of value was whether Mars was habitable, as it would be impossible to determine whether the planet was actually inhabited.

53 W. Campbell, 'The spectrum of Mars', *Publications of the Astronomical Society of the Pacific* 6 (1894), p. 230.

54 'The Lick Observatory of the University of California', *Scientific American* 58 (1888), p. 162.

55 See, for example, his 1894–95 articles in *Astronomy and Astro-physics*, *Popular Astronomy*, and *Atlantic Monthly*, as well as his 1895 book, *Mars*.

56 Hale and Newcomb, of Chicago and Washington, DC respectively, both suffered Lowell's sarcasm regarding their Eastern, near-urban locations. According to Lowell, no one was qualified to criticise his research unless they were working in similar or better atmospheric conditions. He found it especially easy to attack his British critics on the basis of known atmospheric impurities throughout the British Isles, as in this biting suggestion to Walter Maunder of the Royal Observatory, Greenwich: 'if England would only send out an expedition to steady air … it would soon convince itself of these realities [the canals]'. Lowell Observatory Archive, Correspondence Files, P. Lowell to W. Maunder, 28 November 1903.

57 P. Lowell, *Mars and Its Canals*, New York, 1906, pp. 7, 8.

58 R. Nash, *Wilderness and the American Mind*, New Haven and London, 1967. See particularly his discussion of John Muir's representations of the Sierra Nevada Mountains. In this parallel discourse, remote western mountains figured as perfect antidotes to dirty and over-large cities.

59 Lowell, *Mars and its Canals*, p. 15. For a discussion of how turn-of-the-century American enthusiasm for wilderness was rooted in a desire to police national identity in an age of immigration and was also dependent on the mythology of the Western frontier, see D. Cosgrove, 'Wilderness, habitable earth and the nation' in *Geography and Vision: Seeing, Imagining and Representing the World*, London, 2008.

60 E. Holden, *Mountain Observatories in America and Europe*, Washington, DC, 1896, p. iii.

61 *ibid.*, p. 14.

62 See, for instance, Lowell's discussion of telescope size and use in his book, *Mars*.

63 The following passage provided a subtle but damaging critique of Lowell's deputy, Slipher, implying that he

made critical scientific errors because of his lack of understanding of mountain atmospheric conditions: 'What assurance have we that the air columns through which Mr. Slipher observed Mars immediately after dark and the Moon from two to eight hours later were carrying equal quantities of aqueous vapour? … Air masses at high altitudes may and usually do change rapidly. … It is a common occurrence for clouds to form in the afternoons in high and mountainous regions, chiefly because of convection currents which carry moisture up, for the clouds to clear away about dark.' Campbell, 'The spectrum of Mars as observed by the Crocker expedition', p. 161.

64 For discussions of the ways that mountaineering – as a science and a sport – became embedded in Western notions of masculinity, heroism and nationalism, see Hevly, *op.cit.*; K.M. Morin, *et al*., '(Troubling) spaces of mountains and men: New Zealand's Mount Cook and Hermitage Lodge', *Social and Cultural Geography* 2 (2001), pp. 117–39.; R. Macfarlane, *Mountains of the Mind*, New York, 2003.

65 A. Pang, 'The social event of the season: solar eclipse expeditions and Victorian culture', *Isis* 84 (1993), pp. 252–77.

66 'Mapping the southern sky from a mountain peak 14,000 feet high', *Scientific American* 64 (1891), p. 36. For more detail than the following discussion provides, see B. Jones and L. Boyd, *The Harvard College Observatory: The First Four Directorships, 1839–1919*, Cambridge, MA, 1971; H. Plotkin, 'Harvard College Observatory's Boyden Station in Peru: origin and formative years, 1879–1898', in A. Lafuente, et al. (Eds.), *Mundialización de la ciencia y cultura nacional. Actas del Congreso Internacional 'Ciencia, descubrimiento y mundo colonial'*, Madrid, 1991; S. Bailey, 'Expeditions and foreign stations', in: *The History and Work of Harvard Observatory, 1839–192: An Outline of the Origin, Development, and Researches of the Astronomical Observatory of Harvard College together with Brief Biographies of its Leading Members*, New York, 1931.

67 W. Pickering, 'Mars', *Astronomy and Astro-Physics* 11 (1892), p. 675.

68 S. Bailey, 'Harvard Observatory in Peru', *Scientific American* 76 (1897), p. 329.

69 Solon Bailey, cited in Jones and Boyd, *op.cit.*, p. 291. See also 'Harvard Observatory in Peru – The Highest Meteorological Station in the World', *Scientific American* 70 (1894), p. 67.

70 Lowell telegraphed Todd from Flagstaff with the following: 'The world, to judge from the English and American papers, is on the qui vive about the expedition as well as about Mars. They send me cables at their own extravagant expense and mention vague but huge (or they won't get 'em) sums for exclusive magazine publication of the photographs'. Lowell Observatory Archive, Correspondence Files, P. Lowell to D. Todd, 26 July 1907.

71 Lowell, 'New photographs of Mars'; D. Todd, 'The Lowell expedition to the Andes', *Popular Astronomy* 15 (1907) 55, pp. 1–53; D. Todd, 'Professor Todd's own story of the Mars Expedition: first article published from the pen of the leader of the party of observation', *Cosmopolitan Magazine* 44 (1908), pp. 343–51.

72 Campbell, 'The spectrum of Mars', p. 152.

Endnotes for chapter 9

1 B. Messerli and J. Ives (Eds), *Mountains of the World: A Global Priority*, New York, 1997, p. 456.

2 P. Viazzo, 'Le paradoxe alpin', *l'Alpe* 1 (1998), pp. 28–33.

3 There are attempts to establish a 'mountain science', which means to 'build an interdisciplinary and intersectoral mountain discipline'. Messerli and Ives, *op.cit.*, p. 460.

4 J. Blache, *L'homme et la montagne*, Paris, 1950 (1933), p. 7.

5 Messerli and Ives, *op.cit.*, pp. 2–3.

6 B. Debarbieux and F. Gillet (Eds.), *Mountain Regions: A Research Subject?,* Brussells, 2002; M. Price and D. Funnel, 'Mountain geography: a review', *Geographical Journal* 169 (2003), pp. 183–90.

7 I. Sacareau, *La montagne, une approche géographique*, Paris, 2003, p. 9.

8 *ibid.*, p. 283. '*Territorialités*' which she describes as 'individual and/or collective relationship to the territory'.

9 O. Dollfus, 'Réalités et perceptions comparées des Andes au Pérou et en Colombie', in B. Debarbieux (Ed.), *Quelle spécificité montagnarde?, Revue de géographie alpine* 1 (1989) p. 172.

10 *ibid.*, pp. 171–85.

11 Debarbieux and Gillet, *op.cit*., p. 140.

12 A. Turco, 'Géographie, ordre symbolique et cycle de l'information', in J.P. Guérin and H. Gumuchian (Eds.), *Les représentations en actes: actes du Colloque de Lescheraines*, Grenoble, 1985, p. 78.

13 *ibid.*, p. 79.