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The Survey in Nineteenth-Century American Geology: The Evolution of a Form of Patronage

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By 1890, the United States Geological Survey emerged as the largest and best-supported governmental scientific research organisation in the world. The scientific achievements of the federal geological surveys are well established. The equally impressive political and administrative achievement is yet to be understood as such. The pioneers of the geological survey, particularly John Wesley Powell, succeeded in the task of combining adherence to scientific standards and hence scientific autonomy, with the acquisition of the patronage necessary to support their research. Patronage in the sense of the rewarding of political clients, in which benefits are conferred for political support—typically, official appointments in return for votes—has, on the surface, little resemblance to the bureaucratic arrangements by which governments today finance, encourage and direct scientific research. However, the modern, bureaucratic form of support is patronage nonetheless, although of a very different sort from the relationship of patron and client of the spoils system of the nineteenth-century American republic. It grew out of the older type in a series of steps, some of which were deliberate political acts by scientists aimed at enlarging the place of scientific merit and the discretion granted to scientists in the scientific work supported by public bodies. The survey, understood as a method of organising scientific investigation, was the principal scene for one step in this evolution of modern methods of patronage; support for scientists, as clients, in the broad tradition of the spoils system, was replaced by wide public and political support of science, largely separated from the spoils system and legitimated by explicit invocation of the collective authority of the scientific community, and the practical benefits of scientific research. Through a slow and often difficult evolution, the geological surveying which was initially done by the states and by the military, and which was usually modest and superficial, was transformed into a large enterprise.

The surveys ultimately trained, utilised and supported a large number of field geologists, and made possible careers in geology. A geologist would typically be employed in several surveys in succession, and younger geological surveyors who had served their apprenticeships in the state surveys became in the course of time directors of surveys. The same community of geologists supplied the leadership for the earliest federally supported surveys of the "Old Northwest", the area of Michigan, Wisconsin and Minnesota. Those who participated in the enormous and sophisticated

later Western federal surveys were also largely drawn from the ranks of those who had learned their skills as field geologists in the employ of state surveys. By the 1880s, this corps of geologists dwarfed parallel governmental geological activities in the nations of Europe. The annual operations of the geological section of the British Ordnance Survey which employed De la Beche were comparable in scale to those of a middle-size state survey; even the larger French survey did not provide employment for as many persons as did some of the state surveys in the United States.[1] Because of these activities and the opportunities they afforded, particularly to talented amateurs, geology was one of the fields in which American science first established itself internationally.

The cognitive substance of the nineteenth-century geological survey derived from its combination of two strands of geological work: the body of surveying and map-making techniques and the geological "walk" or reconnaissance. Much of the early survey work was very close to the pattern of a walk. After 1820, it became common practice to invite a geologist to join an expedition of exploration sent out by the army; the observations by these geologists were published, often as part of the reports of the expedition. State surveys were sometimes equally simple, but were usually more ambitious. Sometimes, where there were adequate maps, the geologists coloured the maps by type of rock, and supplemented these by cross-sections; sometimes making maps was part of the job. The precision and methods of making basic maps varied, and what was put on the map varied. In some states, types of soil were mapped. In other states the focus was on the primary geological issue of the day, describing and correlating orderly stratigraphic series, an effort which paralleled, and interacted with, the Great Devonian controversy, and depended on paleontology, which advanced along with surveys. Much of the work was "descriptive", but at the time the practices of description were not routine, and many of the particular stratigraphic problems were extremely knotty, raising serious methodological, theoretical and substantive issues. The long-running and bitter "Taconic controversy", which began with the New York state survey of the 1830s, paralleled the Devonian dispute, and involved similar issues of evidence and method. The later federal surveys of the West raised new "theoretical" problems through the novelty of the phenomenon of aridity.

The Origins of the Surveys

In the 30 years from the beginning of the first state survey in Massachusetts, in 1830, to the Civil War, virtually all the states in the Union conducted some sort of geological survey. The earliest state surveys served as models for others. The first surveys varied widely in several respects.

[1] Rudwick, Martin J. S., *The Great Devonian Controversy: The Shaping of Scientific Knowledge among Gentlemanly Specialists* (Chicago: University of Chicago Press, 1985), pp. 90–91.

Political sentiment in favour of surveys was generally associated with the larger movement for "internal improvements", of which the establishment of state universities was also a part;[2] the antagonism to surveys generally was associated with antagonism to other governmental expenditures. The state in which the movements for internal improvements were the strongest, New York, was the state that developed the most elaborate and best-financed survey, but here, as in all states, the story of the development of the survey involved a more complex set of motivations.

The primary political supporter of the New York survey was Stephen van Rensselaer, the patroon of Albany, a man with large holdings under the Dutch leasehold system, which had been largely preserved under British rule. Out of his annual income of $100,000, van Rensselaer had helped to found and support several educational and scientific institutions, including the Polytechnic Institute that now bears his name. Van Rensselaer had long been a supporter of geology. Amos Eaton, a student of Benjamin Silliman, who had himself taken a "geological walk" in Connecticut in 1806, taught in the Rensselaer Polytechnic Institute. In 1832 Eaton claimed to have devoted more time and labour to American geology than any other individual, for which he credited van Rensselaer's patronage.[3] In 1821 van Rensselaer had financed a private geological and agricultural survey of Rensselaer county, and in 1824 he financed one of the area adjoining the Erie Canal. Both were performed by Eaton.[4]

Governor Dewitt Clinton's success with the Erie Canal, the chief internal improvement in New York, and his support, helped van Rensselaer and his lieutenants in the Albany scientific community to present successfully the geological survey as a similar public good. But van Rensselaer's personal support for the survey was continuous with his support for the Rensselaer Polytechnic Institute; both were means of employment as scientists for the scientists whose careers he was fostering. The graduates of the institute, who sought work as scientists, were the major beneficiaries of the opportunities for employment created in the surveys. The desire to find employment was an element in other early surveys. In Indiana, David Dale Owen had languished in the small town of New Harmony, which his father Robert Owen, the industrialist and socialist reformer, had purchased from a chiliastic utopian community in hopes of establishing a secular, scientifically inspired utopian community. David Dale Owen's older brother, a state legislator, and Governor Noah Noble, a family friend and political ally, proposed a survey in 1836, after David Dale had prepared himself for the task by attending medical school in Cincinnati and learning some field geology with Gerard Troost's survey in Tennessee in 1835. Troost's career

[2] Hendrickson, Walter B., "Nineteenth-century State Geological Surveys: Early Government Support of Science", *Isis*, LII (1961), pp. 361–363.

[3] Merrill, George P., *The First One Hundred Years of American Geology* (New Haven: Yale University Press, 1924), p. 132.

[4] *Ibid.*, pp. 79, 98.

was more typical of the first generation of surveyors than was Owen's. He had performed a small survey for a Pennsylvania agricultural society in 1826, and two years later was appointed to a professorship of chemistry, geology and mineralogy in Nashville, where a group of Tennesseans took the opportunity of his presence to initiate a state survey.[5] Surveys in Massachusetts and North Carolina, two of the early state surveys, begun in 1830 and 1823 respectively, employed local teachers; in each case they were students of Silliman.

Local scientific or agricultural societies often played a considerable role in agitating for a survey, but the immediate political motives for the creation of a survey varied considerably. State pride and the desire to appear "liberal" and enlightened were important, especially in New York. The aim of discovering particular minerals important for the development of the region was primary in the states of the Old West, notably Ohio and Michigan, but the minerals sought varied from coal in such industrial areas as the Hudson Valley and Cincinnati to salt in regions which were largely unsettled, such as Michigan.[6] Anxieties over economic exploitation were central to the political rationale for the surveys in Indiana and later in New Jersey. In Indiana, Noble had argued that the state needed to develop its own resources in order to avoid being exploited by Easterners; the first survey in New Jersey was justified by the argument that it would protect citizen land-holders from sharp practice by making public the true mineral value of the land.[7] In no state was there a successful alliance between the survey and a particular industry. Where it was attempted, as in the case of the first Ohio survey, which concentrated on finding coal, the legislators from regions without coal objected.[8] The political necessity of satisfying legislators representing widely dispersed counties had more effect on the surveys than any other political fact. The geologists gradually learned to adapt their proposals and practices to the necessity of saying something about every county. In some states, where little of interest to either economic or scientific geology was found, the surveyors adapted themselves by performing surveys which applied basic chemistry to problems of soil type and soil exhaustion. In some states, including Massachusetts and Kentucky, the geological work was combined with map-making, and the expensive method of topographic mapping established by the Coast and Geodetic Survey was gradually adapted to the needs and limited financial means of geological work.

[5] *Ibid.*, p. 111.

[6] Merrill, George P. (ed.), *Contributions to a History of American State Geological and Natural History Surveys* (Washington, DC: US Government Printing Office, 1920), pp. 158, 351, 389.

[7] Hendrickson, Walter B., *David Dale Owen: Pioneer Geologist of the Middle West* (Indianapolis: Indiana Historical Bureau, 1943), pp. 25–26; Merrill, G. P., *State Surveys*, *op. cit.*, p. 309.

[8] Merrill, G. P., *State Surveys*, *op. cit.*, p. 396.

The political resourcefulness of the early state geologists was decisive for the success of the state survey movement, which tried and tested many of the organisational, practical and economic arrangements which were adopted by the later federal survey movement. Most significant, however, was the shaping of the survey as a project which legislatures could support. The experience of the states of the Middle-West presaged later practice, for in these states it became evident that development and settlement was greatly aided by reliable descriptive information on the mineral and agricultural resources of a region, was welcomed by residents and landowners, and was readily regarded by legislators as a necessity which justified state action and expense.

The internal organisation of the surveys varied a great deal. Most were very simple affairs, with one geologist and an assistant who travelled the state in a wagon or on horseback collecting samples. The large New York survey had five regions, each with an assistant geologist, and a specialist in Albany in conchology and chemistry to aid in the analysis of finds. In the second series of surveys, the pattern gradually changed. The practice of employing local professors diminished, in part because the states which had not been surveyed in the 1930s were likely to be states with little higher education, in part because the local teachers could no longer compete with the new forms of organisation, special expertise, and networks of skilled workers that had developed out of the early surveys. Owen was the central figure in this transformation.

Owen's highly successful first survey in Indiana was an impressive reconnaissance by a single investigator who aspired to giving the legislature value for money. Idle in the period of the late 1830s and early 1840s, between the two peaks of activity in state surveys before the Civil War, he was given an opportunity to perform a survey on an emergency basis for the General Land Office, the federal agency which distributed lands in the national domain to homesteaders and miners.[9] This survey proved to be of great significance as a successful political precedent for federal geology. The government faced a political crisis over the distribution of mineral rights. The law provided for the leasing of mineral lands, rather than their sale. However, the classification of lands was in the hands of geologically untutored land surveyors, and land containing ore was frequently sold for agricultural purposes. There was an air of corruption about the procedures: false affirmations and refusals to pay for leases of mineral rights were common. The survey Owen was commissioned to perform was to cover a rapidly developing district containing parts of Iowa, Wisconsin and Illinois. The commissioner of the General Land Office, a fellow resident of Indiana, gave him a great deal of autonomy, with the understanding that speed, not cost, was of the essence. Owen assembled a team of untrained workers, trained them in basic field geology, sent them out to collect samples,[10] and

[9] Hendrickson, W. B., *Owen, op. cit.*, pp. 42–43.
[10] *Ibid.*, p. 45.

completed the field-work in the few months before winter made surveying impossible; he finished the analysis at his home and laboratory in New Harmony.

Geologists had travelled with army exploratory expeditions since 1820, but Owen's survey in 1839 was the first case in which the federal government contracted with a private geologist for a major survey independently of a military expedition. The legal character of Owen's appointment reflected practice in state surveys. The states, being sovereign, were not bound by contracts in the ordinary way, in that the expenditure of funds required legislation which could be changed before the completion of the work, and occasionally was repealed by angry legislators or in the wake of the electoral defeat of friendly governors or legislators. James Hall, who insisted to the state of Wisconsin that his "contract", under seal with the governor, could not be annulled, went away empty-handed, in spite of his persistent dunning of the state.[11] The contracts are better described as legislative authorisations to submit a bill to the state for specified salaries and expenses, if it is understood that the authorisations were revocable and that the bills were sometimes not paid. The authority of legislatures to tax and spend expired with their terms, so geologists were ordinarily obliged to return to later legislatures, especially for the expenses of publication which were often as great as the cost of the original survey; this was often a source of trouble. The office of state geologist was a temporary one, as was Owen's appointment in the Land Office, but it was not merely a business relationship. Sometimes the choice of the state geologist was delegated to an executive officer, such as a governor or secretary of state, or a board of overseers, such as a commission for internal improvements or a board of regents. The geologist, like ordinary beneficiaries of political patronage, was an unelected "official", without constitutional status.

During the late 1840s and 1850s, Owen, James Hall of the New York survey, and a few other geologists had become sufficiently well known to gain appointments as state geologists in more than one state. In several cases, these appointments were held concurrently; in each, the geologist retained a base in his home state. Owen had a relatively large laboratory in New Harmony, where he did the analyses for his surveys of Arkansas and Kentucky, and some of the regular employees in his surveys moved to New Harmony; Owen developed an organised team of workers with a division of labour in accordance with their varying degrees and kinds of skill, and his surveys provided a setting in which careers could be made by persons with specialised ability to do field-work, and in which new skills could be acquired, and new connections with other surveyors could be established. Many aspiring field geologists worked as subordinates on his surveys in Kentucky and Arkansas and later became state geologists themselves; many of these relationships endured long after Owen's death, and geological

[11] Merrill, G. P., *State Surveys*, *op. cit.*, p. 523.

appointments were often formed through these relationships. Hall had a good eye for talent, and encouraged young men with useful skills or abilities to come to Albany, where he found them employment with others or put them to work on his own projects. But his relations with these protégés and helpers was often strained. He worked best as a kind of senior adviser to a team of younger geologists who were doing most of the field-work themselves. He tended to quarrel with his associates and employees, and because he spent most of his time in the East, the geologists on the ground not infrequently decided that they could get along without him, and themselves deserved the title of state geologist.

Hall and Owen were both concerned for their reputation as scientists, and both did in fact gain international recognition. Albany and New Harmony became standard ports of call for European geological visitors, such as Lyell,[12] as well as for American academics; Hall's close relationship with Agassiz dated from the beginning of Agassiz's American career. Hall was especially well known in Europe: he received the Wollaston medal,[13] and was made a life-member of the geological society of France,[14] after Count de Verneuil visited him. Owen's work had been discussed with interest by the great names of British geology—Buckland, Sedgwick and De la Beche—when an abstract of his journey was presented to the Geological Society in 1843 by Murchison, having been presented at the meeting in Manchester of the British Association for the Advancement of Science the year before.

Hall's sensitivity about his reputation often led to conflicts with state politicians; Owen developed a body of surveying and reporting practices which gained rather than alienated political supporters. The practices and costs of publication were the source of most of the conflicts. Prior to Owen's federally financed study, publications had varied between two extremes. Owen's first report had been a 34-page, cheaply printed presentation of basic geological principles and a general survey of the distribution of the mineral resources of the state.[15] The final report of the second Ohio survey, in contrast, ran to 1,000 pages and was produced in special editions in German, in addition to the English-language version.[16] The cost of publication for the larger surveys was very high, sometimes exceeding the cost of the work of the survey itself, and legislators were often extremely reluctant to appropriate sufficient funds. In Pennsylvania, it took the state geologist ten years to persuade the legislature to pay for publication.[17] In other states, these costs made legislatures unsympathetic with the very idea of surveys.

[12] Clarke, John M., *James Hall of Albany: Geologist and Paleontologist* (Albany, 1923), pp. 109, 127, 149, 257; Hendrickson, W. B., *Owen*, *op. cit.*, p. 69.
[13] Clarke, J. M., *Hall*, *op. cit.*, pp. 347–348.
[14] *Ibid.*, p. 164.
[15] Hendrickson, W. B., *Owen*, *op. cit.*, p. 34.
[16] Merrill, G. P., *State Surveys*, *op. cit.*, p. 408.
[17] *Ibid.*, p. 433.

From his first federal survey onwards, Owen had written for an audience broader than either the scientific community, which was the audience of Hall's publications and the publications of several of the other well-financed surveys, or the audience of local landowners to which Owen's first publication of his Indiana survey had been addressed. The new form of publication Owen developed was far more substantial than the simple reports on economic geology of the less well financed state surveys; it was directed at an audience of potential settlers and investors. The reports contained descriptions of the natural beauty of the region which were often quoted at length by publicists and promoters, who also reproduced the charts and drawings. The costs of publication were high, but the public uses were broad and numerous. Moreover, the work served to establish a valuable practical alliance with copy-hungry newspaper editors, and this relationship continued and increased in importance in the later surveys.

The form of publication by Owen was a success in scientific circles as well. Owen's later federal survey of the region of the Chippewa district, an area of Minnesota, Wisconsin and Iowa as large as the state of New York, which most fully corresponded to his own ideas about appropriate publication, was highly praised. "The *American Journal of Science and Arts* devoted several pages to a review, emphasizing its excellent format. In fact so much space was given to praise of the illustrations that the reviewer merely summarized the findings without criticism."[18] The scientific success was conveyed to the new commissioner of the General Land Office, John Wilson, who, "commenting on the praise of the report by the English paleontologist, Richard Owen, and Sir Roderick Murchison, said with pride: 'Such testimony falls gratefully on the ears of young America, coming as it does from the patriarchs of science in Old England as it volunteers to answer the taunting question, thence propounded not many years ago, Who reads an American book?'"[19] More tellingly, his scientific competitors grasped that Owen had stolen a march on them. Whitney, who had completed the report on the geology of the Lake Superior region, was "envious of Owen's success in having his report published in such excellent form".[20]

The primary purpose of this publication was not in accord with the simple ethic of fidelity to the individual interests of his patrons, but linked survey work to the more general tasks of settlement, development and publicity. In this Owen had moved the survey to a new stage. The earlier surveys have sometimes been unfairly described as prospecting trips, and certainly legislators often had regarded them in these terms. Owen's surveys for the Land Office combined scientific sophistication and appeal to a scientific audience, which some of the state surveys had achieved, with a new kind of practical value for a larger and more diverse audience than any previous geological works had found.

[18] Hendrickson, W. B., *Owen*, *op. cit.*, p. 106.
[19] *Ibid.*, p. 98.
[20] *Ibid.*, p. 105.

The Beginning of the Western Surveys: Hayden's Role

Owen, in the course of his Land Office survey in 1847 of western Wisconsin, eastern Minnesota and northwest Iowa, had sent John Evans to the nearby Badlands; Evans reported that "organic relics of extinct animals" lay "strewn in the greatest profusion".[21] After corresponding with Joseph Leidy, professor of anatomy at the medical school of the University of Pennsylvania, who had paleontological interests and who was analysing the finds, and learning that some German collectors were going there in the summer of 1853, Hall, who was notoriously stingy, set up his own expedition, sending two of his protégés, and searching for sources for the reimbursement of expenses in return for the fossils he expected them to find. Hall's men were Fielding Meek, who had been employed in Owen's survey and had been appointed by Hall, as an artist, in 1852 to help him with his paleontological work, and a young man named Ferdinand V. Hayden, whom Hall had met in 1851, at the home of John Newberry. Hall "proposed to Hayden that he enter the Albany Medical College, holding out to him the promise of geological service when his course was over. It was too tempting a proposition to resist and the young man came on, entered the school and lived at Hall's house",[22] and graduated in 1853. The expedition ran into difficulties, in part because of Hall's reluctance to fulfil his promise to pay Hayden's expenses, and when Hayden returned to Albany, he broke with Hall.[23]

Hayden assumed the role of an expedition leader; he searched for private patrons with some success. In 1854, he went back to the upper Missouri "partly under the auspices of the American Fur Company",[24] but largely by scraping together small surveys from miscellaneous sources. Persons he befriended in the country, such as an Indian agent, helped him. The scientific results of the two years which passed in this way included vertebrate remains, which were reported on by Leidy, and invertebrates, which Hayden and Meek described. A report by Hayden on the geology of the region was incorporated in a report in 1855 of Lieutenant G. K. Warren, who had been exploring the Dakotas.[25] The period of struggling for support was formative for Hayden. He made a variety of alliances, and kept up one crucial scientific partnership. Meek, at this time still in Hall's employ, became his scientific Man Friday.[26] Although Hayden's important geological accomplishments of the 1850s, such as his geological map of Yellowstone, were done with Meek's advice, Meek also depended on Hayden. Hayden's own work was of high quality. The standard stratigraphic

[21] Quoted in Merrill, G. P., *One Hundred Years*, *op. cit.*, p. 276.
[22] Clarke, J. M., *Hall*, *op. cit.*, p. 244.
[23] Goetzmann, William H., *Exploration and Empire: The Explorer and the Scientist in the Winning of the American West* (New York: W. W. Norton, 1966), p. 492.
[24] Merrill, G. P., *One Hundred Years*, *op. cit.*, p. 502.
[25] *Ibid.*, pp. 502–503.
[26] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 493.

sections Hayden established for the West, modelled on Hall's work, served, in turn, as a model for other work, such as John S. Newberry's section of the Grand Canyon.[27]

Hayden learned to construct partnerships to support his projects. Among his sources were several local learned societies and the Chocteau family.[28] Gaining the support of local learned societies was a hard education about what aspects of Western geology were of interest to the public. Spectacular fossils were easy to find, and Hayden's vertebrate finds for Leidy, including camels, elephants and rhinoceroses, were simple to comprehend and to use to justify his work in the eyes of potential sponsors. They also had scientific importance, which enabled him to develop his ties to Eastern academics. Without his shipments of fossils, Leidy would have been unable to do much of the scientific work, especially *The Ancient Fauna of Nebraska*,[29] on which his reputation rested. Because of his growing reputation as a geologist, Hayden was in demand as a geologist on army expeditions, although these appointments often had an irregular character. Hayden's "appointment" to the Warren expedition of 1856 was as an assistant to the exploration party, with his scientific role specified in a letter which proposed the following exchange: Hayden would supply Warren with geographical information Hayden already possessed, and Warren would "accept" Hayden's "services" for $1,000 in annual salary, made retroactive to the beginning of the year, and $200 in travel expenses from St Louis. In addition, Hayden had to supply his own horse, and his own subsistence except while in the field, and had to give anything he collected to the government; Warren promised to transmit Hayden's report with his own, to give it the same chance of congressional support for publication, and in addition, promised that if funds were available, he would make Hayden's appointment retroactive to the previous July and give him an extra $100 per month for the period. The arrangement was a success, and Hayden accompanied Lieutenant Warren on an abortive expedition to the Black Hills the next year.[30] Appointments such as these were nevertheless impermanent and insecure.

The Civil War, in which Hayden served as a military surgeon, postponed his work. When it was over, he was given an academic appointment at the University of Pennsylvania.[31] In the summer of 1866, he resumed exploration, returning to the Badlands with the support of the Philadelphia Academy of Natural Sciences. The expedition resulted in Leidy's greatest work, a 450-page octavo volume with 30 plates containing descriptions of the mammalian fossils they had found. Hayden contributed a 12-page geological introduction to the work. With these achievements in hand, he was ready to enter a new stage in his career. When the new state of Nebraska was

[27] *Ibid.*, pp. 492–493.
[28] *Ibid.*, p. 492.
[29] *Ibid.*, p. 494.
[30] *Ibid.*, p. 492.
[31] Merrill, G. P., *One Hundred Years, op. cit.*, p. 525.

organised as a territory, $5,000 of federal funds originally earmarked for a geological survey to be supervised by the General Land Office remained unexpended. Hayden learned of this through S. F. Baird at the Smithsonian Institution,[32] and assembled support for his appointment to perform the survey.[33] He was granted the funds, with the help of an Illinois politician interested in Western development, the army generals in charge of Western expeditions and the Smithsonian Institution, and went into the field in 1867. The first survey was done by a small organisation: his own salary was $2,000; he had $1,000 for an assistant and $700 for collectors and labourers; the rest was allocated for chemistry, natural history and general expenses.[34] The final report appeared as a 264-page document of the House of Representatives in 1872, and contained a coloured map by Meek.[35]

In 1868, Hayden received another $5,000, provided in an appropriation attached to the Sundry Civil Bill, which enabled him to push beyond Nebraska to the Rockies. In 1869, Hayden's appropriation was doubled, and he had his survey separated from the Land Office, which was part of the Treasury Department, and given the status of an independent agency which reported directly to the secretary of the interior. The survey was given the official title of United States Geological Survey of the Territories.[36] The impressive title concealed an odd legal and political structure. The Sundry Civil Bill was a precarious basis for any organisation. Unlike statutory agencies, which routinely submitted budgetary requests and which, in practice, were routinely provided with funds until they were abolished by repeal of the statute, an organisation based on the Civil Bill existed only so long as new appropriations for the organisation were initiated in Congress. Thus Hayden was wholly dependent on congressional support. Yet this was an arrangement with significant advantages from the point of view of flexibility and autonomy, for the control over the appropriations for Hayden's surveys was extremely loose. The statutes for the first three years of his survey consist of the following:

No. 1—1867.

That the unexpended balance of the appropriations heretofore made for defraying the expenses of the legislative assembly of the Territory of Nebraska is hereby diverted and set aside for the purpose of procuring a geological survey of Nebraska, said survey to be prosecuted under the direction of the Commissioner of the General Land Office. (US Statutes at Large, vol. 14, p. 470, sec. 2.)[37]

[32] The letter is reproduced in *ibid.*, p. 715.
[33] *Ibid.*, p. 509; Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 495.
[34] Merrill, G. P., *One Hundred Years*, *op. cit.*, p. 509.
[35] *Ibid.*
[36] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 489.
[37] US Congress, House of Representatives, Congressional Report 81, *Geological and Geographical Surveys*, 45th Cong., 2nd Session, 1878, p. 11.

No. 2—1868.

That the Commissioner of the General Land Office is hereby authorized to continue the extension of the geological explorations as begun in Nebraska under the provisions of the second section of the deficiency act of Congress, approved March two, eighteen hundred and sixty-seven, United States Statutes eighteen hundred and sixty-six and eighteen hundred and sixty-seven, page four hundred and seventy, to other portions of the public lands; and for that purpose the sum of five thousand dollars is hereby appropriated, out of any money in the Treasury not otherwise appropriated. (US Statutes at Large, vol. 15, p. 119, sec. 6.)[38]

No. 3—1869.

For the continuance of the geological survey of the Territories of the United States, by Professor Hayden, under the direction of the Secretary of the Interior, ten thousand dollars. (US Statutes at Large, vol. 15, p. 306.)[39]

The formal instructions he received under the supervision of the Interior Department were only slightly more detailed, reminding him that "it is expected by this department that you will make your expenditures of the public money with the most rigid economy and care", and asking him to direct his attention:

to the geological, mineralogical, and agricultural resources of the Territories herein designated; you will be required to ascertain the age, order of succession, relative position, dip and comparative thickness of the different strata and geological formations, and examine with care all the beds, veins, and other deposits of ores, coals, clays, marl, peat, and other mineral substances as well as the fossil remains of the different formations, and you will also make full collections in geology, mineralogy, and paleontology to illustrate your notes taken in the field.

The documents he was required to produce included a preliminary report at the end of the field season, collections of finds and a final report, which "it is expected . . . will embody the entire results of the survey, and be accompanied by a geological map, with carefully prepared sections and diagrams, with drawings and descriptions of the characteristic fossil remains of the different groups of strata".[40] These vague instructions enabled Hayden to operate within little more than the very loose political constraints entailed by the congressional appropriations process: he produced results, told his bureaucratic supervisors what his plans for the year were, and was free of any onerous supervision.

The primary products of Hayden's activities were publications, including four series of works: atlases; a "bulletin", started in 1873, which functioned as a scientific journal, large monographs or "final reports"; and "annual reports".[41] The foundation of Hayden's success was the series of annual reports, which followed the example of Owen's Land Office surveys by mixing scientific and practical geology with scenic description. Hayden's

[38] *Ibid.*
[39] *Ibid.*
[40] *Ibid.*
[41] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, pp. 527–578.

contributors clearly understood Hayden's purposes: one of his geologists, Leo Lesquereaux, forwarded a report with the comment that it was "at your request, popular and scientific at the same time".[42] The formula worked as well for Hayden as it had for Owen: the 8,000 copies of the report of 1869 had been distributed in a few weeks, and Hayden himself was left without a copy.[43] The expedition of 1870 included a landscape painter and a talented photographer, Jackson. With the fourth report, the volumes evolved into a distinct literary form. To reduce the long time between the survey and publication, Hayden presented the work in the form of a diary, and included works by other scientists on assorted topics, ranging from Cyrus Thomas's discussions of the agricultural possibilities of the regions surveyed to papers on paleobotany and paleontology by Eastern academics.[44]

Hayden's personal reputation as a scientist was high, and not only as a consequence of these reports. James Dana, editor of the *American Journal of Science*, responded to one of Hayden's papers with a note saying: "Your article came this morning, and I at once took it to the printers without reading it, not doubting that it was all right."[45] The range and quality of Hayden's scientific connections also grew. The fourth volume began Hayden's fruitful alliance with E. D. Cope, a private scholar who spent his summers with the expeditions. Cope's efforts later resulted in a standard work on vertebrate paleontology, a "pudgy quarto volume of 1,009 pages and 134 full-page plates", which became known as Cope's primer.[46] Hayden did favours for scientists just as he did for Washington politicians. He was sensitive to the needs and ambitions of the scientists around him. The series of bulletins served as a valuable outlet for the publications of the scientists who worked on his surveys, as well as for many of the other scientific talents of the day, including Asa Gray and David Starr Jordan.[47]

But Hayden did not limit himself to the issuing of reports. His Yellowstone expedition of 1871 became the object of enormous publicity, and Hayden himself contributed an article to *Scribner's Magazine* extolling the wonders of the Yellowstone.[48] He distributed Jackson's photographs and stereopticon slides widely. Hayden was also adept at the cruder methods of gaining the support of politicians, such as including the sons of congressmen on his trips and taking with him guests who became political advocates on his behalf. These practices have been described as a "combination of publicity, patronage, and persistence",[49] and many

[42] Hayden Survey, Letters Received, 1870–72, 9 June, 1870, National Archives, Washington, DC.
[43] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 498.
[44] *Ibid.*, p. 502.
[45] Hayden Survey, Letters Received, 6 January, 1872, *op. cit.*
[46] Merrill, G. P., *One Hundred Years*, *op. cit.*, p. 513.
[47] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 528.
[48] *Ibid.*, pp. 503–509.
[49] Darrah, W. C., *Powell of the Colorado* (Princeton: Princeton University Press, 1951), p. 242.

commentators viewed them with distaste. Nevertheless they were essential to maintaining the large appropriations he received. His dependence on the mechanism of the Sundry Civil Bill required him to rely on congressional friends at crucial points in the committee system; maintaining these alliances was a demanding task which few scientists could have performed.

Political talent and persistence, and the devices of publicity and patronage, were not Hayden's sole or even primary means of securing political support. Hayden made the important political discovery that the same political forces that had driven some state legislatures to require the state survey to give equal time to each county could be used to strengthen congressional demands for the extension of his own survey. The delegate from the Dakota territory sent Hayden an editorial from the *Yankton Press* of 12 December, 1871, which noted that:

> The government has shown its liberality toward Nebaskra and Wyoming, as well as most of the Northwestern Territories, within the past three years, by making ample appropriations for geological surveys in those sections, which have been prosecuted under the supervision of eminent scientific men, and have resulted in discoveries of coal and other minerals in various localities of incalculable value the reports of which have been spread through various portions of the states, advertising the country and greatly aiding in settling up those favored sections. But nothing of this character has been done for Dakota.[50]

The editorial goes on to ask: "how can we be denied this boon?" Hayden's reports were indeed "advertising the country", as the editorial put it. His contributors were expected to bring out the best features of the areas surveyed, and this made the reports into a "boon" which was likely to be demanded as a region's "due".

King and the Army Survey

Clarence King had been a student in the Sheffield Scientific School at Yale in the early 1860s, where he was a classmate of O. C. Marsh and William H. Brewer. Brewer's letters to his chemistry teacher George Jarvis Brush were read aloud to King, and inspired him to go West and become a field geologist.[51] His ambitions were soon fulfilled, for he was employed on the California survey of Whitney, which had employed Brewer. King learned several political lessons from the California survey. Whitney had been given a four-year term as state geologist. The legislature expected mining benefits, but Whitney made various pessimistic pronouncements on mining possibilities, and the only publication the survey produced by the end of four years was William Moore Gabb's *Paleontology*, which aroused the ire of the clerics who regarded it as blasphemous.[52] The legislature extended the

[50] Hayden Survey, Letters Received, sent by M. K. Armstrong, 20 December, 1871, National Archives, *op. cit.*

[51] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 432.

[52] *Ibid.*, p. 372.

survey in 1864, but only on the condition that Whitney devote his time to economic geology, and it enforced its insistence by halving his budget.[53] King went to Washington in 1866 to propose a survey of his own, which became known as the 40th Parallel Survey. He had the endorsement of prominent Eastern academics, the support of Smithsonian scientists, and of Whitney himself.[54] He might have chosen to seek a direct appropriation from Congress, in the fashion of Hayden, but he did not. He worked out an arrangement with the army which involved direct appointment by the secretary of war and regular reporting to General Humphreys, chief of the Army Corps of Engineers; the army supported his requests for appropriations. In the winter of 1867, King was authorised by the army to perform a large survey of the territory which is today Nevada and northwest Arizona. He then assembled a team of young scientists from Yale and Harvard, several of whom had studied in Europe, as well as several specialists with experience in army surveys.

King's surveys consistently produced economically valuable results, and he proved adept at keeping his military sponsors happy. At the close of his first season in the field, the summer of 1867, during which the explorers had run into serious health problems, he was nevertheless able to claim that: "Our economical results alone, [obtained especially by examining mines] I believe are worth to the Government all I have expended."[55] King returned to Washington to seek the extension of his survey, which was supported under the biennial congressional budgetary cycle. In spite of a chillier climate for surveys, King succeeded. In his next season, he made sure of economically valuable results by surveying the Comstock lode. His team grasped immediately that faulty smelting had resulted in a waste of ore at the Comstock mines at the rate of 40 million dollars in eight years, and one of his best men, Arnold Hague, trained at the Sheffield School, Göttingen, Heidelberg and the Royal School of Mines, was put to work on suggesting improvements. King, as leader of the survey, was able to take credit for the economically important results of this effort. King concerned himself with ore resources, and concluded, in contrast to Whitney, that substantial amounts of high-quality ore remained. King also produced some interesting scientific results by grasping the significance of the great salt flats, though here he was preceded by G. K. Gilbert of Wheeler's military survey. By mid-August of 1869, King had himself discovered new coal formations, James Hague had restudied the Colorado gold fields, another member had studied mining districts, and others had studied the Great Salt Lake.[56] That winter King returned to the East to do the analytic work which would turn the raw results of the survey into a significant scientific contribution. He was reluctant to return to the field in 1870, apparently tired of the effort and

[53] *Ibid.*, p. 373.
[54] *Ibid.*, p. 433.
[55] Quoted in *ibid.*, p. 442.
[56] *Ibid.*, p. 448.

eager for the conviviality of Eastern club life. General Humphreys, however, ordered him back into the field, and it was on this trip that his party achieved its first dramatic scientific result, the discovery of glaciers on Mts Rainier and Hood. The reports were treated with some scepticism, but they enabled King to reach a wider audience.[57]

King's ability to charm congressmen was perhaps unparalleled in the history of the surveys. James Hague later recalled his mode of lobbying:

> King appeared in Washington, early in 1867, as the advocate and promoter of his newly conceived project, the organization and conduct of the United States Geological Exploration of the Fortieth Parallel. He came furnished with the best of social introductions, letters of scientific commendation and political endorsement; but it was his personal charm and captivating speech that won for him an immediate and enduring success. Senators, representatives and government officials of every grade became at once his admiring friends. Fessenden, of Maine, after an evening's companionship with King at Sam Hooper's genial dinner-table, was himself almost persuaded to be a scientist, and professed his conversion in saying, "If I were not United States Senator I would be United States Geologist." Another senator, on the same occasion, was so charmed by King's descriptive powers that he confessed a strong desire to actually see with his own eyes "those marvelous isothermal lines" which King had pictured to him with the fascinating effect of an Aurora Borealis.[58]

One of those whom King dazzled was the Californian John Conness, who became "King's ardent advocate and a most zealous worker for his interests in all matters demanding senatorial action",[59] and who "was a faithful supporter of the Fortieth Parallel Survey"[60] as long as he remained in the Senate.

Support of this kind often had strong effects on annual appropriations without reflecting much commitment on the part of Congress as a whole, as the following vignette shows:

> On one occasion, when legislative authority and appropriation of money became necessary for the work of the Survey and, especially in the case referred to, for the publication of the report, Mr. Conness, being just then absent from Washington, on being advised that the then pending bill, containing the vitally important item, would probably come up for action next morning, hastily returned by night and took his place in the Senate Chamber at the opening of the session. The attendance of senators was very small when the measure was finally brought to a vote, fortunately, in the hands of a friendly presiding officer. The call for "ayes," notwithstanding the encouraging voice of Mr. Conness, was met with what seemed like deadly silence to King, anxiously watching and listening in the gallery. The call for "noes" passed, happily, with still less noteworthy response. "The ayes seem to have it," said the presiding officer tentatively—"the ayes have it," he continued decisively—"it is a vote," he announced in conclusion, and the thing was done, much to King's relief and satisfaction.[61]

[57] *Ibid.*, p. 450.
[58] *Clarence King Memoirs*, Century Association (New York: G. P. Putnam's Sons, 1904), pp. 381–382.
[59] *Ibid.*, pp. 382–383.
[60] *Ibid.*, p. 383.
[61] *Ibid.*, pp. 383–384.

The influence of a single well-placed senator was not enough to keep a survey alive, but it protected King's survey, and the sponsorship of the army freed King from questions about the propriety of government geology which dogged rival civilian surveys. Military control also enabled King to choose less onerous methods of reporting results. He was able to spend more time on the geological work itself, and did not need the report itself to be used by a wide audience. Consequently his reports were closest to contemporary academic ideals of scientific writing.

The army continued its long institutional history of military surveying and exploration in the West; the role of geology, while remaining subordinate, was enlarged. George Wheeler, a West Point graduate of 1866 who, as a second lieutenant, learned the trade of military topography, was the star of army surveying. He became a survey leader in 1871 at the age of 30, charged by General Humphreys, head of the Corps of Engineers, to:

> obtain topographical knowledge of the country traversed by your parties, and to prepare accurate maps of that section. . . . It is at the same time intended that you ascertain as far as practicable everything relating to the physical features of the country, the numbers, habits, and disposition of the Indians who may live in this section, the selection of such sites as may be of use for future military operations or occupation, and the facilities offered for making rail or common roads, to meet the wants of those who at some future period may occupy or traverse this part of our territory.[62]

Wheeler's surveys also expanded rapidly, and his expenditures, by 1878, were second only to Hayden's, ahead of King's, and double those of the small survey headed by John Wesley Powell.[63]

Powell's Progress

Powell had served the Union cause with some distinction, and had lost an arm at Shiloh.[64] In the postwar atmosphere of Washington, his military record gave him some claim to the attention of politicians and bureaucrats, including his old commander, General Grant. In 1867 he had used his army connections to get rations for a geological trip to the Rockies which had included nine amateur naturalists from the Midwest and three students from the Illinois State Normal School, where he taught geology. He had the support of a number of Illinois institutions,[65] including the "State Museum", of which he had been appointed curator in 1867. He used his salary to support his expeditions. Powell's mode of piecing together support resembled Hayden's procedure in the 1850s. After a successful initial expedition, which included the ascent of Pike's Peak, Powell proposed in

[62] Quoted in Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, pp. 469–470.
[63] *Ibid.*, p. 485.
[64] Darrah, W. C., *Powell*, *op. cit.*, p. 57; Stegner, Wallace, *Beyond the Hundredth Meridian: John Wesley Powell and the Second Opening of the West* (Boston: Houghton Mifflin, 1962), p. 17.
[65] Darrah, W. C., *Powell*, *op. cit.*, pp. 81–82; Stegner, W., *Beyond the 100th Meridian*, *op. cit.*, pp. 18–19.

1868 a much more ambitious geological exploration of the little-known Grand Canyon area. He was supported again by a number of Illinois institutions, but he also had modest federal support, having gained it in part with the help of a letter of endorsement from Joseph Henry at the Smithsonian, but primarily with the help of certain Illinois congressmen.[66] In addition, he asked for, and was given, free transportation for his men by four railroad companies, and free transportation for parcels by two express companies.[67]

In 1869, Powell extended his work on the region with a journey down the Colorado River through the Grand Canyon, supported by a renewal of the order permitting him to draw army rations for his men together with another patchwork of small contributions: $500 from the Illinois Industrial University, a similar sum from the Chicago Academy of Sciences, and some small subscriptions from friends. The spectacular success of this expedition enabled him in 1870 to procure significant federal support through a bill which gave him $10,000 for a larger "Geological and Topographical Survey of the Colorado River of the West".[68] He returned to the Colorado in 1871. These trips established Powell as a man of great initiative, capable of leading a scientific team. What Powell did was as much in the tradition of Western exploration and adventure as in the tradition of scientific geology, but the expeditions achieved scientific results of some novelty and attracted public attention. Like Hayden, Powell employed a photographer, and the sales of the photographs of the trips, produced as stereopticons, impressed his Washington sponsors, and were a significant source of funds for the work. The pattern of Powell's initial successes in Washington, the financing of the Colorado River trips, became a familiar one—as with the state surveys, he first accomplished a limited task with small resources, produced visible results, and then appealed for more ample support for the continuation of the work.[69]

Powell had difficulties in obtaining funds, in part because he sought them as a private citizen, rather than as an agent of the Land Office, as Hayden had done, or of the army, as King had done. He did not ask for a salary or an official position, but only for funds to support the explorations themselves, a request that was both modest and somewhat unconventional. His attempts to gain federal support in the form of rations had drawn senatorial objections, notably the objection that providing financial support for Powell would invite other individuals to seek support for equally deserving projects.[70] The appropriation of 1870 was the first for which Powell was not

[66] Darrah, W. C., *Powell, op. cit.*, pp. 91–95; Stegner, W., *Beyond the 100th Meridian, op. cit.*, p. 45.

[67] Stegner, W., *Beyond the 100th Meridian, op. cit.*, p. 45.

[68] Darrah, W. C., *Powell, op. cit.*, p. 152; Stegner, *Beyond the 100th Meridian, op. cit.*, p. 113.

[69] The pattern is described in Hendrickson, W. B., "19th Century State Surveys", *op. cit.*, p. 360.

[70] Darrah, W. C., *Powell, op. cit.*, p. 93.

seeking supplementary funds, but full support. Accident and political circumstance led to an unusual bureaucratic arrangement. As he had been lent topographic instruments by the Smithsonian Institution for the expedition of 1867 in exchange for data, he turned to Henry for help. He also called on Salmon Chase, a childhood acquaintance, and James Garfield, both of whom were on the board of trustees of the Smithsonian Institution, and both of whom had been ardent if unsuccessful supporters of the resumption of the Ohio state geological survey in the late 1850s and early 1860s, when Chase was governor of Ohio and Garfield a state senator.[71] Garfield was then the best orator in the House of Representatives, and through his influence Powell was given his first appropriation of $10,000, which paid his salary, making him a federal employee. As a result of a clerical error, the survey was required only to report to the Smithsonian.[72] The arrangement with the Smithsonian Institution was convenient, for Powell reported to scientists and persons favourable to science, rather than to a bureaucracy for which scientific work was subordinate, such as the army. Nevertheless it was a weak position politically, for the Smithsonian Institution had no great political influence, and Powell's organisation lacked the connection to cabinet officials which King's and Hayden's had.

The Conflict over Civilian or Military Control of Surveys

The manner in which the federal government made decisions on financial support for these surveys was bound to lead to difficulties. From the point of view of the aspiring surveyor, the problem was to establish oneself as a serious competitor for funds, to gain the endorsement of an administrative officer whose department would take formal bureaucratic responsibility for the survey, to be endorsed by some set of scientific notables, preferably including one or two residing in Washington, and cultivate whatever congressional friends one could find to sponsor legislation on one's behalf. The Western domain was so vast that no geologist could hope to monopolise all the work of surveying. But there was no central direction to the work, and inevitably, ambitions overlapped and collided; the surveyors began to appear threatening to each other, and sometimes to threaten one another. Hayden successfully defeated the ambitions of the Land Office to launch a survey in 1870,[73] but a more serious conflict was provoked by an incident in the summer of 1873, when Hayden's survey party encountered a detachment of Wheeler's War Department's survey commanded by W. L. Marshall,[74] in the remote Twin Lakes region of Colorado. The two surveys began to map each other's territory, each claiming, with some justification, that the work was within its purview. The dispute became an issue in congressional debate

[71] Merrill, G. P., *State Surveys*, *op. cit.*, pp. 399–400.
[72] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 556.
[73] *Ibid.*, p. 499.
[74] *Ibid.*, p. 478.

in 1874, and in the hearings in the House of Representatives on the subject it was made evident that jealousies between soldiers and civilians, together with Wheeler's ambitions, were the major sources of trouble. The significance of this dispute was not in its administrative results, which were meagre, but in the fact that it changed the way the geologists thought about their relations with the state.

The House of Representatives requested reports from the survey organisations then in the field and from the departments that supervised them. The reports were to answer the question of "whether it be not practicable to consolidate [the surveys] under one department or to define the geographical limits to be embraced by each".[75] President Grant responded that he considered the War Department the most appropriate agency for survey work on the grounds that field parties needed escorts for protection against Indians, and that this meant that a large portion of the expense was borne by the War Department. The Corps of Engineers, he argued, is composed of scientific men educated for survey work, and given that they are being paid whether or not they perform the work, as a matter of economy it is best to use them for the purpose.[76] The secretary of war, William W. Belknap, seconded this, expressing his "conviction that economy and efficiency would be the result of consolidating all such surveys under the War Department".[77] Humphreys developed these themes, noting that "The parties are essentially military in their organization, and are nearly always accompanied by troops"; he stressed the additional point that: "The chief labors of these parties are devoted to the geographical, astronomical, geodetic, topographic, hydrographic, and meteorological determinations, without which the geological and mineralogical would be comparatively useless—especially in their practical application to military, mining, and agricultural purposes."[78] Wheeler's testimony expanded these arguments. He was able to point to a long tradition of "army exploration and surveys" from Lewis and Clark down to King and himself, thus bringing these activities together into the same broad category, and pointed out that:

> The War Department and its parties have always maintained cordial relations with the many scientific societies and men of science of the country, who are interested and skilled in the inquiries that form part of the labors of the expeditions, and they have been consulted in the organization of the expeditions, and in the methods of observation to be followed in their own special branches—geology, botany, and natural history.[79]

In the testimony which followed his formal statement, Wheeler stressed the idea that his reconnaissances and surveys—this was now to become a salient distinction—had been conducted according to instructions which called for his parties "to make geological investigations, and such collections in

[75] US Congress, House of Representatives, House Report 612, *Geographical and Geological Surveys West of the Mississippi*, 43rd Cong., 1st Session, 1874, p. 1.
[76] *Ibid.*, p. 2.
[77] *Ibid.*
[78] *Ibid.*, p. 4.
[79] *Ibid.*, p. 5.

natural history, and such observations on points connected with the character and habits of the Indian tribes, as might be necessary to meet the general needs of the War Department", but which called primarily for work which met the "great necessity that exists, so far as the War Department is concerned", which was "to have a correct topographical map of that country",[80] a practical necessity which arose from the inadequacies of then existing maps.

Wheeler's purpose in connecting his own work to this "great necessity" reflected his belief that the civilian geologists had a conception of the aims of their work, and of the proper relation between geographic and geological considerations,[81] which rendered their work unsuitable and his own work not only suitable, but fundamental to all the main uses of mapping. His view was that "we must found" the work "upon geographical considerations", and that if we do so, "the other parts will co-ordinate and harmonize naturally". The source of the disagreement as he saw it was that "the other party wishes to inflate, as it were, and place geological considerations in advance of geographical considerations beyond the necessities of the case".[82] Wheeler made the distinction between the geological and geographic or topographic aspects of survey work in terms of a distinction between exact sciences, which are matters of the application of mathematical formulae, and "allied sciences", which, he said, "are outside of the pale of critical mathematical deduction, and depend upon facts and analogous reasoning for the establishment of their truths". In this latter group he placed "geology and natural history", in the former, "astronomy, geodesy, topography, and the hypsometric part of meteorology". All of these he took to be "integral parts of geography".[83]

The special claim of the War Department to the charge of this work rested for Wheeler on the considerations that the army was the greatest user of maps at the level of precision allowed by ordinary topographic work, that, as the primary user, the army had the best grounds for making decisions about how the work should be done, and that the special training of the engineers enabled them to assess the quality of topographic work during the work process itself. He amplified the latter point in testimony given in refutation of Hayden's testimony, where he suggested that Hayden knew little about topographic work, and remarked that Hayden was forced to rely on a topographer, James T. Gardner, who had learned his business on the California survey and with King's survey, which had been sponsored by the army. In his testimony, Hayden had made some general remarks about triangulation, and had his assistant answer the technical questions. Wheeler observed that "his calling upon Mr. Gardner to explain the features of triangulation, &c., confirms what I have had reason to believe is true, and that is, that here is a person in charge of a great geographical work, unable to

[80] *Ibid.*, p. 20.
[81] *Ibid.*, p. 24.
[82] *Ibid.*, p. 25.
[83] *Ibid.*, p. 65.

perform, or intelligently direct, the astronomical, geodetic, or topographic portions thereof".[84] This raises a significant organisational problem: "Were it not for this man, the most important part of Dr. Hayden's survey must fail"—yet this person was in a subordinate position, and therefore vulnerable to the consequences of incompetent supervision. "Whatever his capabilities or character may be, when the uncertainty as to the tenure of his official relations depends upon the will of one who cannot intelligently supervise his labors, the condition can better be imagined than described."[85]

Hayden's case, and his assistant's rebuttals of Wheeler, relied on a different set of distinctions. Their discussions invoked the tradition of the state surveys and the ideal of the supervision and control of survey work by competent scientists who are proven leaders. "The experience of geological surveys of the States, and of the civilian surveys under the United States, have thoroughly demonstrated their value," Hayden argued, and the lesson of these surveys is that:

> much greater efficiency has always been gained where the leader of the survey is himself an ardent worker in geology and science generally, as he is better able to judge of the work to be performed, and as he urges forward all his scientific assistants by the force of his example and enthusiasm. As an evidence of this, it is only necessary to refer to the geological reports of Owen, Foster, Whitney, Hall, Wharton, and others in this country, and those of Sir W. E. Logan in Canada, and Sir Roderick Murchison in Europe, &c.[86]

These examples were meant to support the claim "that when a scientific party is placed under charge of one who is not himself a devotee and enthusiastic laborer in some special field of science, the work done is inferior in quality and quantity",[87] and that "the higher the scientific character of the party, the more certainly do they demand a leader in full sympathy with them".[88]

Experience also taught that military supervision was an unnecessary expense, since it involved "a leader accompanying the parties mainly to direct the movements of those who have the entire work to perform". "The geologist in charge," Hayden argued, was sufficient, for he "finds no difficulty, when he has the arranging of his own party, in doing his full share of personal scientific labor and at the same time guiding the general movements". In addition, Hayden observed, "a [military] leader not only occasions unnecessary expense to the Government, but often proves a source of discord and conflict".[89] Other considerations were brought to bear against the superficially appealing idea of a single bureau devoted to geology. His first argument was cost, the consideration that a bureau "necessitates the expense of a number of salaried officers, clerks, and employees, who are not needed so long as these surveys are special",[90] the

[84] *Ibid.*, p. 64.
[85] *Ibid.*
[86] *Ibid.*, pp. 7–8.
[87] *Ibid.*, p. 8.
[88] *Ibid.*
[89] *Ibid.*
[90] *Ibid.*

second that the security which the office of bureau head affords would be detrimental to the work because it "destroys that healthy emulation which produces extra exertion, gives stimulus to energy, and a proper regard for expenses".[91]

Hayden could visualise only two alternatives, "a bureau system", which "tends very strongly to crush out and destroy that scientific individuality from which the greatest results have always been derived", and the present system, where the continuation of a survey depended "upon the value of the work performed, . . . [in which] Congress is left the sole and the immediate judge as to the value".[92] To this he had no objection. His own conception of the aims of survey work and the public responsibilities these implied echoed the state survey tradition. He argued that:

> [as] these surveys are made at public expense, their utilitarian or general economic object should never be lost sight of; although I believe the Government would be justified in carrying them on if confined to a purely scientific purpose, yet it is the duty of Government to make them of a more general and public benefit. This, therefore, should be, and also has been with me, a very prominent object; while I have endeavored, as far as possible, to add to our scientific knowledge, I have always felt it to be my duty to keep constantly in view, as the primary object, the gathering of such facts and knowledge as will be of use to the public, and tend to develop the material resources of the Territories.[93]

This placed the burden of producing useful results squarely on the geologist, who was to use the freedom granted him to support the development of the material resources in a broad sense; Congress could competently judge these efforts, which were aimed to satisfy directly public needs, and the results could be made intelligible to the public. Hayden gave his annual reports as an example. "Popular language is used in them," he said, "in order to make them more acceptable to what I might call the great intelligent masses of the people, who are interested in such work as this. They have proved to be very acceptable, because they meet the wants of the people."[94] Of course, Hayden was also able to defend his scientific competence, which he did by producing "letters and testimonials of some of the ablest scientific men in the land, who are best able to judge of the labor and results of the survey".[95]

On the technical issue of the relation between uses of topographic maps, Hayden took the line that the standards demanded by the use of maps in geological work were higher than those set by army uses. To the suggestion that geographical limits be placed on the surveys, his response was that to a certain extent this could be done, and would more easily be done if all the surveys reported to the secretary of the interior. But he cautioned that for the work of geology and paleontology overly strict limitations were impractical, because the study of a ridge or a coalbed might require

[91] *Ibid.*
[92] *Ibid.*
[93] *Ibid.*, p. 9.
[94] *Ibid.*, p. 36.
[95] *Ibid.*, p. 71.

following out the geological forms beyond artificial administrative boundaries. Hayden sidestepped the problem of duplication between the surveys by insisting that there was no duplication, because the objects of a military survey, whatever these might be, "could have no relation to or in any way necessarily conflict with the geological survey under my charge".[96]

Powell's statement did not deal with organisation, except to agree with the suggestion of placing the surveys in one department. He also asserted that "it is of the most immediate and pressing importance that a general survey should be made for the purpose of determining the several areas which can thus be redeemed by irrigation",[97] thus introducing the subject which was to be central to his own career—the aridity of the West. He observed that a serious problem of policy was emerging as a consequence of the fact that "already the greater number of smaller streams, such as can be controlled by individuals who wish to obtain a livelihood by agriculture, are used for this purpose", and that "the largest streams, which will irrigate somewhat greater areas, can only be managed by co-operative organizations, great capitalists, or by the General or State governments".[98] In his testimony, Powell, who could claim to "have served as military engineer during the war, part of the time, and have some knowledge of what an engineer officer needs in the field",[99] agreed with Hayden's claim that while the topographic maps the geologists produced could be used for military purposes (a point Wheeler declined to contest),[100] the military maps were useless for geological purposes—a disingenuous claim, in that the "meander" methods he objected to had only been used in preliminary reconnaissances by Wheeler, and were not the methods Wheeler was then using.[101] Unlike Hayden, Powell showed his sympathy for the concerns of the congressmen over the "unnecessary expense" of duplication, and he used this point to support the idea that "all the surveys which are intended for scientific and economic purposes should have one direction and should be under one Department".[102]

King had entered in the public dispute only indirectly. As his survey was, legally, a creature of the army, he was not asked to prepare a report to the committee; his survey was nevertheless discussed by the civilian surveyors in a way which tended to reinforce the attack on the military and to deprive the military of any credit for his achievements. Hayden's topographer (and King's former employee) recalled that:

[96] *Ibid.*, p. 7.
[97] *Ibid.*, p. 10.
[98] *Ibid.*
[99] *Ibid.*, p. 55.
[100] *Ibid.*, p. 69.
[101] *Ibid.*, pp. 53, 67. Powell later relied on Wheeler's maps: Manning, Thomas G., *Government in Science: The U.S. Geological Survey, 1867–1894* (Lexington: University of Kentucky Press, 1967), p. 95.
[102] *Ibid.*, p. 52.

it was at one time an open question as to what Department it was best to have [King's] appropriation placed under for disbursement, and the War Department made certain concessions to Mr. King in order to secure it. Prominent among these was the promise that he should not have any officer placed over him, but should report directly to General Humphreys. Under no other consideration, would this appropriation have gone to the War Department.[103]

Neither Wheeler nor Hayden presented himself well at these hearings: Wheeler was arrogant, Hayden cavalier. But the hearings nevertheless served to sharpen the political issues of military control and civilian control. Military control was assumed by both sides to be more rigidly bureaucratic and to represent a greater potential for subordination to non-scientific purposes. Civilian control was assumed to involve a larger element of personal politics of the sort practised by Hayden, and consequently to be less stable. The choice between Wheeler and Hayden embodied the serious political alternatives at the time. Wheeler's defence of military control was often telling. The fact that "upon the survey under my charge alone there are more civilian assistants than upon the one under Doctor Hayden", and that "these assistants are in harmony with all persons on the work upon which they are engaged",[104] enabled him to reject the bogey of civil–military antagonism, and to remark that "judging, however, from the precedent established by the sending out of Clarence King on the fortieth-parallel survey",[105] the policy and practice of the War Department were not adverse to good scientific work. But this claim of harmony was undermined by the continuation of the bitter dispute which had been exhibited at great length before the committee itself. As Hayden himself commented:

the animus of Lieutenant Wheeler, in his statement before the committee, proves most clearly, what has generally been believed, that it is not the love of science, but of power, that has induced him to precipitate this conflict; and scientific men, all over the country, may well be filled with apprehension at the bare possibility of these officers gaining control of our national scientific work.[106]

Wheeler was more persuasive when he pointed out the dangers in Hayden's notion of how science ought to be supported. Beginning with his start "as a collector of specimens in natural history under a War Department expedition in 1855", Wheeler recounted Hayden's rise, which he described as "jumping from one pretentious pinnacle to another" to his present "hopeful ambition of receiving the position of head of a geological bureau under the Interior Department". Wheeler implicitly treated this career as irregular and suspect, and warned the committee accordingly: "Gentlemen of this committee, if you further legalize this man, may you not in twenty years from now have twenty like unto him, or twenty thousand if you please, and meanwhile your corridors may be thronged with ambitious parties, the would-be custodians of geographical or geological plans?"[107]

[103] *Ibid.*, p. 56.
[104] *Ibid.*, p. 62.
[105] *Ibid.*, p. 64.
[106] *Ibid.*, p. 71.
[107] *Ibid.*, p. 67.

This spectre was no less haunting to scientists who hoped for governmental support, and who faced the unpleasant necessity of "thronging the corridors" of Congress. But Hayden's arguments against control by the military were compelling, at least to geologists. Jules Marcou, recalling in 1885 an episode in the 1850s during his work for the Pacific railroad explorations, supervised by the army, described submitting "to the arbitrary act of Jefferson Davis", then secretary of war, who had ordered him to give up his geological notes before leaving for Europe, where he had intended to write his report. The experience of "his overbearing manners and tyrannical power, which a few years later made him so conspicuous as the leader of the rebellion against the United States"[108] made a lasting impression. Similar, less dramatic conflicts with military supervisors had similar effects on other scientists. The general principle at stake was formulated by James Dana, who wrote to the committee that "it would be as reasonable to put a geologist or naturalist at the head of the Army, or of a corps for war defenses, as to place scientific surveys of any kind under officers of the Army, or to make them subject in any way to the management of the War Department".[109]

From the point of view of the congressional committee, the weakness of the military's argument was evident at once: the model of military supervision and staffing was not followed by the military itself. As the committee's summary pointed out, "all the officers of Clarence King's surveys made under the War Department were civilians, as well as the larger portion of those under Lieutenant Wheeler".[110] This led them to the conclusion that the War Department lacked the capacity to perform the work on its own. The committee simply dismissed the issue of the need for military escorts. Hayden had long since dispensed with them, and Powell never had used them.[111] The committee concluded that "there is an abundance of work for the best talent of both the War and Interior Departments in these scientific examinations of the Western Territories for many years to come",[112] and declined to place the surveys under any one department, calling instead for the continuation of a "generous rivalry", but warning the secretaries of the army and the interior that they should avoid duplication. In fact, the political warfare continued.[113]

Powell's survey, the smallest and least entrenched of the four, was the one least likely to survive continued political contention. Powell lacked Hayden's and King's academic connections. Yet Powell was rapidly consolidating his scientific reputation. The "great monograph" on the Colorado River survey came out in 1873. Before this, Powell had little in the

[108] Merrill, G. P., *One Hundred Years*, *op. cit.*, p. 681.
[109] House Report 612, 1874, *op. cit.*, p. 74.
[110] *Ibid.*, p. 16.
[111] *Ibid.*, p. 18.
[112] *Ibid.*, p. 16.
[113] Manning, T. G., *Government in Science*, *op. cit.*, p. 37.

way of scientific achievement to point to. Legislators seemed to regard him as a scientific purist, for he had not allied himself to a particular set of special interests, nor had he been eager to produce the annual reports that led to renewed financial support, preferring to base his claims on finished monographs.[114] The location of his survey under the Smithsonian Institution seemed to emphasise the impression of separation from any practical interests. The price of this was insecurity—every appropriation might be his last.

The hearings changed his administrative situation. The appropriation in 1874 for the continuation of this work made his in effect a second division of the geological and geographical survey of the territories, reporting to the secretary of the interior. This made Powell the equal of Hayden in the administrative structure of the government, although not in support or in scientific prestige. The hearings did not resolve many other problems. Duplication continued, especially between Powell and Wheeler, each of whom operated under instructions from his own department; there were other difficulties within the Interior Department, largely a consequence of inadequate instruction and control by the secretary. The surveys continued to operate as before—without any constraints other than those of the political tug of war governing the making of congressional appropriations.

In early 1877, J. S. Newberry, geologist and paleontologist of Columbia College, apprised Powell of a plan in the House committee on appropriations to stop supporting all surveys but Hayden's. Newberry assured him that the plan would be opposed within the committee. Powell replied that he was afraid it would be "a tight squeeze".[115] In the same year, Hayden approved plans to send his photographer, Jackson, into Powell's domain to record pueblo settlements, and considered expanding his own ethnological work. After complaining of Hayden's encroachment to the secretary of the interior, Carl Schurz, Powell sought an accommodation with Hayden.[116] Powell agreed to focus any new investigations on "ethnography" and leave the lion's share of survey topics, "researches in Natural History, including Paleontology in its several branches, Zoology in its several branches and Botany",[117] to Hayden. He was, however, expected to complete the writing up of the geological work he had begun. Hayden agreed to this, and the secretary of the interior approved it, but it was hardly a solution to Powell's troubles; ethnography was, if anything, more distant from practical demands than his other work. However, Powell took a significant step to rectify this.

His monographs *The Exploration of the Colorado River of the West* and

[114] *Ibid.*, p. 27.
[115] Quoted in *ibid.*, p. 38.
[116] *Ibid.*, p. 37; Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 581.
[117] From a copy, Office of the Secretary, 1863–1879, Incoming Correspondence, Record Unit 26, Smithsonian Institution Archives.

The Geology of the Uinta Mountains,[118] which appeared in 1875 and 1876, were both "pure" scientific works of great distinction. Each had embodied the idea that "geology is expressed in topography";[119] each described uninhabitable regions which had few mineral resources. Joseph Henry suggested that Powell apply the concern with erosion and drainage to the topic of irrigation. He followed these monographs with his *Report on the Lands of the Arid Region of the United States, with a More Detailed Account of the Lands of Utah*, which was published in 1878.[120] The issue of the arid lands was a matter of public interest, and the book placed Powell in the centre of an enormous dispute: a printing of 1,900 copies[121] was quickly exhausted, and a second printing of 5,000 authorised. Thus, Powell's role had begun to change when, in the spring of 1878, the matter of the conflicts between the surveys again came to a head.

The Consolidation of the Surveys: Powell Comes Out on Top

The House of Representatives committee on appropriations in 1878 again called for reports to be submitted by the three surveys. The move was perhaps instigated by Hayden; nevertheless, it had unfortunate effects for him, for it quickened sentiment in the scientific community against him and the system of patronage he represented and defended. Congressman Hewitt, a member of the committee who became a prime mover in the events, had been sent a letter in 1877 by Newberry that had asserted that Hayden had become "so much of a fraud he has lost the sympathy and respect of the scientific men of the country".[122] The same letter praised Powell's collaborators for their scientific dedication and competence. In the face of such signs of disunity among the civilian scientists, the congressmen turned, with the encouragement of Clarence King, to the National Academy of Sciences, asking for an independent review of three of the survey groups.[123] Joseph Henry had recently died, so the task of appointing a committee was left to the vice-president, O. C. Marsh, a Yale paleontologist who had made at his own expense important fossil discoveries in the West.[124] The committee of the National Academy of Sciences included several persons who were familiar with the scientific issues in

[118] Pyne, Stephen J., *Grove Karl Gilbert: A Great Engine of Research* (Austin: University of Texas Press, 1980), p. 74.
[119] Quoted in Manning, T. G., *Government in Science*, *op. cit.*, p. 75.
[120] Powell, John Wesley, *Report on the Lands of the Arid Region of the United States: With a More Detailed Account of the Lands of Utah*, ed. Stegner, Wallace (Cambridge, Mass.: Harvard University Press [Belknap] 1962).
[121] Manning, T. G., *Government in Science*, *op. cit.*, p. 29.
[122] Quoted in Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 581; full letter quoted in Darrah, W. C., *Powell*, *op. cit.*, pp. 240–241.
[123] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, pp. 582–583.
[124] Dupree, A. H., *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge, Mass.: Harvard University Press [Belknap], 1957), p. 205.

surveys, but who were not closely linked to any of the principals in the dispute among the three groups. It also included a number of persons with grounds for disliking Hayden, including Marsh himself, who was a bitter rival of Cope, one of Hayden's allies.[125]

The outcome of the deliberations of the committee of the National Academy of Sciences represented a triumph for Powell. The main organisational suggestions contained in his report were accepted, including his call for a division of labour between surveys concerned with land measurement and those concerned with geology and economic resources, and his proposal that the latter two types of survey be placed under two separate agencies within the Department of the Interior.[126] The proposal would have had the effect of taking authority away from the Land Office, of reducing Hayden to the status of a subordinate within one of the agencies, and of eliminating military control. The members of the committee of the National Academy of Sciences were intensely interested in establishing a pattern of the control of scientific work by scientists, and this was the focus of the report of the Academy. The organisational solutions proposed by the report, particularly the creation of a board of scientific notables representing various branches of science, including the military branches of governmental science, reflected the conviction that disputes arose solely from the interference of non-scientists.[127]

Some scientists, notably Alexander Agassiz, had opposed extensive governmental activity in science, and they found allies in Congress. The fact of opposition necessitated the development of a coherent rationale for governmental geology. Powell, who had accepted the political task of pushing for a consolidated survey, was forced to respond to these questions in the forms they took at the time, and his grounds shifted. In 1878, he was a public advocate of the view that "'the endowment of science by governments . . . be very limited and scrupulously confined' because 'the efforts and energies of individuals acting from no other stimulus than the love of science' brought better results than government patronage".[128] He showed that he was cognisant of the fact that in a democracy "science must show results 'for the immediate use and wants of all classes'; any survey valuable chiefly for 'abstract science' must always be 'weak and have an uncertain tenure of existence.'"[129] These narrow justifications sufficed to justify geologic mapping, which was valuable to mining, as well as topography and hydrology, which were of value to agricultural settlers. Botany and zoology, which were successfully pursued by individual scientists and which lacked conspicuous economic value, failed these tests,

[125] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 583.
[126] *Ibid.*, p. 585; Manning, T. G., *Government in Science*, *op. cit.*, p. 43.
[127] Manning, T. G., *Government in Science*, *op. cit.*, p. 54.
[128] *Ibid.*, p. 42.
[129] *Ibid.*, pp. 42–43.

except where, as in the case of forestry or insect infestations,[130] government intervention was demanded.[131] Powell's later arguments were more subtle; they also justified support of a broader range of scientific activities. But the arguments for surveys bearing on mining were at the centre of attention in 1878, and this was Clarence King's area of expertise.

Divisions among the scientists associated with Powell and Hayden reflected a deeper problem which could not be readily discussed in public, the problem of the effects on science of the concentration of authority implied by the regularisation of governmental financing of geology. Writing to Professor A. G. Wetherly of the University of Cincinnati on 21 November, 1878, at the time that the outcome of the work of the committee of the National Academy of Sciences had just become known, one of Powell's geologists, C. E. Dutton, formulated a contrast between surveys as "purely personal affairs", as was Hayden's, and surveys as a "vital part of government", which he favoured. "The question," he wrote, "is not one of persons but of measures." Persons, however, had a stake in the measures, and Dutton speculated that "Hayden may . . . oppose [a consolidated survey] in the fear that if a consolidated scientific survey were established he might fail to be appointed as the sole head of it or might be curtailed in the exercise of unlimited discretion in the management of any appropriation which might be made for it". He also acknowledged that if Hayden wanted the position, and the president sought the views of scientists, Hayden could not be effectively opposed.[132]

Hayden's former employee Cyrus Thomas, then professor at the newly established Southern Illinois Normal University, understood the issue in much the same terms. He wrote to Hayden in 1879 that "consolidation looks fine on paper as it looks like system, but it is a death blow to native talent and personal energy". Thomas remarked that he thought the Coast Survey, the source of some jealous criticism of Hayden, was an expensive "humbug", but he expressed no animus against Powell, and indeed suggested as a resolution to the dispute that the topographical surveying work be given to the army engineers, who were so eager for it, "and leave you and Powell to work up the geology and geography for the Land Department".[133] Hayden's own actions were largely consistent with this reasoning. Because the survival of his own survey was at stake, he was forced to take the civilian side in the dispute over the control of geology, but covertly he opposed consolidation.

The congressional action which followed the Hewitt committee's inquiry, of which the report of the National Academy of Sciences was a part, was not

[130] An interesting exception, in that Cyrus Thomas and Hayden had manoeuvered successfully to create an entomology commission on which Thomas was then employed (Hayden Survey, Personal Letters Received, 1872–79, National Archives). At the end of his service on this temporary body, Thomas became Powell's subordinate, as director of the only subunit of the Bureau of Ethonology, which had as its business the opening of Indian Mounds.

[131] Manning, T. G., *Government in Science*, *op. cit.*, p. 43.

[132] Rocky Mountain (Powell) Survey, Letters Sent, National Archives, Washington, DC.

[133] Hayden Survey, Personal Letters Received, *op. cit.*

a clear decision between these rival conceptions of the proper pattern of governmental surveys. It did result in the displacement of the old idea of military control of surveys. Although Hewitt, at the beginning of the proceedings, assumed that military geology would not be diminished, he was won over to the idea of control by civilian scientists by the end of the proceedings.[134] When Hewitt presented the proposal for a single unified survey, controlled by civilians, to the House of Representatives in early 1879, military control was depicted as a "foreign" idea. His proposal for geological research was well received; his suggestions on surveying related to the land system were not, and the surveying activities of the General Land Office were not disturbed.[135] In the Senate, Hayden's friends on the committee on appropriations sought to stop consolidation and attempted to give the $100,000 intended for all of the surveys to Hayden. The proposal the Senate finally approved gave the Wheeler survey $20,000 to complete its work; it abolished the Powell survey, and gave Hayden's survey the $20,000 Powell would have received. The House version of the consolidation bill, however, became law, as a result of a compromise attached to the Sundry Civil Expense Bill of 1879—a legislative event closer to an accident than to a ringing endorsement.[136] Moreover, as one stated motivation for consolidation was budgetary, total appropriations would be reduced. With this inauspicious start, Hayden and King began their competition for the directorship of the newly consolidated United States Geological Survey.

The position of director was not conceived in very precise terms by the competitors. Hayden had been a staunch defender of autonomy for the head of the field party; decentralisation was implicit in his argument regarding the impossibility of directing surveys from a distance. Hayden's candidacy did not imply any change in aims. Nothing in his many pronouncements on the organisation of geological research, or in his claim that the organisation he had built up had the capacity to take on larger and larger parts of governmental geological and topographic work, indicates that he regarded the directorship of a unified survey as a role in which he would pursue any agenda other than the one he had himself pursued. Hayden was not a party to the ideal of pure science which animated some of the authors of the report of the National Academy of Sciences. In the course of the dispute he continued to express rather sourly his doubt that the federal government was ready for "a bureau of science".[137]

The opponents of Hayden used a method he himself had long practised, the method of producing letters of endorsement from a relatively small group of prominent scientists.[138] These opinions were presented as a representation of the collective opinion of American scientists, but the list of

[134] Manning, T. G., *Government in Science*, *op. cit.*, p. 45.
[135] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 588.
[136] Manning, T. G., *Government in Science*, *op. cit.*, pp. 52–53.
[137] House Report 612, 1874, *op. cit.*, p. 8.
[138] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, pp. 590–591.

King's supporters was not in fact representative; it was drawn largely, as one of Hayden's supporters pointed out, from New England, where King was an insider, friendly with "most of the . . . important powers in the scientific establishment",[139] and well connected in "society" and literary circles.[140] King was far from later notions of professionalism in science. He was not active in scientific societies, and, at a time when the ideal of the life of science was becoming sharply distinguished from the aspirations of business men, King was more eager to become rich than to be a scientist. Scientists were aware of his ranching and mining ventures; indeed, Hayden's supporters complained of these enterprises, which King had pursued while head of the Fortieth Parallel survey, and they complained about his consulting work, including a report written for $7,500 on a mine owned by Senator Logan of Illinois.[141]

While King was concerned to make geology useful, his notion of utility was not what David Dale Owen had in mind, i.e., utility to a wide range of persons in the community and a part of the general scientific education of citizens. He envisioned, rather, increasing activity in those areas of geological investigation which would have economic significance; he sought an alliance between geology and industry broadly understood, maintained by personal connections between geologists and mining entrepreneurs. He wanted to eliminate the constant necessity of creating new alliances, and he hoped that the establishment of the Geological Survey as a permanent agency would create a long-lasting bond with a powerful and stable interest group.

In King's first year as director he pursued his vision of the survey with great tenacity. He allocated funds for those projects which best corresponded to his aims, namely those projects which had the greatest promise for mining and for the alliance with the industry. His plan for the first year, described in a letter of 1 July, 1879, to the secretary of the interior, was "to confine all the purely geological investigations to the immediate neighborhood of certain prominent mining districts" and in each of the districts "to make a rigid geological and economical investigation of the origin, nature, structure, and commercial products of gold and silver together with an exhaustive study of mining, method of mining, and metallurgical treatment of the ores". The selection of sites was "arrived at from a consideration of the present and prospective products of the precious metals".[142] He established a Rocky Mountain District with a permanent headquarters and laboratory in Denver, with Emmons at its head. Emmons's purpose was to improve the efficiency of prospecting by mapping and making sections of the Leadville area.[143] King then sent George F. Becker to the Comstock lode, and commissioned a historical study of its

[139] *Ibid.*, p. 589.
[140] *Ibid.*
[141] Manning, T. G., *Government in Science*, *op. cit.*, p. 56.
[142] United States Geological Survey, Letters Sent, National Archives, Washington DC.
[143] Goetzmann, W. H., *Exploration and Empire*, *op. cit.*, p. 593; Darrah, W. C., *Powell*, *op. cit.*, p. 275.

mining and miners: this was an act motivated by the desire to celebrate the industry and its heroes.[144] But King's workers were not uncritical of mining practices, and held up the ideal of a more stable industry, less subject to the inflated promises and speculative fever that ordinarily accompanied efforts to attract capital for mining schemes.

The promises made by Hewitt could not be realised, however, simply by tending to the relatively well-known and well-understood needs of the Western mining industry which, in any event, proved to be slow to take any action on behalf of the survey. King himself knew that support of the survey depended on satisfying broader groups of supporters. One group which had been especially receptive to Hewitt's message and which supported the survey was a group of politicians of the "New South" who were interested in bringing industry to the South. The survey, however, had insufficient funds to do work east of the Missisippi. King estimated that extending the survey to the country as a whole would require an appropriation of $500,000 per annum. Moreover, although the act which created the unified survey referred to the "national domain", a term which had been inserted, on Powell's advice, through some legislative manipulation, the lawyers of the Department of the Interior, like the Congressmen who had voted on the bill, construed the term to refer only to public lands in the states and the territories, thus restricting the survey to the far West. The term could have been construed differently, and the survey could have been extended accordingly. But there were grave risks to doing so apart from the legal issues. Some scientists, notably James Dana, opposed the extension of the survey. The state geologists, with some exceptions, were favourable: they knew that the successes of the state survey movement had been patchy, and that the position of the surveys was often unstable. As J. S. Newberry observed, some states had contributed nothing, others little, and legislatures had all too often brought their surveys to "premature and more or less abortive conclusions",[145] as they did his own in Ohio.

The legal and constitutional issues, the opposition of Dana, the original aim of reducing expenditures, and the lack of new achievements all conspired against King. In the end King's prowess with legislators seemed to desert him, and "the perfect clubman" did not find the life of Washington appealling. He presented his resignation in March 1881 to the new president, James A. Garfield, after assuring that Powell would be appointed in his stead. The appointment reflected the fulfilment of one of Powell's earliest political alliances. Garfield had aided Powell in his first attempt to obtain federal funds in 1868.[146] Hayden, who would have been a strong candidate for the position, was unaware of what had happened until the appointment was on its way to the Senate for confirmation.[147] Powell was

[144] Manning, T. G., *Government in Science*, *op. cit.*, p. 63.
[145] Quoted in *ibid.*, p. 67.
[146] Darrah, W. C., *Powell*, *op. cit.*, pp. 93–94.
[147] *Ibid.*, p. 271.

perhaps better suited to the new tasks faced by the director. In any case, he pursued them differently.

King had tried to gain his ends through his personal relations with politicians, and with the scientists he had known in the east, as well as through the ties he had established with the geologists who worked in his surveys. The task he had set for himself in the division of labour of the survey was to serve as an intermediary between the politicians and his geologists, who worked independently in distant regional offices devoted to projects of interest to his mining constituency. He became a lobbyist for science. The ceaseless lobbying which King engaged in might itself have worked against him, but the narrowness of his conception, combined with the prospect of the immense expenditure it entailed, was probably decisive.

Like the earlier surveys, the consolidated survey had little in the way of a clear mission understood by all. The oratory of Hewitt granted the survey a licence to aid in developing the mineral wealth of the country. Miners did come, slowly, to be grateful for the help, and they ultimately supported the survey. But they did not provide the kind of stable support which the survey needed. The state surveys had already shown the weakness of this kind of alliance. The practice of extending survey work to all counties in a state, regardless of their mineral wealth, and of including soil and agriculture under the jurisdiction of the survey was one means by which the state surveys had sought to broaden the base of political support for the surveys. The existence of a separate federal arrangement for agricultural research prevented the United States Geological Survey from taking this path.[148] King's failure left Powell with the task of gaining a mandate that would assure permanence for the consolidated survey, which still depended for its continued existence, as the earlier surveys had, on the Sundry Civil Bill. To this he devoted his political efforts.

Powell in Charge

"Consolidation" had brought together diverse scientific and industrial interests, styles of science, ambitions, and loyalties and tasks. King had done little to reorganise the work of the survey. His primary innovation was to save the Western surveyors the trouble of returning to Washington for the winter appropriations. Powell reorganised the central administration of the survey partly along geographic lines, but largely in terms of special expertise or function. This form of organisation, in sharp contrast to the older pattern which had been retained under King, precluded the possibility of the separate units acquiring separate groups of political supporters. Emmons had in fact done this in Denver with the miners, and later used it to resist being closed down by Powell. Powell's organisational units depended on one another and therefore on the co-operation of a team of scientist–

[148] Malin, James C. *The Grassland of North America: Prolegomera to Its History with Addenda* (Lawrence, Kan.: James C. Malin, 1956), pp. 212–221.

administrators at the centre of the survey. Had Powell imposed this structure by abolishing other units, he would have met strong resistance from his staff, as he ultimately did from Emmons. Instead, he allowed the remnants of the other surveys to survive and to continue with little interference the tasks they had set for themselves. Indeed, he encouraged these units to separate themselves from developments in Washington—Hayden for example returned to Philadelphia to work. Powell moved, although very slowly, to dismantle the regional offices. But from the start he had reduced these offices and projects to a secondary position in relation to the central goals of the organisation. Powell could not have pursued this mode of reorganisation without increased appropriations, and in this he was conspicuously successful. Appropriations grew from $156,000 in 1881 to $489,000 in 1884–55 to $503,240 in 1885–86.[149] He was able to obtain these increases, and in 1884 to have the survey made into a permanent organisation within the government, by formulating a new objective which attracted broader support.

The reorganisation increased the participation of senior scientists in the administration of the survey, it made the continued influence of these scientists contingent on their willingness to sacrifice their scientific work to the demands of administration, and it demanded much personal loyalty. These new responsibilities were time-consuming and often were not in harmony with the individual intellectual interests or aspirations of the scientists themselves. Powell made his best man and close confidant, G. K. Gilbert, "geologist-in-charge" of the Appalachian division, and put him to work on the map programme, on editorial work and on other such tasks.[150] He sacrificed the best years of his scientific career to this effort, but he nevertheless accepted the necessity for it.

The organisational approach Powell employed in his relations with his senior scientist–administrators was not very far from the model of a field party, and the field-tested personal relations between Powell and his main subordinates were maintained by a continuation of the pattern of field camaraderie. Powell's chosen colleagues had a lunch group called "The Great Basin Mess" after the Great Basin survey of which several, including G. K. Gilbert, had been members. It began as an "indoor picnic"[151] with frugal meals, a service of "wooden plates, cheap cutlery, and paper napkins"[152] in one of the rooms of the survey. Later, "silverware supplanted tin, china displaced wood, a professional caterer took the place of the provider, and a special room across the street from the survey office was hired for the club".[153] One member recalled that "the formalities of election or rejection were brief and emphatic and effective",[154] and that disloyalty

[149] Stegner, W., *Beyond the 100th Meridian*, *op. cit.*, p. 273.
[150] Pyne, S. J., *Gilbert*, *op. cit.*, pp. 120–123.
[151] *Ibid.*, p. 162.
[152] Darrah, W. C., *Powell*, *op. cit.*, p. 323.
[153] *Ibid.*
[154] Quoted in *ibid.*

was one ground for exclusion.[155] With his subordinate, Dutton, he had created another such institution, the Cosmos Club, which was founded in 1878[156] and is important even today. Powell's extraordinary intellectual range and interests complemented his social leadership.

Powell grasped, by the time of the hearings in 1874, which centred on disputes over mapping, that despite the genuine interest in economic geology and the long and successful use by geologists of the promise of the discovery of mineral wealth, maps were very valuable apart from their geological and military uses. He discerned that the old idea of the completion of a national topographic map, a task which could, by including the work of the pre-consolidation surveyors and the Coast Survey, be said to have already begun, could be made politically irresistible. A national map, like an agricultural survey, benefited every congressional district. Those congressmen who had not had the benefits of a map would insist on their district getting its fair share; those whose maps needed revision or improvement would insist on such a survey. There were nevertheless major difficulties in turning the idea of a national topographic map into the great task for the survey . First was the problem of making the map "national". Second was the problem of convincing Congress that such an enormous expense was warranted. Third were issues which arose from the fact that the uses of topographic maps varied so much that the methods and standard of precision selected would either make the project impossibly costly or make its results too imprecise for important political purposes. These issues had appeared repeatedly in technical discussions before congressional committees in the past, and had not been overcome. Powell pushed ahead with the great scheme in spite of these obstacles. "The enormity of the task of preparing a complete topographical atlas of the United States was as usual underestimated—even by the Major,"[157] as one of Powell's workers later recalled. In fact, Powell overcame the second obstacle by promising far more than he could achieve. But the promises served his political purpose—they aroused support for a task which would assure the long-term existence of the survey. The step of authorising the national map was taken in 1882, when the survey was empowered "to continue the preparation of a map of the national domain".[158] Powell proceeded with his plans on the basis of this equivocal wording, and Congress acquiesced in his interpretation of the term "national domain".

The New Model Survey

The geologists inherited from King, who had stronger academic backgrounds than Powell's close associates, stood apart from the

[155] *Ibid.*, p. 324.
[156] Pyne, S. J., *Gilbert*, *op. cit.*, p. 162.
[157] Darrah, W. C., *Powell*, *op. cit.*, pp. 276–277.
[158] Manning, T. G., *Government in Science*, *op. cit.*, p. 72.

topographic efforts and administrative work. Powell permitted them to retain their old programmes and laboratories,[159] but they were alienated from the direction in which Powell had taken the survey, and did not conceal their dissatisfaction. Even many of those geologists who were personally close to Powell observed the organisational transformation with horror. By 1885, C. E. Dutton could see that "the 'organisation' is rapidly 'perfecting,' i.e., more clerks, more rules, more red tape, less freedom of movement, less discretion on the part of the geologists and less out-turn of scientific products".[160] For Powell, this was intentional; the new organisation was designed for the rapid generation of routine, technical, topographic work. The change corresponded with the new mandate for the survey. Powell could have pointed to the events of 1884 in support of the claim that the new task and the form of survey work it enabled him to carry out best served the advance of scientific knowledge. It assured a secure basis of political support, significant financial support, and allowed enough discretionary power to apply some of the funds to "pure" scientific investigations, enabling Powell to extend governmental science far beyond the limits he had envisaged in 1878. His best formulation of his design, and his broadened conception of the governmental role in the advancement of scientific knowledge, was presented in the course of his congressional testimony in 1884 in the context of renewed political controversy over governmental science.

Following a change of presidential administrations and in the face of serious charges of malfeasance in the Coast Survey, the whole question of governmental science had been reopened, and a commission, headed by Senator Allison, was created to look into the subject.[161] The charges against the Coast Survey were largely baseless, but the atmosphere was such that Powell's enemies were given an opportunity to damage him by directing similar charges at the Geological Survey. Charges of "incompetence, extravagance, patronage, favoritism, and political dealing",[162] were elaborately detailed in an anonymous 23,000-word report prepared by a scientist named Endlich, an associate of Cope. Alexander Agassiz joined the fray by criticising Powell's cartographic techniques, comparing them unfavourably with the work of the Coast Survey, with which Agassiz had some connections and which was jealous of the successes of Powell's survey within the government.[163] Agassiz also charged that Powell had squandered money on a useless project, a history of the discovery of the Comstock lode, and again expressed his general reservations about governmental science. Paleontology, he claimed, should be left to private persons, and economic

[159] Pyne, S. J., *Gilbert, op. cit.*, pp. 127–128.
[160] *Ibid.*, pp. 117–118.
[161] US Congress, Senate, Congressional Report 1285, *Joint Commission to Consider the Present Organizations of . . . [Certain Bureaus]*, 49th Congress, 1st Session, 1886.
[162] Darrah, W. C., *Powell, op. cit.*, p. 291.
[163] Stegner, W., *Beyond the 100th Meridian, op. cit.*, p. 287–288.

geology to the mining companies.[164] These arguments were welcomed by Senator Hilary Herbert, a devotee of states-rights who pursued Powell at length during the hearings over the question of the limits of federal authority in this area.

The National Academy of Sciences had immediately been questioned by the commission, and had responded with a proposal for a federal department of science, arguing that "in this day the pursuit of science itself is directly connected with the general welfare".[165] This proposal was not taken seriously by the politicians. Powell endorsed it, but in endorsing it he entered some qualifications that served to change its meaning. His version proposed that the various "informational" bureaux be assigned to the Smithsonian Institution;[166] this would have insulated the survey from Congress. He also stressed the desirability for the administrative and scientific autonomy of the bureaux engaged in research,[167] by which he meant the desirability of granting wide discretion to the scientist–administrators. Powell also spoke of the value of a closer connection between governmental science and the national interest; he grasped that scientists might fail to ensure in practice the connection with the general welfare they professed in the abstract, and he observed that the "method of utilizing the results of all scientific research" was a crucial issue for Congress to consider in any plan of reorganisation.[168]

Powell's own testimony began with a discussion of the national map and the progress which was being made towards its completion,[169] in part with the co-operation of the state governments of New Jersey and Massachusetts. He displayed some proof sheets and explained what features would appear on the maps.[170] The discussion focused on the problem of use of the national map and the unceasing problem of publication costs, which continued to dog the survey and was raised again in the hearings by the defenders of the Coast Survey. In the testimony of 1874, surveys of less precision than the Coast Survey's very expensive and detailed work had been denounced as "conjectural"[171] and this theme was taken up again in several novel forms in 1884 and 1885. Wheeler pointed out that uses varied, and the expenses, such as printing and degree of precision, varied accordingly, and noted that a national map "were the contours carried for instance to the greatest precision demanded by military engineers in the studies for construction of permanent fortifications, and made applicable to the entire area of any given country, might readily be made to cost more than the value of all the land

[164] *Ibid.*, pp. 290–292; Darrah, W. C., *Powell, op. cit.*, p. 293–294.
[165] Quoted in Darrah, W. C., *Powell, op. cit.*, p. 292.
[166] Stegner, W., *Beyond the 100th Meridian, op. cit.*, p. 287.
[167] Darrah, W. C., *Powell, op. cit.*, p. 293.
[168] Quoted in *ibid.*, p. 292.
[169] Powell, John W. *On the Organization of Scientific Work of the General Government* (Washington, DC: US Government Printing Office, 1885), pp. 4–5.
[170] *Ibid.*, pp. 6–7.
[171] House Report 612, 1874, *op. cit.*, p. 65.

and other wealth found therein".[172] Powell defended a specific, and questionable, response to their claims: that geological uses were or ought to be the controlling uses in topographic work. As earlier surveys, including the state surveys—and, up to 1873, his own—had used topography sparingly because of its immense cost, he was compelled to make the astonishing claim, in response to a query about the state surveys, that "Maine and Massachusetts properly never had a geologic survey". He went on to say that "Pennsylvania has, and Pennsylvania makes topographic maps. Maine has had an examination of certain rocks of the State for the purpose of discovering whether there were ores in her rocks",[173] and he reiterated his insistence that "a proper geologic map cannot be made without the basis of a topographic map".[174] Where states had begun to make topographical surveys, they had not always connected them with geological surveys, but they often had, and this helped Powell's case.

The fragile connection between topography and geology which Powell emphasised in the course of his testimony[175] was extended to integrate the whole of the work of the survey. His basic premise was that "the United States, like all other civilized nations, is engaged" in governmental operations which "involve in their nature original investigation. They are designed in large part to furnish needed information to the people, and they involve not only questions of applied science, but, that the purpose for which they are prosecuted may be properly accomplished, new facts and principles must be discovered".[176] Original investigations, he reasoned, "are in their nature interrelated and interdependent", so "the success of one is dependent, to a large extent, upon the success of the others".[177] In short, "furnishing information" sometimes entails original or pure investigation, and one kind of original investigation often entails other kinds. It was the specific claim of the integral role of paleontology, the most controversial of the surveys' activities, which both Powell and his congressional critics had in mind when these claims of interdependence were presented.[178] Powell used the same reasoning to support the claim that survey work required far-reaching administrative discretion:

> The operations of such institutions [as the survey] are exceedingly complex, and, from their very nature cannot be antecedently planned and executed according to such original plan. At every step of the work plans must necessarily be modified, as necessitated or suggested by discovered facts. It is therefore impossible by law to organize such operations; and more, it is impossible for the directors or

[172] Wheeler, G., *Facts Concerning the Origin, Organization, Administration, Functions, History, and Progress of the Principal Government Land and Marine Surveys of the World, Being Extracts from the Report on Third International Geographical Congress and Exhibition* (Washington, DC: US Government Printing Office, 1885), p. 81.
[173] Powell, J. W., *Scientific Work*, *op. cit.*, pp. 8–9.
[174] *Ibid.*, p. 9.
[175] *Ibid.*, pp. 168–172.
[176] *Ibid.*, p. 23.
[177] *Ibid.*, p. 24.
[178] Cf. Senate Report 1285, 1886, *op. cit.*, pp. 48, 80–81.

superintendents of such work to lay out plans of operations which shall be a full guide to their assistants. A clear conception of the object to be attained, and a comprehensive knowledge of the principles to be used in the guidance of research are necessary; and beyond that, from time to time, as facts are discovered and the avenues of investigation are opened, the work is directed in its details. It will thus be seen that it is impossible to directly restrict or control these scientific operations by law.[179]

Thus, while "the general purpose of the work may be formulated in the statutes, and the operations may be limited by the appropriations made therefor, . . . this is as far as the statute itself can properly go".[180]

The medium by which Congress could exercise control over institutions which must be "self-governed" and "to a great degree autonomous"[181] was through "control of the official personal organization," i.e., through the selection of the director, and through control over the accounting and disbursing practices he may adopt.[182] The director was also constrained by the intrinsic character of the work. He could not "lay out the work for his assistants in detail",[183] for "the plans of the work prosecuted by an organization for scientific research must originate with the experts and specialists who are themselves engaged in the investigation, and the most important function which the director of such an institution has tó perform lies in the selection of the proper men, the specialists who have a genius for research".[184]

Powell dealt with the issue of the relation between governmental science and the kinds of scientific work that would be done by professors and other private persons by arguing that the role of government was not to direct science, but to perform those investigations which were beyond private means. Such investigations, he claimed, arose from the voluntary and pluralistic[185] division of labour which scientists had developed in their own institutions, such as scientific congresses.[186] Not everyone accepted this reconciliation of the conflict between centralised governmental financing of research and free individual inquiry. Powell's regime was roundly attacked by Herbert as a "geological dictatorship", which threatened "to coerce and control the opinions of geologists";[187] this view was perhaps shared by some scientists. Powell responded to Herbert that "there is a solidarity and organization of the whole body of geological workers in the country, every man to whatever organization he may belong, or in whatever part of the work he may be engaged, is always sharply examining, criticising and

[179] Powell, J. W., *Scientific Work*, *op. cit.*, p. 24.
[180] *Ibid.*
[181] *Ibid.*, p. 25.
[182] *Ibid.*, p. 24.
[183] *Ibid.*, p. 25.
[184] *Ibid.*, pp. 25–26.
[185] *Ibid.*, p. 187.
[186] *Ibid.*, p. 178.
[187] Senate Report 1285, 1886, *op. cit.*, p. 124.

correcting the work of others".[188] To scientists, he gave a more subtle reply. In the *American Journal of Science* in 1885, he argued that:

> A scientific institution or bureau operating under government authority can be controlled by statute and by superior administrative authority but to a limited extent. These operations are practically carried on by specialists, and they can be controlled only in their financial operations and in the general purposes for which investigations are made. Their methods of investigation are their own, originate with themselves, and are carried out by themselves.[189]

He observed that, for a governmental scientific institution:

> there is an unofficial authority which, though not immediately felt, ultimately steps in to approve or condemn, viz: the body of scientific men of the country; and though their authority is not exercised antecedently and at every stage of the work, yet it is so potent that no national scientific institution can grow and prosper without their approval, but must sooner or later fall and perish unless sustained by their strong influence.[190]

Previous governmental scientists might have have taken care to protect themselves from criticism; but the explicit recognition that the intellectual legitimacy of government scientific agencies rests on the collective opinions of scientists was novel.

The results of the Allison hearings were generally favourable to Powell and the survey. The commission was not eager to be drawn into technical or scientific disputes, and it reduced the issue to the matter of business practices. It also largely ignored one of the issues that had been central to the older state surveys, namely the issue of the completion of projects, raised by a number of Powell's critics, who noted that almost nothing in the way of maps had yet appeared. The maps his staff had produced for the purpose of exhibiting them to congressmen, persons who of course had no means of judging their adequacy, were, in fact, premature.[191] The critics were also right on the larger issue, for only a small part of the total task was complete even 50 years later. Powell had pointed out in his defence that Congress had initiated changes that made completion impossible, and his reply was persuasive. When a searching audit was performed on his agency and on the other scientific agencies of the federal government, Powell was vindicated against his enemies. The system by which the geological "survey accounts were kept was publicly commended for its thoroughness and accuracy".[192] The audit of the Coast Survey, which included some of his detractors and their allies, was not so favourable; this survey was severely criticised and several of its chief officials were forced to resign.[193]

[188] *Ibid.*
[189] Powell, John W., "The Organization and Plan of the United States Geological Survey", *American Journal of Science*, XXIV (February 1885), p. 93.
[190] *Ibid.*
[191] Darrah, W. C., *Powell, op. cit*, p. 325.
[192] *Ibid.*, pp. 295–296.
[193] *Ibid.*, p. 296.

Powell's budget increased to $635,240 in 1888, and reached $879,240 in 1890. Of funds for 1890, $199,000 were allocated for topography, and $100,000 for geological surveys. Paleontology was given a separate allocation. Co-operative arrangements with states brought in additional funds for topographical and irrigation surveys. By 1909, these contributions reached $1,121,869 for topographic work, and an additional $217,754 for hydrographic work.[194] The survey succeeded politically in large part as a consequence of the wide public appeal of its topographic work, and in spite of the fact that it was often done quickly and poorly. The survey's annual reports of 1904, the year after Powell's death, observed that this cheap but fast topographic work established the value of topographic maps and their availability educated their users, whereas precise but slow work would not have been continued by Congress.[195]

The Dispute on Irrigation

Powell had been interested in aridity since 1874. His work on the arid lands had persuaded him that agriculture in the mode of the Old Northwest was impossible west of the 97th meridian. Yet many pioneers had been successful—and this meant that attempts to "close the frontier", which would have been politically suicidal in any case, would be very difficult to enact on the grounds that the land was too arid to support cultivation. Powell knew, from measurements of the level of the Great Salt Lake taken by G. K. Gilbert, that these successes were the temporary consequence of a long wet cycle, so he fought for schemes which would have preserved the possibility of pioneering agriculture. He had proposed, in his *Report on Lands of the Arid Region* in 1878, that land be allocated in such a way that sufficient water rights for irrigation be attached to each piece of farm property, an arrangement which would have required new forms of collective authority and marked a departure from the existing legal traditions governing real property. In the report on arid lands he had presented his policy ideas in the form of two model laws, one for irrigation districts, in which land units were limited to 80 acres, one for grazing districts, with limits of 2,560 acres.[196] By this time, water corporations were already beginning to exercise authority over water by purchasing water rights, to the detriment of farmers without water rights whose land was worthless without irrigation. Powell wanted to prevent this by giving practical control over water to democratically governed "irrigation districts" which were to be regulated by the commissioner of the Land Office.[197] When the drought predicted by Powell

[194] *The U.S. Geological Survey: Its History, Activities, and Organization*, service monographs of the United States Government, Institute for Government Research, Brookings Institution, Washington, DC (New York: D. Appleton, 1918), pp. 124–125.
[195] *Ibid.*, p. 32.
[196] Powell, J. W. *Arid Regions*, *op. cit.*, pp. 42–49.
[197] *Ibid.*, p. 42.

arrived, an irrigation bill was passed which was designed to limit settlement to irrigable land. Powell was given authority over classifying land, or so the Attorney-General held, and this gave Powell control over the whole of the process of settlement, for no land could be released for settlement which had not been classified. But this legal authority was negative. Powell could not insist that irrigation be given the legal structure he had originally advocated.

For Powell, to classify lands as irrigable without answering questions of the collective organisation of water rights made no sense because "irrigable" did not mean "settlable". Settlement demanded real water, and it was water, not land, that was in short supply, sufficient, he believed, to irrigate only a fraction of the land which was fit to be irrigated. Powell was thus placed in an impossible dilemma, for he believed "it would be almost a criminal act to go on . . . and allow thousands and hundreds of thousands of people to establish homes where they cannot maintain themselves",[198] as the law directed him to. Had he wished to placate those with financial interests in western development, or the settlers interested in irrigation, he might have made quick surveys which certified particular areas as irrigable and opened them to settlement—indeed, this was what some western politicians expected him to do. This was precisely what he thought was poor policy.

Powell believed, correctly, that the problem was political, and a movement in Congress did lead to a change in the law, although its aim was to hasten, rather than stop, the process of settlement. This effort produced more criticism of Powell, including insistent questioning of the legality of his use of the bulk of the funds for irrigation for topography rather than for reconnaissance of sites—an administrative decision to which even his own staff had objected. No one rescued Powell from the predicament in which he found himself. Without the legal machinery to achieve the aims of what he considered a rational land policy, faced with expectations of speeding settlement, and having only means which he considerd irresponsible, premature and dangerous, he chose to act in terms of the narrowest possible construction of the law, interpreting it "not as authorizing construction of irrigation works but only as directing a comprehensive investigation of prevailing conditions"[199] relating to possible irrigation. This tactic served reasonably well, but it only bought time. The president, who had the ultimate power to release land, did not override Powell, and did not resolve the problems of policy. Powell was left as the only immediate target against which Congress could act.

The initial political cost of Powell's stand was a small and acceptable decrease in appropriations. Powell's old antagonist from Alabama, Senator Herbert, then broadened the controversy over irrigation by raising again the

[198] Quoted in Stegner, W., *Beyond the 100th Meridian*, *op. cit.*, p. 333.
[199] Quoted in Darrah, W. C., *Powell*, *op. cit.*, p. 306.

scientific criticisms made in the earlier dispute and by striking at the heart of Powell's discretionary power, his control over his own budget. Part of the issue was the proper scope of the survey. Powell again defended an extremely broad conception of its aims; the senator accused him, not entirely inaccurately, of "pursuing the most ambitious scheme of geology ever conceived by the human mind".[200] The issue of Powell's "buying off" scientists by the provsion of opportunities for part-time employment during the summer vacation from teaching, a method which had earned the survey the good will of many geologists, was also raised.[201] The senator ridiculed paleontological studies[202] and used the issue to attempt to prohibit expenditures for such studies by the survey and to decrease drastically its budget and to control its expenditures line by line. This had the effect of eliminating the discretion that Powell had used on behalf of "pure" scientific concerns.[203] In 1893 there was a larger decrease in appropriations, and other scientific activities of the government also received reduced appropriations. Although the next year saw a slight increase for the survey, Powell resigned. He continued as director of the Bureau of Ethnology, a post he held until his death. It is sometimes claimed that the survey method itself had nearly exhausted its scientific possibilities by the end of the nineteenth century,[204] but Powell's broad conception of survey work, matched with the degree of discretion in the use of the funds allocated to him that he enjoyed for a dozen years, was certainly not near exhaustion. The foundations he laid guided the survey for many years. His successor, Walcott, continued the successful emphasis on topographic mapping, but the broad scope of Powell's survey was lost.

Powell himself remained a powerful figure. The Bureau of American Ethnology, as it was called after 1897, produced work of enormous and enduring significance, and employed some of the most extraordinary talents of the day, including Franz Boas and Frank Hamilton Cushing, through whom the bureau became entangled in a bizarre scandal concerning a doctored Florida Indian artifact. When Powell died in 1902, various dissatisfactions with the bureau in Congress, and within the Smithsonian Institution, in which it was administratively housed, led to an investigation, and then to tighter control by the Smithsonian Institution. Powell's prestige had forestalled this. However, the main lines of approach Powell laid down continued to be followed, as with the geological survey.

[200] Quoted in *ibid.*, p. 344.
[201] *Ibid.*, p. 344.
[202] *Ibid.*, pp. 344–347.
[203] *Ibid.*, p. 343.
[204] Daniels, G. H., "The Pure-Science Ideal and Democratic Culture", *Science*, CLVI (June 1967), p. 1704.

The Legacy of the Surveys

Forms of patronage are exchanges of services and rewards and are constituted by the promises, understandings and expectations associated with those exchanges of services and rewards, such as the formal promises contained in contracts and legislative acts. The patronage of scientific research requires informal and tacit promises, between politicians and other providers of the wherewithal which permits research to be done and the individual scientists who are the beneficiaries of the patronage, and also with the larger community of scientific men. The ideals, interests and desires to which the state geologists had appealed varied enormously. These included state pride, the simple desire of citizens of each county that their region be publicly noticed and described, and the economic needs for minerals. These needs changed from salt to coal and iron, precious metals, and, by the end of Powell's tenure, to petroleum, at first a puzzling resource without a clearly established use. It may also be observed that the ideals and interests to which the geologists appealed were often interests which had not been previously articulated, or had not been previously understood to justify governmental provision for science. The idea that a great state must have a great survey was articulated by van Rensselaer and Jackson, among others, as the ideal of a more stable mining industry was articulated by King.

For the most part, the geologists who were supported by governmental bodies and their various allies either relied on political and institutional patterns, which is to say expectations, established by others, or adapted these patterns to the special circumstances of new states or new patrons. Only a few created new forms of patronage and new patterns of alliance between geological science and its audience of users and supporters. These innovations were sometimes genuinely creative political acts, for the range of possibilities was wide: the changed role of mapping, and Powell's successful formulation of a politically viable conception of a national topographical map is an example of this. The assignment which Powell obtained proved to be politically stable, sustained by the wide range of uses to which the maps could be put, including purposes which were never envisaged by the geologists who had promoted the idea of a geological map in the early part of the century. When a bill to complete the topographical survey was introduced in the House of Representatives by H. W. Temple in the 1920s, it was endorsed as a national necessity by miners, civil engineers, conservationists, western governors interested in irrigation, foresters and users of water-power.[205] One of the greatest sources of demand for the topographical map was in highway construction, which was spurred by the automobile and tourism,[206] which Powell could not have anticipated.

[205] *Hearings before the Committee on Interstate and Foreign Commerce*, House of Representatives, 68th Congress, 1st session on H.R. 4522 (Washington, DC: US Government Printing Office, 1924), pp. 2–57.

[206] *Ibid.*, pp. 11–12.

Powell's ideas were responses to circumstances, but they were not wholly determined by them. He was, indeed, as much "a politician with an idea" as Bismarck.

One major interest which impelled the early state surveys, and continued to be politically relevant for the federal surveys, was the desire of men with scientific interests to make careers for themselves. Like other young men of the era, they pursued this by appealing to older men with political connections who might help them to find the places they sought. American political patronage, or the spoils system, operated in this way. It was taken as given that any remunerative posts ordinarily had many feasible candidates—and that among the applicants for a post who were qualified by ability and character, political considerations be decisive. When Gilbert sought the position of director of the second Ohio survey, he was told that an Ohioan would have to direct the survey; but the director in this case was J. S. Newberry, himself highly qualified, and Gilbert was given a place, although only as an assistant. When the states or the federal government could not find qualified persons from among their own citizens or clients, they generally did not hesitate to select others—Featherstonaugh was a British subject; Owen, H. D. Rogers, Jackson, and Hall, among many others, found appointments as state geologists in states in which they were not native or even resident. This happened only once surveys had established their desirability, and state politicians or enlightened citizens sought them as means to such ends as the honour of the state and the development of its resources.

The laws establishing the early state surveys usually called for competent and trustworthy persons, a formula which gave the spoilsmen room to choose among "scientific men". The increase in the competition for appointments which followed the first set of state surveys, and which produced a corps of experienced assistant field geologists eager to move up to the headship of a survey or simply to continue a scientific career, established a balance among candidates or aspirants on which the weight of endorsements by scientists could be felt. The informal but nevertheless usually quite genuine standards of minimum competence which had prevailed were thus replaced by the competitive practice of appealing for assessments from the leading geologists of the country. All the great figures of the day, Hayden, Newberry, Hall and Agassiz, had reputations as scientists which were recognised by those who appointed scientists and, indeed, by the 1870s, letters of recommendation were a large part of their correspondence. These letters were a tangible affirmation of the common standards of the scientific community. A single letter from a mentor was usually not enough for a candidate; several letters, from different authorities, counted more, and young scientists were compelled to widen their circles of personal connections within the scientific community to succeed. Hayden's defeat by King showed the decisive political superiority of organised expressions of scientific opinion over the testimony of a few

individuals. When Powell recognised that the "unofficial authority" of scientific opinion was "potent" and decisive for the survival of any national scientific institution,[207] his statement itself was evidence of the morale of the scientific community.

Another obligation, which was strongly felt, was to educate the electorate in science, not simply out of the self-interest of the geologists, but because they saw that a scientifically educated citizenry was essential to a good society. They thought the scientist in a democracy had a responsibility to educate, and, more generally, to act in the best interests of the whole society, whose taxes paid for science. Hayden's survey was the last attempt to organise survey work around the primary task of producing works which were "popular and scientific at once". Although Powell's directorate abandoned this programme, he did not abandon the task of communicating science to the general public. Some of the tensions between this task and other aims could be resolved by new divisions of labour and new institutions—the work of applied science, and of popular science, could be assigned to separate institutions, which could develop their own relationships with one another. In the state agricultural institutions, this process of differentiation began with professors trying to establish schools with experiment stations, and also travelling around the state giving advice, and ended with agricultural colleges, agricultural experiment stations, and extension workers organisationally and often physically separated but linked in numerous ways. In geology, something similar occurred. Powell's new division of labour relieved many of his subordinates from the old obligation to communicate directly with a larger public. Although the publications of the survey were edited by Gilbert to make them readable, the mathematical geophysics of George Becker, for example, was supported as part of the work of a division for which the task of public enlightenment was only incidental.

The main business of the survey was redefined by Powell as topographic mapping, which led to a widely appreciated product. The relation between mapping and the development of geological thinking is not simple. The idea of a national geological map was an old dream. Powell adapted it to a larger set of purposes by stressing topography, and he was led to acquire a command of topographic matters and to a belief in the importance of topographic work by his geological preoccupations. Without this belief, he would not have come to his ideal of a national programme for a great topographic map, nor would he have been able to convey the idea personally to congressmen. Although Powell's geological ideas about erosion were made more prominent by the work of the new, topography oriented survey, this was not the main scientific result of the survey under his directorate. It was the work of the more mathematically and geophysically oriented Becker and Gilbert—marginal to the main tasks of the survey—but which not have

[207] Powell, J. W., "Plan of the Survey", *op. cit.*, p. 93.

been supported at all without it, which was perhaps the greatest scientific product of the survey.

Topography was technically distinct from geology, and during Powell's era as director and later, it was organised into a separate division, the work of which was co-ordinated with the work of other divisions. Powell's unified vision, which was not shared by some of the members of the staff of the survey, and not understood by others, was essential to the politics of support for the survey in Congress. Powell had to explain his new conception of the survey repeatedly and persuade his supporters that the charge he sought from them was a desirable one for them to support. The national mapping was a task which demanded a high degree of co-ordination, agreement on procedures, and, in the East, of political dealing with state governments. The states ultimately provided much of the financial support for the survey, and this support helped the survey to ride out the politically motivated curtailment of financial aid in the 1890s. The political tasks were removed from the desks of the working scientists, who were thereby freed to work on scientific and technical matters and to be assessed on that basis alone. Powell took upon himself the political and administrative responsibility for the fulfilment of the charge which he had persuaded the politicians to entrust to him. The various responsibilities of the directorship of the survey were understood by him to correspond to one particular fact of administrative authority, for which he considered himself above all accountable, namely, the authority to select his staff.

Powell became director before he received the charge. When he resigned, the charge remained. What he left was a "mission agency". This was an appropriate vehicle for Powell personally, for it was a mission that both imposed on him the obligation to speak out, when asked, on policy, and to gather the relevant scientific information for major practical issues. It gave him the opportunity, and imposed on him the responsibility, to support a wide range of "pure" scientific research which was integral to the larger tasks of the survey. Powell's conception of the survey as an integrated body of work made the whole, rather than its elements, the substance of the task assigned to him by Congress. This had the effect of undermining the distinction between practical science and impractical, pure, science in a way that made "all science valuable", as Powell's nemesis from Alabama complained.[208] The combination served pure science well while it lasted. The administrative discretion that Powell acquired enabled the performance of scientific work free from congressional intrusion, motivated by scientific curiosity and supervised by scientists. He was free to support physical geology and paleontology, to give time to Lester Ward for his sociological studies, and to lend support to his administratively separate Bureau of Ethnology, only because he was pursuing his larger task and producing enough to satisfy Congress. To be sure, the autonomy was to a

[208] Darrah, W. C., *Powell, op. cit.*, p. 344.

large extent the autonomy of the director—but it was real, and Powell used it to support work which he and his confidants considered valuable. Scientists might have chafed under their dependence on scientist–administrators that this type of organisational arrangement entailed and in one sense, as Hayden saw, the concentration of this power in a single director constituted a loss of scope for "initiative", in that geologists could no longer go to Congress with schemes of their own devising. Nevertheless it did embody the main political goal of many scientists in the 1880s, the independent administration of science by scientific men.

Powell's intellectual ascendency, his ability to sustain the loyalty of highly competent scientists, and his bearing, which enabled him to withstand the scrutiny of congressmen, could not be reduced to a routine. Later schemes of governmental support of science have found procedural substitutes for Powell's appeal to the collective judgement of science; the discretion to appoint particular scientists that Powell regarded as the essence of autonomy has long since been replaced by bureaucratic procedures that serve to disperse discretion by distributing it to lower levels of government organisations devoted to patronising science, and often by giving the judgements of scientific "peers" a large formal role in patronage. Powell's contribution to this development was to maintain to as great a degree as possible the autonomy of scientific activity from the control of statute and "superior administrative authority", by persuading the latter of the ultimate dependence of the intellectual legitimacy of governmental science on the approval of "the body of scientific men of the country".[209] It was Powell's achievement to have gained from his governmental patrons who had no tradition of dealing with science an understanding that the scientists who benefited from their patronage would be judged more effectively by this "body" than through the personal or political judgements which the patrons themselves would make. This was a remarkable accomplishment in a country with a scientific community which was rather small and loosely integrated, and provided a precedent on which later forms of federal patronage were able to rely.

[209] Powell, J. W., "Plan of the Survey", *op. cit.*, p. 93.