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PUBLICATION IN AMERICAN GEOLOGY TO 1850

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Abstract

Activity in American earth science increased at an exponential rate from 1780 through 1850, on the basis of the number of geologic publications recorded in the *Bibliography of American-Published Geology: 1669 to 1850.* Subdisciplines of earth science, such as vertebrate paleontology, mineralogy, and field mapping, grew in a regular succession of stages. At first, publication was sporadic because natural phenomena were observed but not understood in a larger framework. A key work, such as a new theory or classification scheme that succeeded in unifying isolated observations, stimulated a period of exponential increase in activity as many researchers were shown a clear direction to pursue. In some fields, the publication rate eventually slowed down and then reached zero as the objectives of a research tradition were met or a new competing program was more successful. The overall exponential increase of activity in geology was the net result of several subdisciplines being in various stages of growth.

Key Words: History of Geology, Geology-literature and libraries.

Introduction

A hallmark of Western science for the past three hundred years has been a steady increase in activity of the scientific community. Price (1961, 1963) developed a method to characterize and quantify this scientific activity by analyzing the number of published references, authors, or citations as a measurement of the growth of science. This technique, called bibliometrics, can be applied to early American geology. With the 14,000 entries in the *Bibliography of American-Published Geology: 1669 to 1850* (Hazen and Hazen, 1976, 1980) as a data base, one can investigate how fast and in what stages earth science grew in America.

Other factors besides publication, including private correspondence, scientific meetings, advanced education, and outside funding, are also of obvious importance in assessing the nature of scientific activity. Furthermore, in certain aspects of science, particularly those relating to technological developments and scientific apparatus, the published literature may not be an adequate guide to advancements. In spite of these additional factors in measuring the activity of the scientific community, publication (the permanent record of scientific achievements) can be used as a sensitive measure of scientific effort.

Before quantifying scientific effort one should examine what types of activities are represented in geologic publications. Many authors engaged in original research and contributed new data, new facts, or new hypotheses. Many publications such as textbooks and book reviews contain syntheses of information from other sources. A large number of popular articles and books on earth science, which appeared in America after 1820, reflect attempts of scientists to disseminate geologic information to the general public. The many facets of scientific activity should be kept in mind when viewing the simple growth curves of the subsequent sections.

The activity of geologic research has been measured by counting the number of articles, books, maps, and other works relating to earth science published in America versus time. No attempt has been made to weight the relative significance of these publications; such an attempt at weighting would violate the inherent objectivity of the bibliometric method. Each of the 14,000 entries in the *Bibliography of American-Published Geology: 1669 to 1850* has thus been counted as one publication in the following illustrations.

The number of earth science publications versus date is illustrated in Figures 1a and 1b. Before 1800, publication was sporadic. A few chance events such as the New England earthquakes of 1727 and 1755, and occasional periodical volumes controlled the rate of publication. Geology articles appeared regularly only after 1780. By 1800, however, the annual publication level grew rapidly and in 1850 almost 1000 references are to be found. The cumulative growth of American earth science is perhaps best illustrated by a semi-logarithmic plot of number of references versus year (Figure 2). The cumulative total of references closely approximates an ideal exponential curve, with a doubling rate of ten years; between 1780 and 1850, each decade saw the production of a volume of geologic literature equal to all that had been produced before.

A similar rate of increase is seen in the number of Americans who published earth science books, articles or maps per year from 1780 through 1850 (Figure 3). The number of named authors in a given year may be significantly less than the number of publications due to unsigned works, foreign authors, and multiple publications by a single author. The period of doubling for

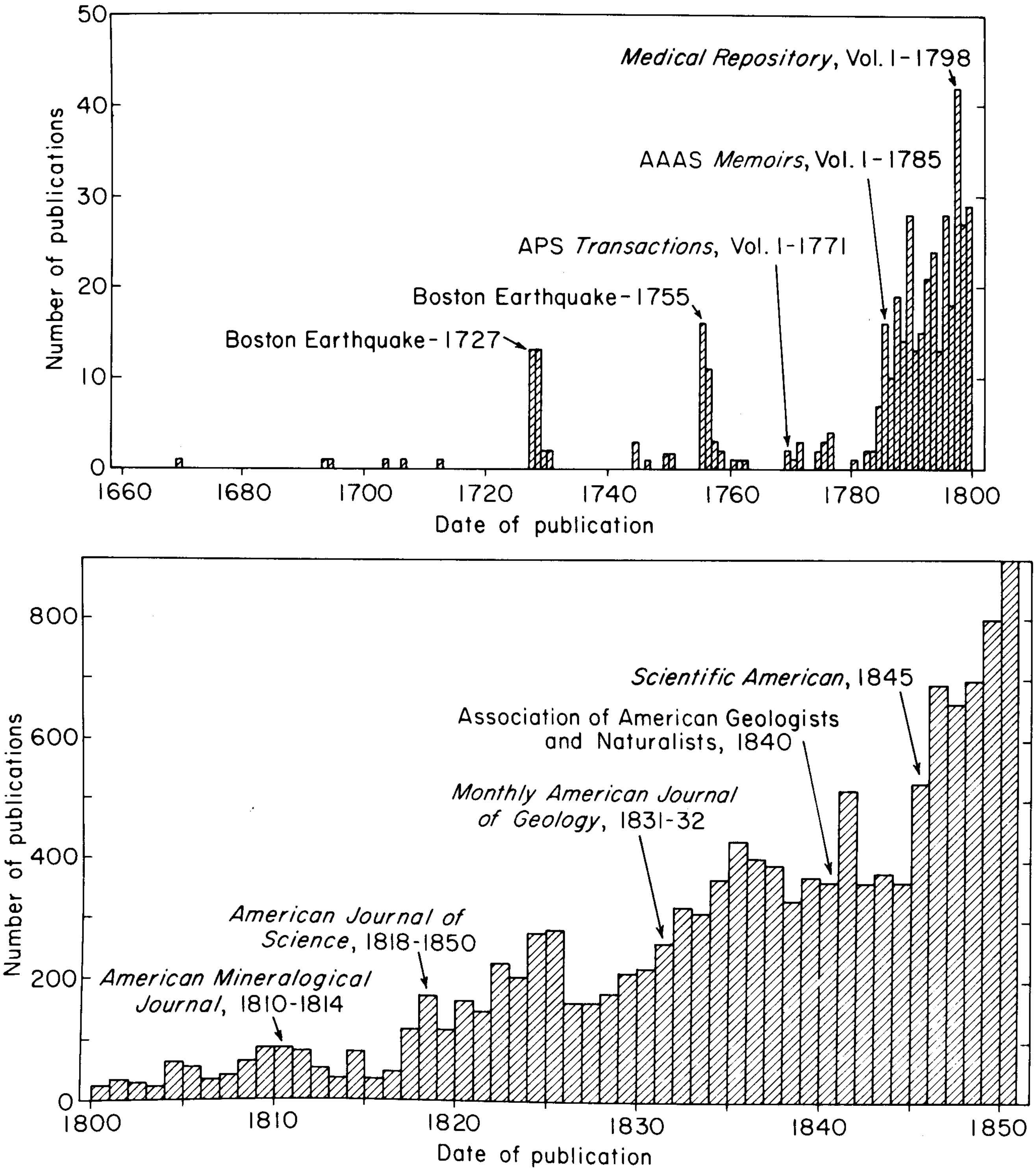

Figure 1. Number of American-published earth science books, pamphlets, maps, and periodical articles versus time. (a) 1660-1800, (b) 1800-1850. Note that the vertical scale of 1b is fifteen times greater than 1a.

the yearly (not cumulative) number of geologic authors is approximately 15 years, which is significantly shorter than the 24-year doubling period of the American population. The proportion of Americans who published geologic studies, therefore, increased dramatically in the first half of the nineteenth century from 4 to 13 named authors per million population in the United States (Figure 4).

The exponential increase in geologic activity represented in Figures 1 through 4, though striking, has been typical of all Western science for nearly three centuries. Price (1963) illustrates similar growth in numbers of periodicals, abstracts, authors, and universities. Typical doubling periods for other sciences have been 10 to 15 years. The growth of science thus far has outpaced the increase in world population. As emphasized by Price, such rapid growth cannot be maintained indefinitely.

The Mechanism of Scientific Growth

One way to understand why activity in geology grew exponentially is to examine the development of individual subdisciplines. One such subset of geologic investigations is mapping based on field studies. The number of geologic maps produced in the United States per decade, shown in Figure 5, is a clear example of an exponential increase. The reason for this rapid growth is the dominant influence of the map of William Maclure (1809), which set an example for subsequent authors to follow. At a time when few authors cited any previous literature, virtually all mappers in the twenty years after Maclure credit him. Maclure's map was a *key work* that established a new research tradition in the United States. (European geologists of the time were well aware of geologic mapping, but in America Maclure's map was the first widely recognized model.)

The idea of a key work establishing a research tradition is also apparent in early American vertebrate paleontology (Figure 6). Before 1820 publication was sporadic. As unusual fossil bones were discovered they were publicized, but fossils were not described in any systematic way, for there was no well known

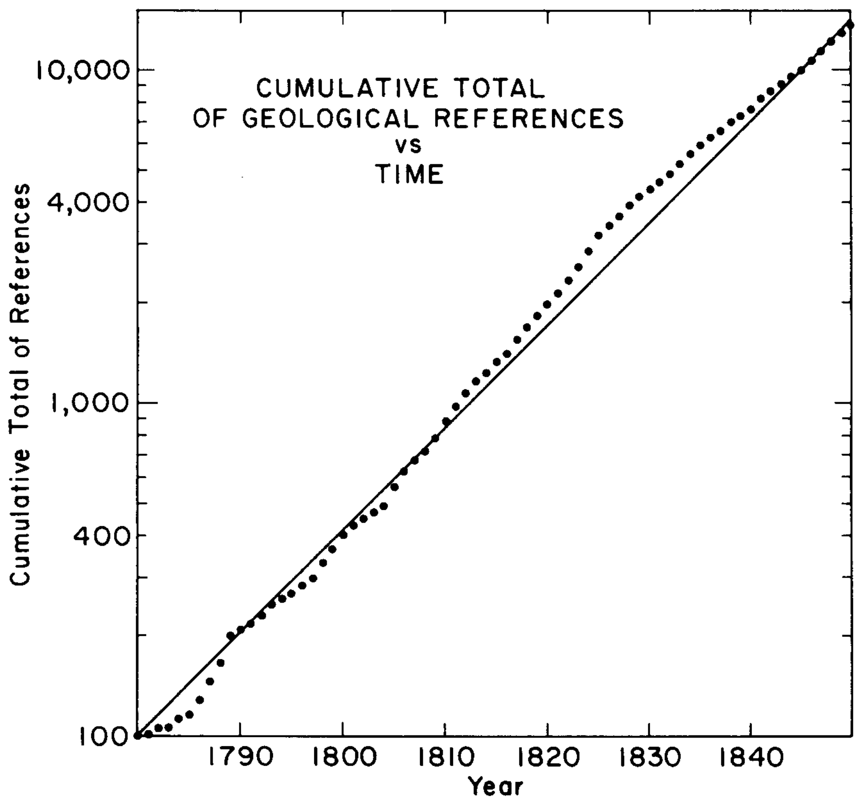

Figure 2. Cumulative total of American geologic references versus time. The vertical scale is logarithmic. The solid line represents doubling every ten years.

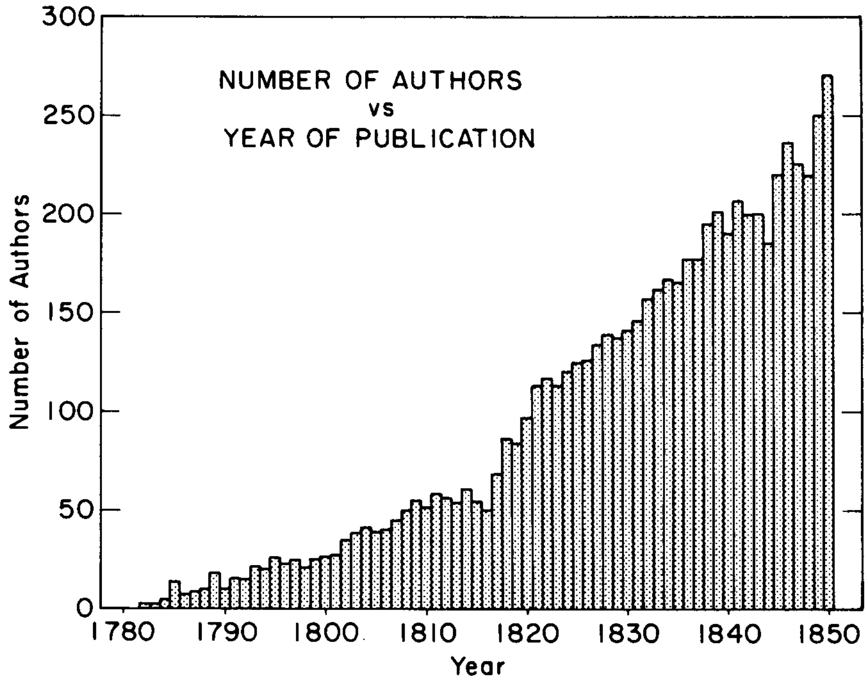

Figure 3. Number of named American earth science authors versus year of publication. The number doubles every ten years.

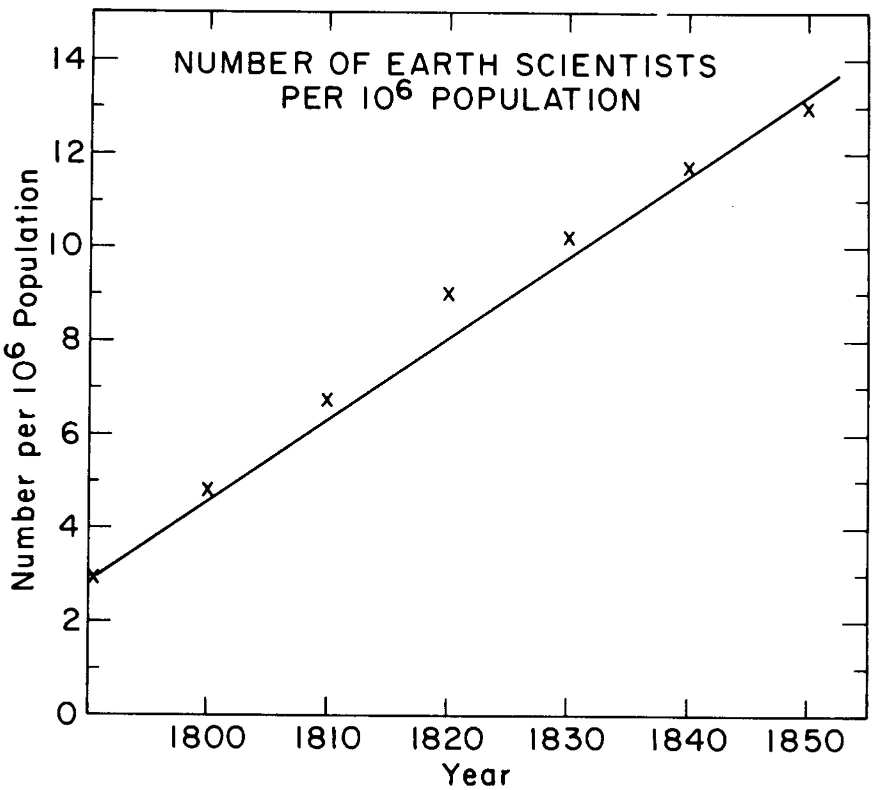

Figure 4. Number of named American earth science authors per million population versus time.

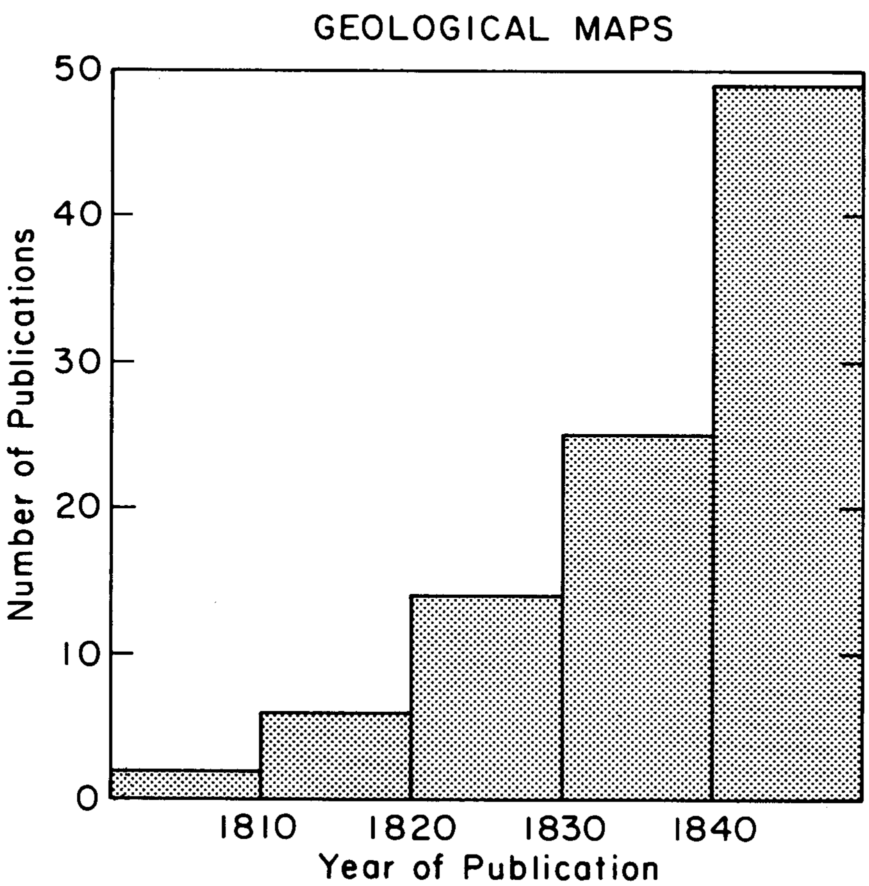

Figure 5. Number of published geologic maps versus time.

classification scheme for organic remains. George Cuvier's *Essay on the Theory of the Earth*, published in an American edition in 1818, was perhaps the first work to present systematic paleontology to America. It seems more than coincidental that the exponential rise in studies of vertebrate (and invertebrate) fossils followed shortly after the publication of Cuvier's text.

Not all fields show continuously increasing publication rates. Medical topography, introduced in America by Samuel Latham Mitchill (1799), was the study of the relationship between types of bedrock and the prevalence of disease. An important conclusion of medical topography was that calcareous terrains make more healthy places to live than those underlain by argillaceous sediments (Hazen, 1978, Chapter 3). The number of studies in medical topography grew rapidly in the first decades of the nineteenth century (Figure 7). Physicians and naturalists (especially those from calcareous regions of New York and near Cincinnati) published many local studies based on Mitchill's ideas. By the 1840's, however, the ideas of medical topography were no longer widely accepted, and a sharp drop in the number of studies is seen. This pattern of a key publication, followed by an exponential rise in number of investigations, a plateau, and an eventual tailing off is a commonly recurrent sequence in the development of science.

Descriptive mineralogy provides yet another example of subdiscipline growth in American earth science (Figure 8), but the pattern here is more complex. The overall trend is a rapid increase in number of yearly publications, but there are definite spurts of activity following the publication of what were perhaps the three most important American mineralogy texts prior to 1850. The steep rises just before 1800, 1820, and 1840 correspond to American publication of the *Compendious System of Mineralogy* (Anon., 1794), Cleaveland's (1816) *Elementary Treatise on Mineralogy and Geology*, and Dana's (1837) *System of Mineralogy*. The *Compendious System*, based in part on a work by Swedish mineralogist Axel Cronstedt, was the first systematic classification of minerals published in the United States. It is not clear whether it spurred the growth of American mineralogy by providing a standard of reference, or whether it merely reflected the new-found interest of Philadelphia chemists in mineralogy (Green and Burke, 1978). Cleaveland's *Treatise* was extremely influential. This first American-authored mineral system used a combination of chemical and physical tests for mineral identification that were well suited for application by American researchers. Dana's *System*, a third key work, combined chemical, physical and crystallographic properties of minerals into a system of classification which met with overwhelming success and is still in use today. Once again the key work was followed by a period of great publication activity as new workers learned and applied the classification scheme.

In the preceding discussion, key publications, rather than key events, have been emphasized as stimulating scientific activity. Unusual phenomena or events commonly result in temporary surges of publications. Great numbers of pamphlets appeared following the eighteenth century New England earthquakes (Figure 1a), for example, and the mid-nineteenth century discovery of gold in California triggered another wave of topical publications. Events *by themselves*, however, do not generally inspire the exponential rise of effort seen following key works. Any startling natural event or discovery must first be interpreted in the light of existing research traditions. Should a new key idea be inspired by the event then a new research tradition may begin, but lacking such a key publication, interest in the event will quickly pass.

The first manned lunar landing is an example of an event that inspired much new research, but did not, by itself, result in exponential growth. Virtually all lunar research was approached initially from the standpoint of well-established (i.e. fundable) research traditions. In fact, one of the major rationales for studying the moon was to provide data on the origin and evolution of the earth. Scientists thus seem constrained to approach new events from the standpoint of existing research objectives and concepts.

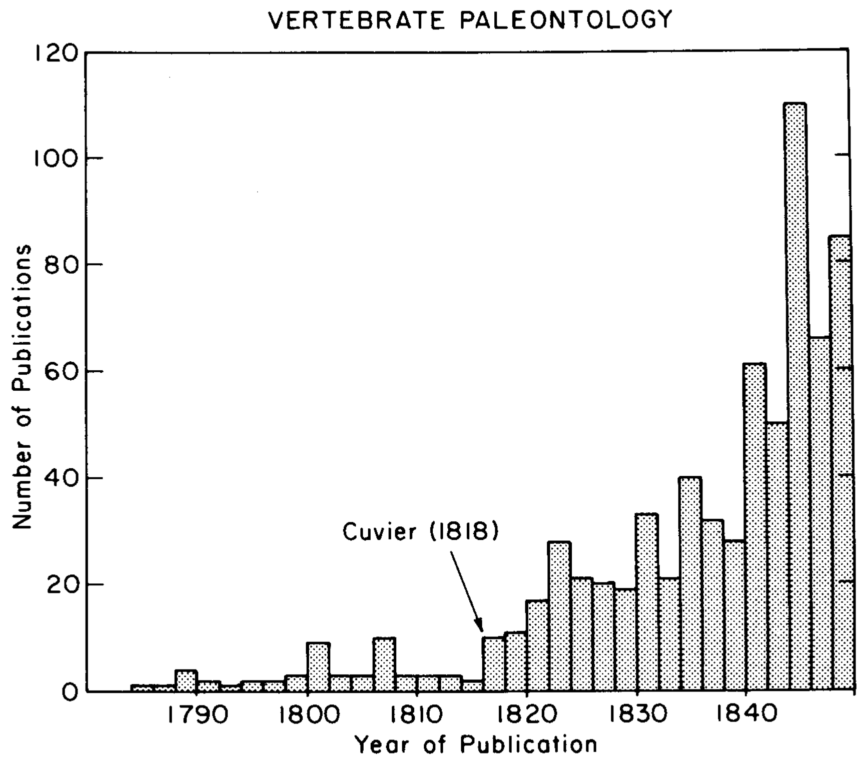

Figure 6. Number of publications on vertebrate paleontology versus time, 1780-1850. Publication was sporadic until after the key work of Cuvier (1818).

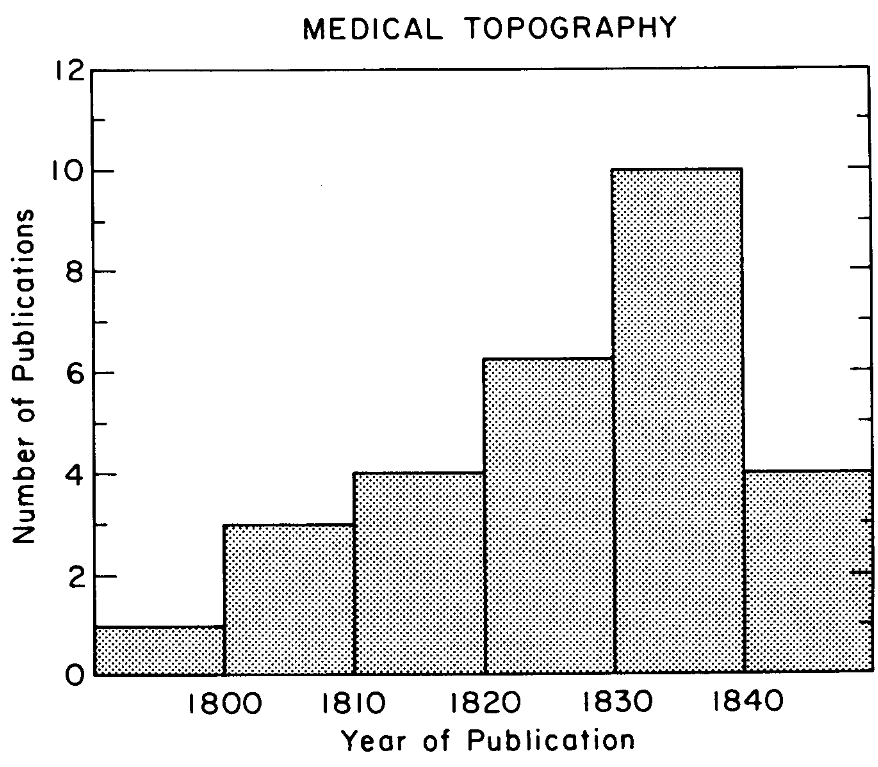

Figure 7. Number of publications on medical topography versus time, 1790-1850. An exponential increase followed by a decline in publication rate is shown.

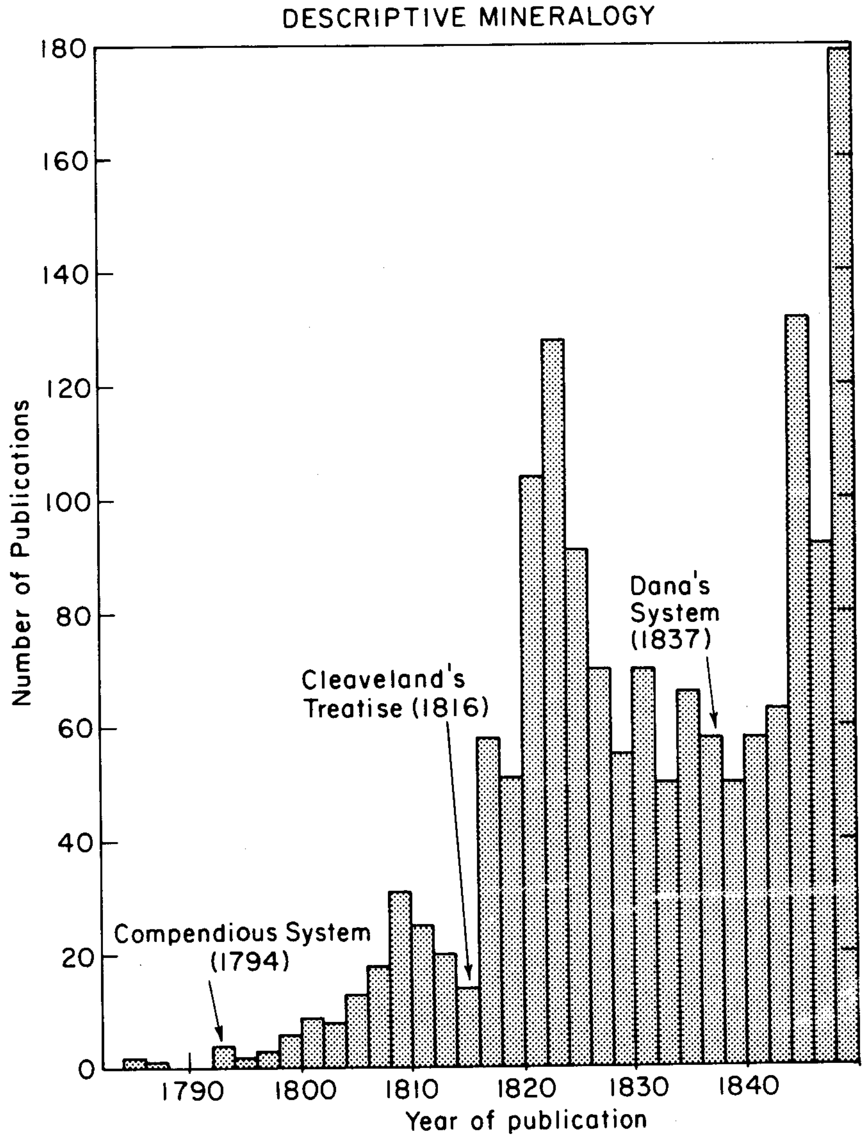

Figure 8. Number of publications in descriptive mineralogy versus time, 1780-1850. Three periods of rapid growth are seen following publication of key classification schemes in 1794, 1816, and 1837.

Idealized Growth of Science

A recurrent pattern of activity is evident in the development of each specific subdiscipline described above. Five growth stages may be recognized in the period from 1660 to 1850:

(1) First may come a period of sporadic observations as in paleontology or mineralogy. This happens when natural phenomena are observed but are not understood in a larger framework such as a classification scheme.

(2) A key work that presents a new research procedure or classification system marks the true beginning of a research tradition. This work may be largely new (such as Cuvier's *Essay*) or it may introduce an established concept to a new audience (e.g. Maclure's geologic map).

(3) A period of exponential activity follows as many new workers join in adding data and refining the research tradition. This stage of growth may be an exciting time of rapid discovery and development.

(4) Growth in activity must slow down and may eventually stop due to completion of the objectives of a research tradition or the success of new competing programs. This mature period in the development of a subdiscipline is often a time when technological applications of the field are pursued.

(5) A few last proponents of any research tradition keep working after most others have changed directions. These last proponents, though often prominent scientists, may have little impact on the course of science.

Conclusions

The growth of early American geology was apparently the net result of overlapping research programs. At any given time the many subdisciplines of the earth sciences may have been in different stages of growth, but the sum of these efforts was steady, exponential increase in activity. Does this growth model hold today? Certainly the curve of key works, rapid growth, saturation, and eventual decline of subdisciplines is still valid in the earth sciences. Modern examples of subdisciplines which have progressed through at least two of the various stages of growth are plate tectonics, paleoecology, descriptive mineralogy, and isotope geochemistry. Extrapolation of data in Figure 1 to 1980, however, implies an absurd annual American geological production of more than 1,000,000 publications. (The total number of references in the Bibliography of North American Geology for 1978 was less than 50,000.) The exponential growth rate of geologic activity has clearly slowed. Is American earth science entering a period of reduced growth, of leveling off? Analysis of the current activity and directions of the earth sciences may help us to understand and plan the future of geology in America.

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