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JAMES HALL JR.
1811–1898

A Biographical Memoir by

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James Hall

Courtesy of the New York State Museum

JAMES HALL JR.

September 12, 1811–August 7, 1898

BY ROBERT H. DOTT JR.

JAMES HALL OF NEW YORK was North America's preeminent paleontologist and geologist of the nineteenth century. That he was a giant among early American scientists is evidenced by the facts that he was a founder of and served as president of the American Association for the Advancement of Science (1856), was a charter member of the National Academy of Sciences (1863), and was chosen to be the first president of the Geological Society of America (1889). Hall was also the best-known American geologist on the international scene in his time. As early as 1837 he was elected to membership in the Imperial Mineralogical Society of St. Petersburg. Later he was the organizing president of the International Geological Congress meetings at Buffalo, New York (1876) and at Paris (1878); he was a vice-president of the congresses at Bologna (1881) and Berlin (1885) and was honorary president of the congress at St. Petersburg (1897). Hall was elected a foreign correspondent to the Academy of Sciences of France in 1884, being its first English-speaking member. It was primarily the 13-volume *Natural*

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History of New York: Palaeontology, published between 1847 and 1894, that initially brought Hall his fame; however, the broader community of geologists now remembers him more for the curious theory of mountains presented in his presidential address to the American Association for the Advancement of Science in 1857.

EARLY LIFE AND EDUCATION

Hall was born near Boston in Hingham, Massachusetts, on September 12, 1811. His parents, James Hall (Sr.) and Sousanna Dourdain Hall, had emigrated from England two years earlier, and James was their first of four children. The father became superintendent of a woolen mill at Hingham. The family was of modest means, but the young Hall was fortunate to have a gifted teacher in his public school who stimulated an interest in nature. Through his teacher, James encountered several leading members of the Boston Society of Natural History. Having developed a strong interest in science, Hall was attracted to a new college in Troy, New York, that emphasized science and employed revolutionary new approaches to learning with an active role for the student coupled with hands-on laboratory and field trip instruction. This Rensselaer Plan was developed by Amos Eaton with financial backing from his patron, Stephen van Rensselaer. Unable to afford commercial transportation, Hall walked the 200 miles to Troy. At Rensselaer he was instructed by Eaton and Ebenezer Emmons and had for classmates such geologists-to-be as Douglas Houghton, Abram Sager, Eben Horsford, and Ezra Carr. Hall graduated with honors in 1832 and undertook a tour on foot to the Helderberg Mountains in southeastern New York to collect Silurian and Devonian fossils. A job as librarian allowed him to continue at Rensselaer for another year and to earn the master of arts degree with honors (1833). He then held an assistant-

ship in chemistry for several more years. In 1838 he married Sarah Aikin, the daughter of a Troy lawyer; they had two daughters and two sons. Sarah died in 1895.

THE NEW YORK SURVEY

In 1836 the New York legislature authorized a four-year geological and natural history survey; an extension of two years was later authorized. Four men—William W. Mather, Ebenezor Emmons, Timothy A. Conrad, and Lardner Vanuxem—were in charge of four respective districts, and Lewis C. Beck was mineralogist for the geological survey. Botanist John Torrey and zoologist James DeKay conducted the biological survey. James Hall was engaged to assist his former teacher, Emmons, in the Second District in northeastern New York, where Hall's first assignment was to study iron deposits in the Adirondack Mountains. A year later the districts were revised; Conrad was appointed state paleontologist, and young Hall had demonstrated such competence as to be put in charge of a new Fourth District in western New York with assistants Horsford, Carr, and George W. Boyd, all Rensselaer products. When the survey terminated in 1841, only Hall and Emmons remained in New York. Hall became state paleontologist and Emmons State agriculturalist.

Lardner Vanuxem, who had studied in France, had been instrumental in introducing to America the value of fossils for subdividing strata and correlating from place to place those of similar age based upon similar fossils. Meanwhile, Timothy Conrad had gained a reputation for studies of Cenozoic fossils of the coastal plain. Thus the survey had strength in paleontology from the start, and its staff soon developed a New York stratigraphy, the formal subdivision of successive strata, which set a precedent of naming stratigraphic divisions for geographic localities that is standard today.

Young Hall's career blossomed quickly after a monograph on the fossils and stratigraphy of the Fourth District was published in 1843. This and the other survey reports soon aroused much interest in Europe, for Paleozoic fossils and stratigraphic subdivisions were being defined there in mid-century. The name "Paleozoic Era," coined in 1838, means "ancient life" and is now known to span from approximately 540 million to 250 million years; it is subdivided into several systems, such as Cambrian and Silurian. Roderick Murchison's *Silurian System* appeared in 1839, John Phillips's *Paleozoic Series* appeared in 1840, and Joachim Barrande's monographs on lower Paleozoic fossils in Bohemia would begin appearing in 1852. The authors of these great treatises and other foreign authors began corresponding with Hall, and soon European geologists began beating a path to Albany, most notably the famous British geologist Charles Lyell during his several American visits in the 1840s. During a visit in 1846, Eduard de Verneuil, a close associate of Murchison, tried to convince Hall not to introduce the name Cambrian to the New World, rather to use only Silurian for the lowest Paleozoic strata, a reflection of a famous Murchison-Sedgwick feud then raging in Britain about which name should prevail for the oldest Paleozoic subdivision. Hall, however, was not swayed, for he was a leading exponent of the widely held nationalistic view that an American stratigraphic classification was best for America.

As geological investigations in America began to mature, stratigraphic nomenclature was becoming important, especially for comparisons among the different states. Hall and others proposed an organization to deal with such nomenclature and other mutual problems, so in 1838 in Albany the American Association of Geologists was created; the first formal meeting was held in Philadelphia in 1840. From this organization evolved in 1857 the American Association for

the Advancement of Science, modeled after the British Association. Still later the Geological Society of America was spawned in 1888 from a division of the AAAS. Hall was promptly elected president.

THE ALBANY TRAINING GROUND

In 1857 Hall constructed a substantial brick laboratory building where he worked for the rest of his life. This Albany laboratory became a veritable training school for a host of young, budding geologists who would distinguish themselves in the history of American science. Although universities were beginning to offer formal instruction in geology during the mid-nineteenth century, there was practically no instruction in paleontology. So apprenticeship had to be the principal entrée into that field, and James Hall's laboratory was the place to apprentice. Among the many who profited from some association with Hall were the following:

Charles E. Beecher
Ezra S. Carr
John M. Clarke
Nelson H. Darton
Grove K. Gilbert
Ferdinand V. Hayden
Eban N. Horsford
Joseph Leidy
W. J. McGee
Fielding B. Meek
Charles S. Prosser
Carl Rominger
Charles Schuchert
Charles D. Walcott
Charles A. White
Robert P. Whitfield
Josiah D. Whitney
Charles Whittlesey
Amos H. Worthen

Hall's assistants learned more from him than just paleontology, however, for they also experienced a strong, egotistical, and irascible personality. Although his sharpest attacks were reserved for his enemies in the New York legislature, most assistants were also treated to his infamous outbursts. Besides

throwing vituperative verbal daggers, he sometimes brandished menacingly either a stout cane or even a shotgun kept at the ready near his desk. Perhaps the most extreme self-righteous attack was upon James T. Foster, a school teacher in Greenbush, New York. Foster had the audacity to publish a popularized geological chart in 1849, which outraged Hall. He was so distressed that he stole aboard a New York City-bound boat and threw the entire printing of the offensive chart into the Hudson River. He had quite a time fighting the subsequent libel suit, which entangled him for several years as well as Louis Agassiz, James D. Dana, and several other notables from whom Hall solicited help in his cause.

Another celebrated example of Hall's erratic temper involved none other than British geologist Charles Lyell during his first visit to America in 1841-1842. At first, Hall and others were greatly flattered by the attentions of their famous visitor, but Lyell's insatiable grilling, which had earned him the nickname "Pump," and his copying of their geologic maps gradually provoked a reaction of resentment and fear of being preempted. In March 1842 an anonymous letter signed "Hamlet" appeared in a Boston newspaper, which charged Lyell with geological piracy. It was written by Hall after some of his compatriots criticized him for being too generous in sharing information with Lyell, especially by giving him a copy of his *Geologic Map of the Western and Middle United States,* which had not yet been published. Needless to say, this letter cast a chill upon the Association of American Geologists' meeting a month later, but the English gentleman participated as if nothing had happened. Although the charge was largely true, Hall was afterward mortified by his rash act. For once, however, he managed to mend the damage done by his intemperate action and to remain henceforth on good terms with Lyell.

Almost as legendary as his paranoiac outbursts was Hall's

acquisitiveness for fossils. He stooped to every conceivable means to acquire outstanding collections. An effective technique was to flatter and invite collectors to work with him in Albany and to bring their collections. Commonly, when the apprentice moved on, however, his collection did not. Hall was a workaholic who drove himself as mercilessly as he did his assistants. He could rarely say "no" to even the most ridiculous schemes, and he ignored the entreaties of close friends—such as Joseph Henry, physicist and first secretary of the Smithsonian Institution—that he should ease his pace for the sake of his own health.

BEYOND NEW YORK

As he completed his Fourth District studies, Hall decided to see how far the New York stratigraphic classification might apply beyond his state. In 1841 he made the first of several odysseys west. With geologist David Dale Owen he made a boat trip down the Ohio River to Owen's base at New Harmony, Indiana, and from there, he proceeded across Illinois to Missouri, Iowa, and Wisconsin. Hall was amply rewarded with evidence for extending the New York stratigraphy in a broad way across that entire region. There were some significant differences, however, which he, and perhaps only he, could recognize. For example, he found that the Paleozoic strata were much thinner to the west of New York and Pennsylvania and that there were important contrasts of the types of sedimentary rocks with more clastic, or fragmental, sediments, such as sandstones and shales, in the east and more carbonate strata (limestones and dolomites) to the west. In effect Hall had discovered the contrast between what would much later be termed the stable craton and the Appalachian orogenic or mountain belt. This trip also provided information to allow him to complete the *Geologic Map of the Middle and Western States*, which was incorpo-

rated in Hall's Fourth District report of 1843. (This was the map that Lyell had used to help prepare his own geologic map of the then United States, which was published in 1845 in *Travels in North America.*)

Hall's finances were always tenuous. He was remarkably gullible for risky ventures, and he also had his salary cut or even suspended by a frequently hostile state legislature. At least once he had to sell some of his fossil collections in order to raise money. As his reputation grew, however, opportunities for temporary outside employment helped to tide him over his New York financial droughts. These ventures also allowed him to expand his knowledge widely. One of the first such ventures took him to the Lake Superior region in 1845 to examine copper deposits for a private company. In 1847 the federal government authorized a geological survey by John W. Foster and Josiah D. Whitney to evaluate the mineral resources of northern Michigan and Wisconsin. The results were published in 1851. In 1850 Hall was engaged to provide his expertise on Paleozoic stratigraphy and paleontology for that survey. He made two brief trips to the region (1850 and 1851) from which he gained further insights into the stratigraphy of the Great Lakes region and added to his ever-growing fossil collections. Perhaps the most important result of his work for this survey, however, was the recognition of fossil reefs in the Silurian strata of southeastern Wisconsin. This was the first recognition of ancient reefs in North America, and perhaps in the world.

When asked to study fossils from western regions, which others had collected during various expeditions, he willingly obliged. He recognized the first known Mesozoic fossils collected by John C. Fremont in the 1840s. In 1853 he agreed to let his assistants Fielding B. Meek and Ferdinand V. Hayden go to the White River badlands of Nebraska Territory (now in South Dakota) to collect newly discov-

ered Cenozoic nonmarine invertebrate and mammalian fossils. Meek, whose artistic as well as collecting skills were vital to Hall's enterprise, was glad to escape from his mentor for a few months. Eventually he extricated himself from Hall's empire by joining the new United States Geological Survey. Meek never forgave his perceived exploitation by Hall.

When Iowa decided to have a geological survey in 1855 and needed a director, the governor looked to New York, which had eclipsed all other states as well as the federal government in the caliber of its geological survey. Hall accepted the position with alacrity because his New York salary had been suspended in 1850 by an exceptionally hostile legislature. Moreover, he welcomed the opportunity to obtain and study fossils from the new state. He soon suggested Amos Dean of Albany to be the first chancellor of the University of Iowa, and he himself was identified as the first professor of geology, but apparently he never lectured there. In fact, Hall mostly directed the survey from Albany and spent little time in Iowa. Four assistants did most of the actual work. Josiah D. Whitney concentrated upon mineral resources, while Amos H. Worthen of Illinois dealt with paleontology assisted also by F. B. Meek and R. P. Whitfield. Hall knew that Worthen had the finest collection in the country of fossil crinoids (a class of echinoderms, most of which are extinct), so a condition of employment was that Hall be allowed to describe them, which he did in the Iowa survey report. Hall came to Iowa for the winter meetings of the legislature to lobby on behalf of the survey, but payment of salaries was so erratic that he had to borrow money in Albany to keep the effort going. Finally in 1859 the survey was suspended, but two volumes had appeared in 1858.

In 1857 Illinois undertook a geological survey, and Worthen was one of three applicants to direct it. Hall wrote

a glowing endorsement of him, but he also supported the other two applicants. This lapse of judgment earned the hatred of all three applicants, and in the end he was denied access to the fossils collected by the survey, which was a great disappointment.

In 1856, while still engaged in work in New York, Iowa, and also paleontological consulting for the Canadian Geological Survey, Hall accepted an affiliation with Wisconsin. He joined a former Rensselaer colleague, Ezra Carr, then a chemistry professor at the University of Wisconsin, and Edward Daniels for this new effort. Hall devoted little time to the Wisconsin initiative, so Carr and Daniels were really in charge. Whitney was engaged to study the lead deposits of southwestern Wisconsin and Charles Whittlesey to study the mineral deposits of northern Wisconsin. A large volume was published in 1862, but a hostile Wisconsin legislature abruptly terminated the endeavor, because it judged the results to be insufficient. It cared only about potentially economic results, so a frustrated Hall and his assistant, Robert P. Whitfield, published Wisconsin's paleontology within a New York report in 1867 and again separately in 1871. This ingenious solution to a publication problem was typical of Hall. Much earlier he devised a scheme to circumvent a New York legislative edict to limit the number of expensive paleontological monographs simply by issuing several volumes as subdivisions of a single part of the series, resulting ultimately in 13 separate monographs—at least twice the intended limit—but numbered as only eight parts of the *Paleontology of New York.*

Hall became involved in several other state surveys to varying degrees, ranging from advising about personnel to being a consultant for paleontology or the titular head of a survey. Included were surveys of Missouri (1853 and 1871), California (1853-1856), the transcontinental railroad survey

(1853-1857), New Jersey (1854-1857), Ohio (1854-1857), Texas (1858), Mississippi (1858), Michigan (1869-1870), and Pennsylvania (1870-1875). While this list is a testimony of his prominence, Hall's contributions to these many surveys were minor except for the identification of fossils.

In 1889, at the age of 77 and while the first president of the new Geological Society of America, Hall made his last trip to the Midwest. His purpose was to obtain brachiopods by any and all means necessary for his latest project, namely, to revise the description and classification of that great group of Paleozoic fossils. Besides success in obtaining many specimens, he also met and lured to Albany a young Charles Schuchert of Cincinnati, who was destined to become his most famous protégé and ultimately a professor at Yale. The ambitious brachiopod study culminated in the last volume, Part 8, of the *Paleontology of New York*, which appeared in 1894.

During the completion of his final large paleontological monograph, Hall had his last and sweetest wrangle with New York bureaucracy. The executive secretary of the regents, which oversaw his program, had become overly zealous in trying to impose strict accounting and efficiency procedures. Such a fuss developed that the legislature had to intervene. To resolve the fracas it appointed crotchety old Hall as state paleontologist and state geologist for life with complete managerial freedom. Doubtless the legislators realized that Hall's days were numbered, and in fact he died three years later. Hall must have recalled with great satisfaction an earlier observation when a particularly vicious political enemy died suddenly that "Providence was usually on my side."

THE ORIGIN OF MOUNTAINS

Hall is most widely known for his theory of mountains, which embodied the concept of the geosyncline, a term

coined not by Hall but by James D. Dana of Yale in 1873. In his 1857 presidential address to the American Association for the Advancement of Science, Hall startled his audience with a discourse on the origin of mountains rather than speaking about paleontology and stratigraphy. In stating that "the greater the accumulation, the higher will be the mountain range," he pronounced that a great thickness of strata was a prerequisite to mountain ranges composed of folded strata. Hall rejected the then-popular theories of mountains of Frenchman Elie de Beaumont and the American brothers William B. and Henry D. Rogers, who postulated catastrophic wrinkling of the crust by wavelike movements in a fluid subcrustal zone. Instead, Hall was influenced by a suggestion by J. F. W. Herschel in 1836, which anticipated the modern theory of isostasy. Herschel argued that vertical movements of the crust are caused by changes of pressure and heat at depth, which in turn respond to erosion and deposition at the Earth's surface. The vertical adjustments of gravitational equilibrium were supposed to be accommodated by a pliable subcrust. The key element for Hall was the accumulation of thick sedimentary layers, which he imagined must depress the crust and in the process become wrinkled to form the structures seen in mountain ranges, such as the familiar Appalachians. He envisioned compression of the upper layers and tension of the lower ones as subsidence occurred much as one can imagine by bending a ream of paper.

In 1859 Hall published the following in the most commonly quoted source for his theory, Part 6 of the *Paleontology of New York*: "The line of greatest depression would be along the line of greatest accumulation [that is] the course of the original transporting current. By this process of subsidence . . . the diminished width of surface above caused by this curving below, will produce wrinkles and folding of

the [upper] strata. That there may be rents or fractures of the strata beneath is very probable, and into these may rush the fluid or semi-fluid matter from below, producing trapdykes, but the folding of strata seems to be a very natural and inevitable consequence of the process of subsidence" (vol. 3, pp. 70, 73).

A year earlier in the report of the Iowa Survey (1858), Hall had also emphasized the contrasts of thickness between the Appalachian region and the Midwest with detailed remarks about contrasting sedimentary rock types as well as thicknesses in various portions of the Paleozoic succession of the two regions. Here, too, he included a brief summary of his theory of mountains by stating that "the thickness of the entire series of sedimentary rocks, no matter how much disturbed or denuded, is not here great enough to produce mountain features" (vol. 1, p. 42). Clearly, he saw the excessive thickness of strata as a prerequisite for mountains.

Hall's theory attempted to explain the crumpling of strata so characteristic of mountain ranges, but it was very vague about the cause of the uplift of mountains. He simply ascribed this to continental-scale elevation of indeterminate cause, which he thought had no direct relation to the folding of strata within the mountains. Contemporaries were quick to challenge him on this point, with Dana noting that Hall had presented a nice theory of mountains with the mountains left out. Hall lamely denied that he ever intended to offer a complete theory of mountain building. His failure to publish the presidential address until 1883 may have been because of such criticisms, but, on the other hand, his first priority was always paleontology, and he knew that the essence of his theory was to appear in both the Iowa and the New York reports (as well as in an abstract in Canada) soon after his oral address.

James Hall's contribution to mountain building theory

was marginal at best and was soon eclipsed by the more profound and comprehensive contraction theory of James D. Dana, which relegated thick strata to a result of mountain building processes rather than the cause. Nonetheless, Hall's emphasis upon some sort of cause-and-effect relationship between orogenic or mountain belts and very thick strata had a significant influence upon three generations of geologists, especially but not only in America. By coining the term "geosynclinal," which was later converted to the noun "geosyncline," Dana formalized Hall's demonstration that Paleozoic strata are 10 times thicker in the Appalachian mountains than in the more stable lowlands to the west (the craton).

CONCLUSIONS

Even though Hall was wrong about the cause of mountain building, he nevertheless was the first person to underscore clearly the profound stratigraphic contrasts between orogenic belts and what are now termed stable cratons. He drew attention at an early stage to large-scale stratigraphic patterns among some of the larger tectonic elements of the Earth's crust and revealed other shrewd stratigraphic insights, which were ahead of the times. By virtue of his breadth of experience in both the cratonic and orogenic regions of eastern North America, he was uniquely equipped to see such fundamental distinctions. He also made important pioneering observations about several physical sedimentary structures such as ripple marks and suggested their value for interpreting ancient sedimentary environments.

Hall was extremely productive, having some 42 books and nearly 200 articles to his name. His major monographic paleontological syntheses appeared in the 13 volumes of the *Paleontology of New York*, but he also published many shorter papers describing a single genus or group of fossils.

In addition, he contributed paleontological sections to several federal and state publications on general geology. The publications on his theory of mountains totaled only three important ones, two of which were buried as parts of larger studies.

Between his prodigious contributions to paleontology and stratigraphy as well as his theory of mountains, James Hall was justly assured of a prominent niche in the history of his science. Geology was the preeminent American science of the late nineteenth century as judged by none other than British physicist John Tyndall during a visit to the United States in the 1870s. Therefore, Hall's leadership role in the professionalization of science and his charter membership in the National Academy of Sciences assure an important niche in the history of American science in general.

REFERENCES

Aldrich, M. L. 2000. *The New York State Natural History Survey 1836-1842*. Special Publication No. 22. Ithaca, N.Y.: Paleontological Research Institution.

Aldrich, M. L. and A. E. Leviton. 1987. James Hall and the New York Survey. *Earth Sci. Hist.* 6:24-33.

Clarke, J. M. 1921. *James Hall of Albany—Geologist and Paleontologist, 1811-1898*. Albany. Privately printed.

Dott, R. H., Jr. 1985. James Hall's discovery of the craton. In *Geologists and Ideas: A History of North American Geology*, vol. 1, eds. E. T. Drake and W. M. Jordan, pp. 157-167. Boulder: Geological Society of America.

Fisher, D. W. 1978. James Hall, Jr. *Dictionary of Scientific Biography,* vol. 6, pp. 56-58. New York: Scribner's.

Hovey, H. C. 1899. The life and work of James Hall, LL.D. *Am. Geol.* 23:137-168.

Stevenson, J. J. 1899. Memoir of James Hall. *Bull. Geol. Soc. Am.* 10:425-451.

SELECTED BIBLIOGRAPHY

1842

Notes upon the geology of the western states. *Am. J. Sci. Arts*, 1st series, 42:51-62.

1843

Geology of New York. Part IV, comprising the survey of the Fourth Geological District. Albany.

Notes explanatory of a section from Cleveland, Ohio, to the Mississippi River, in a southwest direction; with remarks upon the identity of the western formations with those of New York. *Reports of the First, Second and Third Meetings of the Association of American Geologists and Naturalists*, pp. 267-293. Boston.

Remarks upon casts of mud furrows, wave lines, and other markings upon rocks of the New York System. *Reports of the First, Second and Third Meetings of the Association of American Geologists and Naturalists.* Boston. 422-432

1847-1894

Natural History of New York: Palaeontology. (Thirteen separate volumes, but numbered as eight parts.) Albany.

1851

Lower Silurian System (chap. 9), Upper Silurian and Devonian Series (chap. 10), Fossils from the Paleozoic Series (chap. 13), and Parallelism of Paleozoic Deposits of Europe and America (chap. 18). In *Report on the Geology of the Lake Superior Land District*, eds. J. W. Foster and J. D. Whitney. Washington.

1858

With J. D. Whitney. *Geology of Iowa.* (Two volumes.) Des Moines.

1859

Description and figures of the organic remains of the Lower Helderberg Group and the Oriskany Sandstone: Natural history New York, pt. 6. *Palaeontology* 3:1-96.

1861

Descriptions of new species of Crinoidea from the Carboniferous Rocks of the Mississippi Valley. *J. Boston Soc. Nat. Hist.* 7:251-328.

1862

With J. D. Whitney. *Geological Survey of the State of Wisconsin.* Madison.

1865

Figures and Descriptions of Canadian Organic Remains. Decade II. Graptolites of the Quebec Group. Montreal: Geological Survey of Canada.

1871

Geological Survey of the State of Wisconsin, 1859-1863: Palaeontology. Albany.

1875

On the relations of the Niagara and lower Helderberg Formations and their geographical distribution in the United States and Canada. *Twenty-Seventh Annual Report of the State Museum of New York.* Albany: State Museum of New York.

With R. P. Whitfield. *Geological Survey of Ohio, II, pt. 2, Palaeontology, Description of Silurian Fossils.* Columbus.

1877

With R. P. Whitfield. In *U.S. Geological Explorations of the Fortieth Parallel, IV, pt. 2, Palaeontology,* ed. C. King. Washington.

1883

Contributions to the geological history of the North American continent. *Proc. Am. Assoc. Adv. Sci.* 31:24-69.