ETYMOLOGY IN THE EARTH SCIENCES: FROM 'GEOLOGIA' TO 'GEOSCIENCE'

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ABSTRACT

The origin and usage through time of *geologia*, *geognosy*, *geogony*, *oryctognosy*, *geology* and *geophysics*, as characterised by their frequency of occurrence in the Google Books Ngram Corpus, is discussed. The English, French, German, Italian and Spanish corpuses used in this study have been normalised over the same timespan using the average frequencies of occurrence of the same set of 'neutral' words in each language (as advocated by Younes and Reips 2019). Use of the term *geology* is found to predate publication of James Hutton's *Theory of the Earth* in 1795 by about 100 years; *geognosy*, *oryctognosy* and *geogony*, much less commonly used, became established in the 1780s and began to fall out of use around 1820. The terms *geologist*, and *geognost* follow a similar pattern. The emergence of geophysics is a less familiar field: While the phrases *physics of the Earth* and *physical geography* can both be traced back to the early 1700s, *geophysics* only began to be used in the early 1800s and did not really become common until about 1860; *geophysicist* becomes common in German after 1860, but more generally after 1880. The first geophysics-related publications were bulletins from magnetic and seismic observatories and its first dedicated journal, *Beiträge zur Geophysik*, began publication in 1887, eighty years after the formation of The Geological Society of London. The tems *earth science* and *geoscience*, popular today, have steadily increased in their usage since being introduced the 1880s and 1930s respectively.

Keywords: History of geology, history of geophysics, n-gram, geology, geologist, geologia, geogony, geognost, geognosy, oryctognosy, physics of the Earth, physical geography, geophysics, geophysicist, earth science, geoscience.

1. INTRODUCTION

The science of geology gradually developed, from the seventeenth century onwards, as a consequence of a growing interest in rocks, minerals, the disposition of strata, and the nature of mountains. Accompanying this was a desire to understand the nature and causes of world-wide phenomena which depended on invisible forces: magnetism, gravity, earthquakes, the heat of the earth, and atmospheric- and terrestrial-electricity. By the early nineteenth century, the study of these topics had become collectively known as 'geophysics' which, unlike geology, was an essentially instrumentally-based science. In due course, many of the techniques developed in the study of geophysical phenomena came to be employed in the search for minerals and to elucidate geological structures. By the 1920s, this area of application had become known as *applied geophysics* (Ambronn 1926; English translation 1928).

As all these fields of study evolved, development of new terminology became necessary, and this is explored here. It has recently become possible to quantitatively examine long-term changes in the frequency of word usage by means of what are known as *n-grams*: a 1-gram being a string of characters within a text which are uninterrupted by a space. Normally, this will be a single word, such as *geophysics*; a 2-gram consists of two 1-grams separated by a space, and so on; thus, a phrase such as the *figure of the earth*[1] would be a 4-gram (Michel *et al*. 2011). Google LLC had a long-running programme to digitize a vast number of books in several languages and to extract all the n-grams, up to and including 5-grams, from them. By 2012, the texts of over 15 million books (12% of all books ever published) had been digitized and, by using optical character recognition, all the n-grams from over 8 million books in which the scanned text was of sufficient quality were extracted to form the Google Books Ngram Corpus.[2]

For a given language and n-gram, usage frequency is measured as the ratio of the number of occurrences of the n-gram in a year to the total number of words in the corpus for that year. Searches are case-sensitive, so 'Geophysics' and 'geophysics' could be treated as different 1-grams but, in this work, case has been ignored on retrieval (Michel *et al*. 2011, Lin *et al*. 2012). Figure 1 shows the variation in the frequency of usage of the terms *geology* and *geophysics*, expressed as the annual number of occurrences of the n-gram per million words averaged over the English, French, German, Italian and Spanish corpuses, as a function of time between 1700 and 2000.[3] The onset of a continuing increase in usage, from about 1796 and 1861 respectively, is evident and presumably reflects a significant growth in the interest in both subjects. The small oscillations in the curves prior to these times reflect variations in the far smaller number of very early publications in the original sample.[4]

As these new fields of scientific enquiry began to develop, their practitioners found that in order to aid the description and classification of emerging aspects of the natural world, new terminology was required.

2. GEOLOGIA

According to Kidd (1835) and Adams (1938, p. 165), the Latin term *geologia* first appeared in written form in an English work as a heading ('Geologia. Of Earths') to the first section of the volume on mineralogy (Lovell 1661b, p. 1) in a three-part encyclopaedia of natural history written by the English botanist, zoologist and mineralogist, Robert Lovell (ca. 1630−1690) (Lovell 1661a,b[5]), although it was used "not in the sense now attached to it, but in contradistinction to *Metallologia*" (Kidd 1835, p. 284).

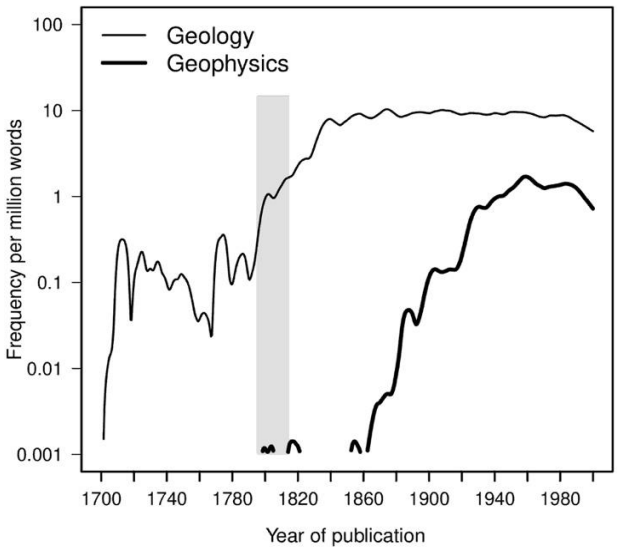

Figure 1. Total relative annual frequency of occurrence of the words geology *and* geophysics *in English, French, German, Italian and Spanish in the Google n-gram database of works published between 1700 and 2000 (see note 3 for details of calculation). The shaded rectangle indicates the beginnings of historical geology from the publication of James Hutton's* Theory of the Earth *(1795) to William Smith's* Map of the Strata of England and Wales with a part of Scotland *(1815).*

However, Lovell appears to have been anticipated by use of the word *giologia* by the Italian natural philosopher, bibliophile and assiduous collector of plants, animals, minerals and fossils, Ulisse Aldrovandi (1522−1605), who lived in Bologna and spent his life and all his wealth collecting for 56 years. By the time he had his lawyer draw up his will in 1603, his Library contained over 4000 volumes and over 800 manuscripts, and his Museum (established in 1547) contained, 4000 fossils and minerals, and thousands of preserved plant and animal specimens (Vai & Cavazza 2006, pp. 47-8).[6] Setting out what should happen to his collections after his death, he is recorded as having said that:

> La Biblioteca penes tabulas, seu indices, che saranno 20 volumi in circa, & anco la Giologia, ovvero de Fossilibus; poi la Botanologia, & Zoologia [The Library with tables or indices will be about 20 volumes, and likewise Geology, or rather Fossils; then Botany and Zoology] (Fantuzzi 1774, p. 81).

At that time, *fossil* meant any object found in the subsurface which was not obviously a mineral. In the quotation above, *Giologia* was evidently intended to mean 'the science of fossils', on a par with *Botanologia* and *Zoologia* (Vai 2003).

Adams (1838, p. 166), suggested that since the word *giologia* did not appear elsewhere in Aldrovandi's written or printed works, and his will remained unpublished for 170 years, his use of the term had little obvious influence during the 16th Century. However, it is known that from 1554 he taught at the University of Bologna and during his lifetime corresponded widely, rapidly establishing "a full network of correspondence and exchanges with the leading natural scientists in Europe" (Vai & Cavazza 2006, p. 47). It may well be as a result of this that Lovell became aware of the term *giologia*, since his own treatise, concerning the medicinal properties of 'earths,' is replete with citations of Aldrovandi as a source of information.

It is a short step from *giologia* to *geologia*, which appeared in 1663 in the title of an English translation of a Danish book concerning a Norwegian earthquake which had taken place in 1657 (Eschot 1663). A few years later, the term *Geologi* (Latin), meaning geologists, ocurred in a book on China, published in 1667 by the German Jesuit scholar, Athanasius Kircher (1602−1680) (Kircher 1667, pp. 136, 205; 1986, pp. 125, 198).

It was suggested by Dean (1979) that use of the word *geologia* preceded Aldrovandi by some 130 years, first appearing in a fifteenth century work in praise of books, written in Latin by the English cleric Richard Aungerville (1287−1345), also known as Richard de Bury. Although his original manuscript, known to have been written in 1345,

has been lost, thirty-one manuscript versions of the work ranging from *ca*. 1370 to 1478 still exist, in varying degrees of completeness. However, both the Latin phrase in question (if given) and its translation vary according to the different translators: The most authoritative translation, by the American classicist Andrew Fleming West (1853−1943) gives details of all of them (de Bury 1889, vol 2):

> 'nor is this faculty to be numbered among the sciences, though by an appropriate word it may be called geology' (de Bury 1832, p.75); the translator, John Bellingham Inglis (1780-1870) noted (p. 145): 'Page 75. "geology" – The earliest authority I have met with for this word; and here it is but a poor joke – an earthly science.'
>
> 'Nec est haec facultas inter scientias recensenda, quam licet *geologiam* appropriato vocabulo nominare.' (my emphasis; de Bury 1861, p. 144); the translation is identical to Inglis's (p. 145).
>
> 'Nor is this faculty which we may call by a special term *geologia* or the earthly science' (my emphasis; de Bury 1888, p. 219).
>
> 'nec est haec facultas inter scientias recensenda, quam licet *geologiam** appropriato vocabulo nominare.' [Side-note '* *geologicam* C, *geneologiam* in *geologiam* corr. D.'] (my emphasis; de Bury 1889, vol.1, p. 90). C and D here refer to the 1440 and 1430 manuscripts of the four primarily used by West in his translation (see de Bury (1889, vol. 3) for discussion).

Adams (1938, p. 166) commented on de Bury (1888), that it was in this work that:

> '*the word "geologia," it is believed, made its first appearance in the literature*. It was apparently invented, if this term may be used, by de Bury, who used it in an entirely different sense from that in which it subsequently came to be employed. By it, he designated the study of *Law*, which faculty, he says, "We may call by a special term Geologia or the earthly science," in antithesis to the sciences which aid in the understanding of divine things, comprehensively speaking, *Theologia.'* [emphasis as in original].

Dean consequently seems to have been in error. It is evident that by the nineteenth century, when the above translations were written, the meaning of 'geologia' was equivalent to the English term 'geology,' and this meaning began with Aldrovandi's work, as described by Vai (2003) and Vai and Cavazza (2006). Inglis and his fellow translators looked back from their nineteenth century perspective and imputed a meaning which it did not have in the fourteenth century.

In the English-speaking world, *geologia* probably reached a far wider audience when it appeared in 1690 in the title of a book by the English cleric Erasmus Warren (d. 1718), Rector of Worlington, Suffolk, written as a refutation of the ideas of his fellow-countryman, the theologian Thomas Burnet (1635?−1715). The latter had argued in his *Theory of the Earth* (Burnet: Latin editions 1681, 1689; English editions 1684, 1690) that the account of the creation of the Earth as described in the biblical Book of Genesis should be taken literally. However, Warren regarded Burnet's account as too simplified, believing, for example, that evidence suggested that there could not have been enough water in the oceans during Noah's Flood to enable all the mountains to be covered. He summarized his thinking as follows:

> [T]he *Manner* of the Earth's Rise . . . is supposed to have proceeded thus. The whole matter of the Earth and sublunary Heavens being confusedly blended together, in one fluid Mass or *Chaos*; the grosser and heavier parts thereof sunk down to the middle of it (as to the Centre of their Gravity) and constituted and [*sic*.] interior Orb of Earth. The rest of the Mass about it, by the same Principle of Gravity, was divided into two Orders of Bodies; the one Liquid, and the other Volatile. The Volatile mounting above the Liquid, constituted the Air: The liquid mass swimming below (and incircling the inward Earth aforesaid) contained in it all Liquors originally belonging to the Earth. These terrestrial Liquors are of two kinds chiefly; either fat, oily, and light; or else lean, and more earthy. The lean and earthy Liquor made up the Element of common Water: The Oily Liquor (which arose out of the Water as it purged it self) got above it, and floated upon it. . . . But this Body of the Air being at first very muddy and impure, through abundance of terrestrial Particles that, as fast as they could free themselves from the Air with which they were mingled, and in which they were intangled, they sunk downward: And meeting, in their descent, with the Oyly Liquor on the face of the Deep, there they stuck; and incorporating with that unctious Substance, made a certain Slime; or a fat, soft, light Earth, spread upon the Waters: Which growing thicker and thicker, by a continual accession of more terrestrial Particles, sliding down still out of the Air, as it purify'd it self; at last it came to its just Dimensions. And then waxing more dry and stiff, and firm and solid, in fine it attained to its due Consistency, and so became the First habitable Earth [emphasis as in original]. (Warren 1690, pp. 46−48).

Burnet took exception to this and a vigorous debate ensued which persisted for some years, thus ensuring that the new word *geologia* was noticed

3. GEOLOGY BEGINS

The term *geologie* appeared in 1695 in an explanation and defence of the theories of the French philosopher René Descartes (1596−1650) published by his fellow-countryman Pierre Cally (1630−1709), a philosopher and theologian. Cally's book included chapters on the World (*Cosmologie*), the Earth (*Geologie*), Water (*Hidrologie*), the Sky (*Uranologie*) and Mankind (*Antropologie*). The section concerning *geologie* consisted of six parts: (1) a synopsis of Geography; (2) a discussion of the nature of terrestrial fire, how it arose, how it maintained itself, and its effects (this included the nature of earthquakes, a burning-glass[7] and gun-powder); (3) the nature of magnetic bodies, such as the compass and iron; (4) Salts; (5) Oils; and (6) other matters the Earth contained within itself, and which mankind used, such as silver, stone, metals and similar bodies (Anonymous 1697).

In 1735, the English instrument-maker, author, lecturer and ardent Newtonian, Benjamin Martin (1704/5−1782) published a 'philosophical grammar' in four parts, the contents of which were summarised on the title page of the book. His synopsis for the last part reads:

> PART IV. GEOLOGY, containeth a philosophical View of the terraqueous Globe, in all its Parts and Productions; as Minerals, Metals, Stones *&c*. The Laws of Fluids; the Sea, its Tides, *&c*. Of Rivers, Springs, *&c*. Of Vegetation, and the Nature of Plants, Trees, *&c*. Of the Parts of animal Bodies; and a Survey of the nature of Beasts, Birds, Fishes, Insects, Reptiles, Shell-Animals, *&c*. (Martin 1735, p. i).[8]

However, in the first chapter of Part IV of the book, he defined *Geology* as:

> A Discourse of the Earth in general, or its terraqueous Globe, as consisting of Land and Water; from the *Greek* words Γή, the *Earth*, and Λόγος, a *Discourse*, [whereas his second chapter would address] Geography, or the Philosophy of the Constitution, Texture, and constituent Parts of the Earth, describing the various Stratas of Earths, Fossils, Minerals, Metals, Stones and other subterraneous Substances [emphasis as in original] (Martin 1735, pp. 189, 205).

His book is written in the form of a dialogue between a pupil ('A') and his master ('B') and it covers many topics. The following extract regarding the "internal Make and Constitution of the Globe of our Earth*"* provides insight as to the state of knowledge in 1735:

A. [W]hat I would know is, of what the internal solid body of the *Earth* doth consist?
B. To this I can only answer, that so far as it is within our Scrutiny near the Supersicies, we find it to consist of different *Strata*, or *Layers* of *Earth*, *Minerals*, *Metals*, *Oars* [*sic.*], *Stones*, and various other compound Bodies both hard and soft: But what the more internal Parts, or Composition of it may be, we can tell but very little concerning: However the deeper you go, the solider and more compact you find its Matter to be, and the more firmly and strongly does it cohere together; yet it is very certain that within the Entrails of the *Earth*, are many Hiatus's, Recesses, Windings, Conveyances, and vast Receptacles of Water, sulphureous Substances, *&c*. which are often the Cause of Earthquakes, and supply *Volcanoes* with their fiery Eruptions, as Mount Ætna, *&c*.
A. What do you suppose to be in the very Middle of the Earth; that is, in and about its Center?
B. No Body can certainly tell; the *Earth*'s Center is near 4000 Miles from us, and we can penetrate towards it but a few Fathoms; how very unlikely then is it, we should know any Thing at such a vast and impervious Distance? However the learned Dr. *Halley*[9] has made it very probable, that a great magnetic Body, or Load-stone,[10] doth possess the central Parts of the *Earth*; which occasioneth the Variations and Declinations of our magnetic Needles, which always conform themselves to the Site and Direction of this central Magnet, or Load-stone; which is supposed to deviate from the *North* and *South* points, and from the horizontal Position, with Respect to us.
A. If that be so, it is very wonderful, and a noble Discovery: But, pray, what is it binds the several Parts of the *Earth*, or makes them cohere so closely together?
B. The Coherence of the *Earth* is entirely owing to the Power of Gravity, or the Weight of its constituent Parts; whence, as I before said, it is reasonable to believe the most weighty and solid Bodies lie nearest to the Center of the *Earth*, as being the Center of Gravity it self.
A. Well then, since the more interior Parts of the *Earth* are so little known, we leave them, and content our selves with what is to be known near the Supersicies of it on which we live; and, pray, what do you first observe thereof?
B. That it does consist of different heterogenous Bodies intermixed with one another, of different specific Gravities, disposed in Manner of Beds, which are called *Strata*, or *Layers* of *Earth*, *Stones*, *Minerals*, *&c*. one under another.
A. Pray in what Order do these *Strata*, or Beds of *Earth*, *&c*. lie among themselves?
B. That they do not lie in Order of their specifick Gravities, is evident (and so not every where alike) from the Order of those observed in digging a Well at *Amsterdam* 232 Feet deep; which was thus, 7 Feet of Garden Mould; 9 of Turf, or Peat; 9 of soft Clay; 8 of Sand; 4 of Earth; 10 of Clay; 4 of Earth; 10 of paving Sand; 2 of Clay; 4 of white Loam; 5 of dry Earth; 1 of muddy Earth; 14 of Sand; 3 of a sandy Clay; 5 of Sand, mixed with Clay; 4 of Sea Sand, mixed with Shells; then 102 of Clay together; and *lastly*, 31 of Loam: Thus you see the different Make of the outwards parts of the *Earth*, which is very different in different Places.
A. Pray how came the Disposition of those various *Strata*, or Beds of *Earth* and *Minerals*?
B. This is not known as to the Time; some say at the Creation, others at the Flood; others supposed in the *chaotick* State of the *Earth* the heavier Bodies subsided, and lay in this Order by the Laws of Gravitation; but Experience rather contradicts than confirms this *Hypothesis*.
A. What Distinction, or Division, do you make of earthy Substances or Bodies?

B. They may be reduced to these general Heads: 1. Earths. 2. Ores. 3. Fossils. 4. Minerals. 5. Metals. 6. Stones. 7. Extraneous Bodies or Substances.
A. What do you include under the first general Head of *Earths*?
B. All those softer earthy Substances we call *Clay, Loam, Marl, Sand* and different Species of Earths, as *Terra Japonica, Lemnia, Armenia, &c...* .
A. What do you include under the second Head of *Ores*?
B. Those *Earths* which contain considerable Quantities of metallick Particles; being that which is dug out of Mines, and whence Metals are extracted, and is dominated accordingly, as *Gold-Ore, Silver-Ore,* &c. . . . .
A. What terrestrial Bodies do you intend by *Fossils*?
B. Though FOSSILS be a general Name for every Thing which is dug out of the Earth; yet I intend thereby, 1. *Salts*, 2. *Sulphurs*, and such like Bodies, which cannot be so well reduced to the Heads of *Minerals*, *Metals*, and *Stones* [emphasis as in original]. (Martin 1735, pp. 206−210).

The book was evidently well received: a second edition followed in 1738, and an Italian translation was published in Venice in 1750. Although a work by Pierre Massuet (1698−1776), a French physician living in Amsterdam, contains an identical definition of 'La Géologie,' (Massuet 1752, p. 73), the wording throughout is so similar to Martin's that it could well be a plagiarised work. However, an article on 'Géologie', in a volume of the *Encyclopédie Méthodique* otherwise devoted to agriculture, places it in a more familiar context: "Geology. This name is given to a science whose object is to make known the nature of the layers of the earth and the phenomena they present" (Tessier *et al*. 1796, pp. 546−547). By 1812 it had become established that:

> The term *Geology* has been applied in two different senses. [1] Naturalists have been always fond of speculating about the original formation of the earth, and about the changes which it has undergone since its original creation. Accordingly, various fanciful theories have been constructed in succession, either founded entirely upon the imagination of the constructor, or partly upon imagination, and partly upon the account of the creation contained in the Old Testament. These whimsical hypotheses have been dignified with the title of *theories of the earth*, and the term *geology* has been very frequently applied to them. . . . [2] [A]n account of all the stony masses which compose the crust of the earth; the order in which they lie with respect to each other, and with respect to the substances which they contain. . . . To distinguish this important branch of science from the absurd speculations about the formation of the earth, Werner[11] has given it the name of *geognosy* [emphasis as in original]. (Thomson 1812, pp. 85-6).

4. A WERNERIAN INTERVAL: GEOGNOSY, GEOGONY, ORYCTOGNOSY

In Frank Dawson Adams book *The Birth and Development of the Geological Sciences* (1938), he noted that the term *geognosy*, popularized by the lectures of the German mineralogist and economic and structural geologist Abraham Gottlob Werner (1749−1817) during his forty years of teaching at the Freiberg Mining Academy (Bergakademie), and through its appearance in his books, such as *Neue Theorie von der Entstehung der Gänge, mit Anwendung auf den Bergbau* [New theory on the formation of veins: with its application to the art of working mines] (Werner 1791a, pp. *xiv*, *xx*, 224), was anticipated by his fellow-countryman, the physician and geologist Georg Christian Füchsel (1722−1773), who had used the words *scienta geognostica* in an article written in Latin (Füchsel 1761; II, p. 209).

Nevertheless, Werner defined geognosy, derived "from the Greek words γη, *the earth*, and γνώσεις, *knowledge*" (Jameson 1830, p. 389), as a purely observational science, concerning what was *known* of "the nature of the Earth in its totality" in contrast to: *Oryctognosy*, "the science of the determination of minerals"[12]; *Mineral chemistry*, "the chemical composition and analysis of minerals"; *Geographical mineralogy*, "the regional geology of specific places, particularly with respect to rocks and ore deposits"; and *Economic mineralogy*, "the characteristics of minerals and their processing for the benefit of humanity".[13] He regarded geology as having been more speculative in nature.

It is interesting that shortly after Füchsel's publication, the German chemist Johann Heinrich Pott (1692−1777) introduced the term *lithogeognosia*, meaning "the knowledge and processing of the common simpler stones and earths" in Pott (1746, p.7), which could be regarded as an early work on geochemistry. It was translated into French as *lithogéognosie* in 1753 and into English as *litho-geognosy* in 1765.[14]

Further examples occur in the English translation,[15] *A geognostical essay on the superposition of rocks* (Humboldt 1823b), of a work in French by the German traveller and geologist, Friedrich Wilhelm Heinrich Alexander, Baron von Humboldt (1823a), which mentions "geogony, or historical geology" (p. 261); "oryctognosy (or descriptive mineralogy)" (p. 8); and states that "True geognosy describes the exterior crust of our globe such as it exists in our days" (p. 6).

The view that 'geology' encompassed many things, including geognosy, is reflected in an article by the Scottish geologist Robert Jameson (1774−1854) on Mineralogy, in *The Edinburgh Encyclopedia* (1830), which began with a short outline of the history of geognosy:

> Geognosy . . . This important branch of natural history makes us acquainted with the structure, relative position, materials, and mode of formation of the mineral masses of which the crust of the earth is composed. The term *geognosy* . . . has been confounded with *orology*, which instructs us regarding the physiognomy of mountains, with *geogony*, which is purely hypothetical, consisting of very abstract speculations regarding the original formation of the earth; also with *geology*, which, however, has a more extensive signification, for the word λογος [Eng: *reason* or *cause*] comprehends the whole science, or rationale of any subject, and therefore geognosy is only a branch of geology. Geology, indeed, according to Werner, comprehends not only *geognosy*, but also *geography*, *hydrography*, *meteorology* and *geogony* [emphasis as in original]. (Jameson 1830, p. 389).[16]

It is interesting that although the introduction to the English translation of Humboldt (1823a) (Humboldt 1823b, pp. 1-84) is replete with the word geognost and its plural, including the statement "Geognosts, who are devoted to the study of the laws of unorganized nature . . . " (pp. 4-5), it also contains references to *geologists* (pp. 8, 28).[17]

Figure 2 shows the relative frequency with which the terms *geology*, *geognosy*, *geogony* and *oryctognosy* occur in the Google database between 1700 and 2000. Geology has been in use the longest but, as has been shown, its meaning has gradually changed with time. Geognosy, geogony and oryctognosy first appear in the database between 1768 and 1787, just before the era of 'historical geology' began, reaching a maximum usage between 1819-27, but it thereafter declined.[18] Even so, 'geognosy' took a long time to die out.

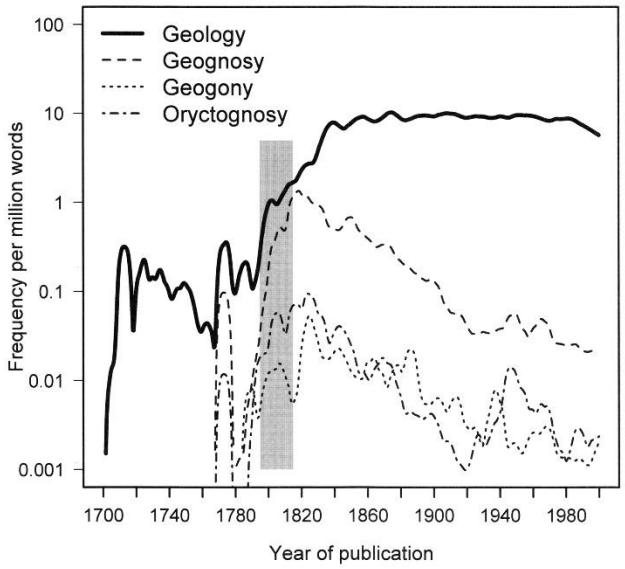

Figure 2. Relative annual frequency of the words geology, geognosy, geogony *and* oryctognosy *(including their equivalents in French, German, Italian and Spanish) in the Google n-gram database between 1700 and 2000. The shaded rectangle indicates the beginnings of historical geology, as in Figure 1.*

Klemun (2018) notes that Glocker (1839, p. 5) explained the difference between geognosy and geology in that while the former "limits itself to the spatial juxtaposition of mountain ranges, geology investigates the origin of and changes in these ranges in successive periods." However, Geikie (1879, 213, 220), regarded geognosy as "an Inquiry into the Materials of the Earth's Substance." But by the turn of the nineteenth century, its meaning had narrowed: "in this department of geological enquiry petrographical research has been greatly pursued and extended," (Geikie 1902, p. 637) and thereafter it appears to have become restricted to petrographic studies. Hunt (1860, vol. 3, p. 364) said of oryctognosy that it was "synonymous with the English term Mineralogy. It is never used."

5. GEOLOGY RETURNS

The Geological Society of London, the oldest of its kind in the world, was founded in 1807,[19] its members resolving in March 1810

> to publish the more important communications made to the Society, but not at stated periods, the title to be the *Memoirs of the Geological Society*; . . . Early in the following year it was resolved, that the term *Transactions* be substituted for *Memoirs*. (Woodward 1908, p. 43).

The *Transactions* began publication in 1811 and continued intermittently until 1856, having been largely replaced by the regularly-published *Quarterly Journal of the Geological Society of London* which began in 1845 and which in 1971 became the still-continuing *Journal of the Geological Society*.

Not long after the formation of the Society, the word 'geology' appeared for the first time in the title of an English book: *An introduction to geology*, by the agriculturalist and geologist Robert Bakewell (1767–1843), an applied geologist who, like William Smith, never became a Fellow of the Society. In contrast to the Wernerian terminology, use of 'geology' began a steady increase just before 1800 which only levelled-off after 1840. Bakewell

(1828, p. 1) regarded "the most important objects of geological research" as "What are the substances of which the Earth is composed? What is the order in which they are arranged? What are the changes they appear to have undergone? By 1872, its definition had changed yet again:

> it confines its attention to a description of the solid crust of the earth, and to the elucidation of those forces and causes which have produced the changes the surface of our planet has undergone . . . The division of the subject we propose is the following:—1. Physical Geology . . . 2. The Geological Systems . . . 3. Mineralogy and lithology . . . Under the general term *Geognosy* is included all that can be said in relation to the structure of the matter composing the earth's crust . . . The rock-masses may be treated of as to their mineral, their internal structure, and those characters which may be determined by handling specimens, such as texture, construction, hardness, etc. All this is *Lithology*. *Petrology* describes the larger characteristics of rock; the relative positions they occupy, and the disturbances they have undergone . . . A study of fossils is of the greatest importance, and this has received the name of *Palaeontology*. *Mineralogy* is a further sub-division of Lithology [emphasis as in original]. (Wallace 1872−1875, vol. 3: pp. 3, 385).

6. GEOPHYSICS

Once the science of geology had become established, when did 'geophysics' arise? The word 'physics' is considerably older than one might imagine and is believed to be derived from the Greek *φυσια* (meaning *nature* or *matter*). It was originally regarded as synonymous with 'natural philosophy' and is generally thought to have originated with the ancient Greek philosophers, such as Aristotle, Pythagoras and Plato. Pythagoras, for example, was held to be skilled in "contemplative physics or natural science" (Gale 1672, p. 171).

By the seventeenth century, the idea of 'physical geography' had also begun to emerge (*e.g.* Desmarest 1757, pp. 613−624) and fleeting references to 'terrestrial physics' likewise began to appear, such as in a book by the French Cartesian philosopher, Gilles de Launay (or De L'Aunay; dates unknown), who lectured on the subject in Paris. In discussing subdivisions of 'physics' he wrote: "Celestial physics explains the nature of the heavens and stars, and elementary or terrestrial physics examines sublunary bodies" (Launay 1667, p. 11),[20] a view which would persist for the next century (Paulian 1769, p. 194). A more detailed categorization is found in a book published by another Frenchman, Pierre-Sylvain Régis (1632−1707). While he did not use the exact phrase 'physique terrestre' [physics of the earth] in his work, the heading to the book's fourth section reads: "Physics or the knowledge of natural bodies, & their properties. Fourth Book. On the nature and properties of terrestrial bodies in general" (Régis 1691, p. 113).[21] He went on to describe the nature of water, air, oil, salt, hardness (which included discussion of the nature of metals, minerals, stones, the lodestone, amber and jet) and fire (including the nature of gunpowder and terrestrial 'underground fire').

At the turn of the eighteenth century, the potential of physics to reveal something of the Earth at a global scale was brought to public attention by the English scientist Edmond Halley (1656−1742), when he used isolines ('contours') to summarise and illustrate the results of numerous measurements of magnetic declination made during his Atlantic voyages of 1698−1701 (Barraclough 1985; Thrower 1978, 1981). As Humboldt remarked:

> It was a happy undertaking of Halley's [1701] to connect graphically by lines or curves all points on the map where the magnetic declination was the same. Clearness of representation, and the advantage of gaining a general view of the connection of detached results, were thus first introduced. (Humboldt 1858*a*; English translation 1868, p. 60).

By the end of the century, the phrases 'physique terrestre' (French) and 'fisica terrestre' (Italian) had also come into use. This suggests that this new field of study was beginning to be recognized in several countries: the phrase 'Fisica terrestre, e celeste' [terrestrial and celestial physics] occurs in passing in a late eighteenth century Italian periodical (Occhi 1757, p. 382) and 'La physique terrestre' appears in a dictionary from the same period, published by the French physicist, Aimé-Henri Paulian (1722−1802), who taught at the Jesuit College in Avignon in 1761:

> Terrestrial Physics, ... requires careful study. The inside of our Globe first provides the spectacle of Underground Fires, Earthquakes caused by Electricity, Fossils, that is to say, Metals, the Lodestone, Ordinary Stones & precious stones, etc. (Paulian 1761, p. 46).[22]

Similar views were expressed by Paulian (1770). 'Physique terrestre' also occurs in an article by the Swiss geologist Jean-André de Luc (1727−1817) in the early French scientific journal *Observations et Mémoires sur la Physique, sur l'Histoire Naturelle et sur les Arts et Métiers*.[23] Usage of the term in Germany and Italy continued into the nineteenth century and can be found in publications by Pilla (1823), Naumann (1824), and Avogadro (1837).

The German mathematician and physicist, Georg Friedrich von Parrot (1767−1852), was born in the Duchy of Württemberg.[24] In 1802 he became professor of theoretical and experimental physics at the Imperial University of Dorpat (now Tartu in Estonia), and in 1826 was appointed head of the physics laboratory at the Academy of Sciences in St. Petersburg, Russia. An accomplished mountaineer, he carried out geological studies as well as geophysical

investigations involving gravity and magnetism. In addition to geology, his book *Grundriß der Physik der Erde und Geologie, zum Gebrauche für akademische Vorlesungen* [Outline of the physics of the earth and geology, for use in academic lectures] (Parrot 1815) included discussion of the figure of the earth, gravity, magnetism, the atmosphere and seas. It was followed by a textbook by the Italian chemist and physicist Giuliano Giordano (1812−1878), a professor at the University of Naples. He too used the phrase 'physics of the earth' in its title and divided 'terrestrial physical phenomena' into six groups: thermal, atmospheric, aerodynamic, aqueous, electric, light (*e.g*. auroral manifestations) and volcanic, each of which was given lengthy treatment (Giordano 1858, pp. 260−466). Curiously, although he taught physics, it was his better-known colleague, the physicist and meteorologist Luigi Palmieri (1807−1896), credited with early development of the seismograph, who taught the course on 'Physics of the Earth' at the University (Scivoletto 1861, pp. 394−395).

The word *geophysik* appears in 1817 in a history of the University of Würzburg, Germany, which stated that 'geophysics (geogenie, physical geography, climatology and meteorology)' was being taught by the chemist and physicist Franz Lothar August Wilhelm Sorg (1773−1827), a native of that city (Goldmayer 1817). Sorg also taught theoretical and experimental physics and chemistry. Geophysik also occurred in a textbook on petrology (Naumann 1824, p. 15) by the German mineralogist, mathematical crystallographer, and stratigrapher, Carl Friedrich Naumann (1797−1873), who was professor of physics in Kaliningrad from 1826. He founded a school of theoretical physics in 1834, where many of the investigations were essentially geophysical in nature (Kertz 1979).

A contemporary encyclopedia distinguished between 'geogenie' and "geophysics or geography, whose purpose is to explain the changes in the landscape that are still present on the earth and in its atmosphere."[25] The term occurred in a similar context in an article entitled *Einiges zur Geophysik, oder besser Geophysiologie oder Geobiologie (zugleich enie kritik jetzt herrschender Ansichten in der Geologie)* [Something about geophysics, or better geophysiology or geobiology (at the same time a critique of geology)], published in the scientific periodical *Isis* (Buquoy 1830) by the Czechoslovak natural scientist, philosopher and entrepreneur, Baron Georg Franz August de Lonueval, Freiherr von Buquoy (1781−1851).

At this time 'geophysics' appears to have been regarded as equivalent to 'physics of the earth', a term which Buntebarth (1981) suggests was used almost exclusively by physicists. He attributes the first use of *geophysik* to a German geographer at the University of Zürich, Carl Ferdinand Julius Fröbel (1805−1893) in the short-lived journal *Mitteilungen aus dem Gebiete der Theoretischen Erdkunde* [Communications from the field of theoretical geography], which Fröbel co-edited with the Swiss geologist and naturalist Oswald Heer (1809−1883), who was a lecturer in mineralogy. In the Foreword (dated February 1834), Fröbel explained that the journal was intended to cover: mathematical and general physical geography; general and special physical terrain ('orography' and hydrography) studies; geognosy and mineral geography; meteorology and climatology; plant geography; animal geography; and ethnography. The first issue opened with a lengthy essay by Fröbel on a "Draft of a system for geographical sciences" in which he mentions:

> the science of geology in the broadest sense of the word, as a general natural science of the Earth (Earth physics; *geophysics*; theoretical geography); [emphasis as in original] (Fröbel 1834, p. 26).[26]

Under 'theory of the earth', Fröbel grouped gravity, chemical 'affinity', heat, light, electricity, magnetism and crystallization together as 'telluric processes'. Gravity was also included as a 'cosmic processes' (Fröbel 1834, pp. 124−125). However, apart from the quotation above, the word geophysics did not occur in his article again, but it is interesting that he clearly drew a distinction between 'geophysics' and 'physics of the earth.'

Kertz (1979) has suggested that in Germany, the works of Naumann, Humboldt, and Ferdinand Reich (1799−1882) were particularly influential in raising awareness of the new science of geophysics. Reich was professor of physics and lecturer on palaeontology at the Mining Academy in Freiberg. His geophysical investigations included studies of the variation on temperature with depth in mines, magnetism, torsion balance measurements of earth density, and the palaeomagnetism of basalts (Reich 1834*a*, 1834*b*, 1838, 1849).

Shortly after this, the German mineralogist, geologist and palaeontologist, Ernst Friedrich Glocker (1793−1858), a Professor at the University of Breslau, used a narrower definition of 'geophysics' in a serial publication *Systematischer Bericht über die Fortschritte der Mineralogie* [Systematic report on the progress of mineralogy] (1835−41), which was largely devoted to systematic mineralogy (Glocker 1837). Its contents list was as follows:

1. History of mineralogy
2. Latest literature on mineralogy
3. Crystallography
4. Mineral physics
5. Mineral chemistry
6. Special oryctognosy
7. Geognosy
   - A. Geology − Earth history
   - B. Geophysics
     - i Geothermal energy
     - ii Geoelectrical
   - C. General geognosy
   - D. Specific geognosy

It is interesting that both geology and geophysics are included as subcategories of geognosy and that 'geophysics' is restricted to two topics (which we would today place in that subject area), namely: *geothermy* (he discusses the increase of temperature with depth within the earth, as observed in mines, and the lack of a relationship between subsurface and surface temperatures) and *geoelectricity* (he reports on electrical phenomena which had been observed in mines in Cornwall, England). Glocker used similar subdivisions in the first (1835) issue of the serial publication.

By this time, increasing numbers of books by leading scientists[27] and articles in serial publications[28] , which were concerned with what would today be regarded as essentially geophysical topics, helped to raise the profile of geophysical (particularly geomagnetic) investigations.

In 1863, a German doctor, Adolf Mühry (1810−1888), who was interested in the connection between meteorology, climate and the spread of disease, published a book titled *Beitraege zur Geo-physik und Klimatographie* [Contributions to geo-physics and climatography]. However, he did not use the term *'geo-physik'* elsewhere and his hyphenated spelling of the word does not seem to have been taken up by others.

More significantly, it was followed by the two-part *Lehrbuch der Geophysik und physikalischen Geographie* (1884−1885) [Manual of geophysics and physical geography] by the German mathematician, physicist and geographer, Adam Wilhelm Siegmund Günther (1848−1923), who was at that time professor of mathematics and physics at the Gymnasium in Ansbach. In 1886 he became professor of geography at the Technische Hochschule in Munich. In a lengthy introduction, he gave an extensive survey of views about geography and the gradual development of the study of physical geography from Antiquity to the eighteenth century. He noted that the science of *terrestrial magnetism* was pioneered by Christopher Hansteen (1784−1873) in Norway, and by Karl Friedrich Gauss (1777−1855) and Humboldt in Germany; *terrestrial electricity* by Benjamin Franklin (1706−1790) in America, and by Carl August von Steinheil (1801−1870) and Johann von Lamont (1805−1879) in Germany; and *volcanic and seismic phenomena* by George Julius Poulett Scrope (1797−1876) in England, Robert Mallet (1810−1881) in Ireland, Karl Albert Ludwig von Seebach (1839−1880) in Germany, Michele Stefano de Rossi (1834−1898) in Italy, and Eduard Suess (1831−1914) in Austria (Günther 1884−1885, I, p. 19).[29] He went on to suggest that "in a narrow sense, the so-called geophysical school" was essentially British, beginning with the mathematician, geologist and seismologist William Hopkins (1793−1866) and subsequently involving the astronomers George Biddell Airy (1801−1892) and George Howard Darwin (1845−1912); the Irish mathematician and physicist, Sir George Gabriel Stokes (1819−1903); and the Irish-born physicist, Sir William Thomson (1824−1907); all of whom applied mathematical analysis to terrestrial phenomena, such as the nature of the earth-moon system, tides and hydrodynamics, geology, secular cooling of the earth, atmospheric electricity and electromagnetism. He concluded (Günther 1884−1885, I, p. 30) that 'geophysics (physics of the earth)' and 'physical geography' could not be conceptually separated and were essentially synonymous.[30]

The contents of his book embodied this view: The first part concerned the solar system, the earth's position within it and the earth-moon system. He then discussed the shape of the earth, gravitational attraction, the geoid, the rotation of the earth and methods of graphical depiction of the earth's surface, using projection methods and the use of isolines to depict land height and ocean depth. Finally, a section "Geophysics in the narrower sense" covered temperature variation with depth in mines, boreholes and tunnels, hypotheses about the interior of the earth, volcanic phenomena and earthquakes. His subsequent *Handbuch der Geophysik* (1897−1899) also held to this plan.

Figure 3 shows that while usage of the phrase 'physics of the Earth' has changed relatively little following its introduction, that of 'physical geography' increased steadily until the 1860s, whereas use of 'geophysics' continued to increase from 1861 until about 1960 and that of 'geophysicist' increased steadily from 1877 into the twentieth century, reaching its peak in 1958 (Figure 4; partly accounted for by an increase in use in the Italian and Spanish literature) before showing a decline in modern times.

The relative frequencies of 'geophysicist' in the various languages (Figure 5) show that its take-up appears to have begun in Germany, Italy and France some 20−30 years before that in English-language publications. This is particularly striking when it is considered that the English-language Google n-gram corpus is over four times larger than that for the other languages. Note the continued increase in the English literature after the 1960s, whereas Italian, Spanish, German and French usage all begin to decline after that time.

The 1880s saw the emergence of the first serial publications dedicated to what we would now regard as 'geophysical' topics (Table 1, Figure 6). Many of these were the products of the growing number of observatories recording earth tremors, the first of which was established in Japan by the English geologist, engineer and seismologist, John Milne (1850−1913). He took up the position of Professor of Mining and Geology at the

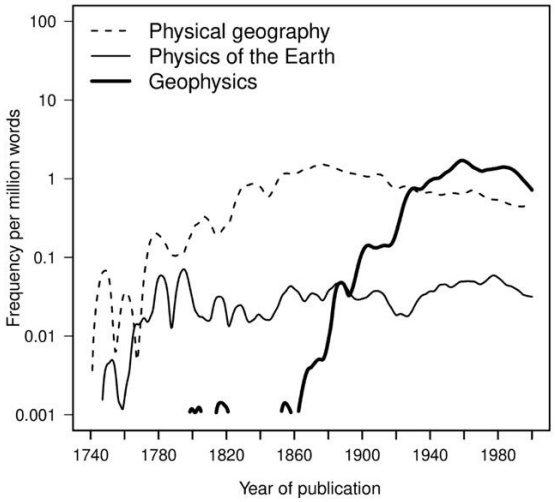

Figure 3. Relative annual frequency of the phrases 'physics of the Earth', 'physical geography', *and* 'geophysics *(including their equivalents in French, German, Italian and Spanish) between 1740 and 2000 in the Google n-gram corpuses.*

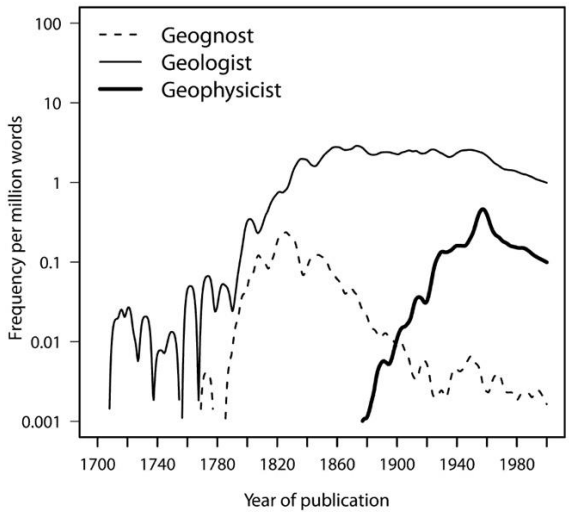

Figure 4. Relative annual frequency of the terms 'geognost, 'geologist' *and* 'geophysicist' *(including their equivalents in French, German, Italian and Spanish) between 1800 and 2000 in the Google n-gram corpuses.*

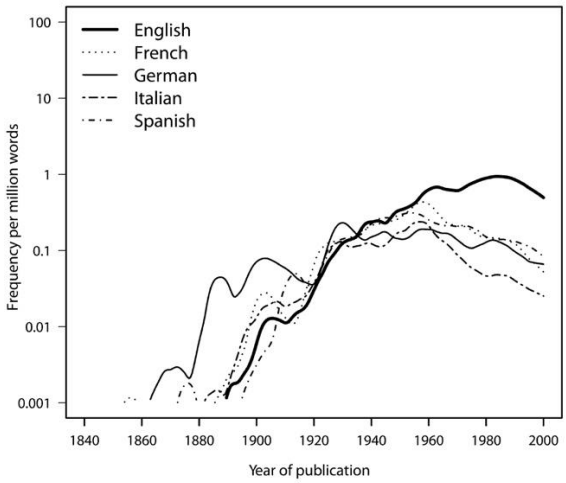

Figure 5. Relative annual frequency of the word 'geophysicist' *and its equivalents in English, French, German, Italian and Spanish between 1840 and 2000 in the Google n-gram corpuses.*

Imperial College of Engineering in Tokyo in 1876. He had an active interest in volcanoes and, following the Tokyo-Yokohama earthquake of February 1880, this broadened into the development of instruments for monitoring earthquakes (Milne 1898). Together with others, he founded the Seismological Society of Japan and the publication of the *Transactions* of this society marks the beginning of dedicated geophysical serials (see also Schweitzer and Lee 2003).

Table 1. Early geophysical serial publications

Duration	**Title**
1880–1892	*Transactions of the Seismological Society of Japan* (Tokyo)
1887–1990	*Beiträge zur Geophysik* [Contributions to geophysics] (Leipzig), subsequently known as *Gerlands Beiträge zur Geophysik*
1887–1945	*Tōkyō-Teikoku-Daigaku-Rigakubu-kiyō* [Journal of the College of Science, Imperial University of Tokyo] (Tokyo)
1895–1930	*Bollettino della Società sismologica Italiana* [Bulletin of the Italian Seismological Society] (Rome)
1897–1926	*Mitteilungen der Erdbeben-Commission der Kaiserlichen Akademie der Wissenschaften in Wien*. [Communications of the Earthquake Commission of the Imperial Academy of Sciences in Vienna] (Vienna)
1897–1930	*Publications of the Earthquake Investigation Committee in foreign languages* (Tokyo)
1899–1948	*Terrestrial Magnetism and Atmospheric Electricity* (Cincinnati, Ohio)
1900–1913	*Circular. Seismological Committee, British Association for the Advancement of Science* (Newport)
1901–1913	*Comptes Rendus des Seances de la Commission sismique permanente de Saint-Pétersbourg* [Proceedings of the Sessions of the Permanent Seismic Commission of St. Petersburg] (St. Petersberg)
1902–1913	*Izvestiya Postornnoi Tsentral'noi Seismicheskoi Komissii. Imperatorskaya Akademiya Nauk* [Proceedings of the Postornoy Central Seismic Commission. Imperial Academy of Sciences] (St. Petersburg)
1907–1937	*Publications du Bureau central de l'Associacion internationale de sismologie. Serie A.* [Publications of the Central Bureau of the International Association of Seismology] (Strassburg)
1918–1969	*International seismological summary* (Edinburgh)
1921–1924	*Seismological Notes. Imperial Earthquake Investigation Committee* (Tokyo)
1922–1934	*Comptes rendus des seances de la Union Geodesique et Geophysique Internationale* [Proceedings of the meetings of the International Geodesic and Geophysical Union] (Toulouse)
1922–1947	*Nihon tenmongaku oyobi chikyu butsurigaku shūhō: gencho oyobi shoroku* [Japanese journal of astronomy and geophysics. Transactions and abstracts] (Tokyo)
1922–1957	*Geophysical supplements to the monthly notices of the Royal Astronomical Society* (London)
1922–1960	*Transactions of the American Geophysical Union* (Washington)
1922–1988	*Zeitschrift für angewandte Geophysik* [Journal of applied geophysics] (Berlin)
1924–1944	*Veröffentlichungen der Reichsanstalt für Erdbebenforschung in Jena* [Publications of the German Empire Institute for earthquake research] (Jena)
1924–current	*Zeitschrift für Geophysik* [Journal of geophysics] (Braunschweig)
1925–1927	*Izvestiya Instituta Prikladnoi Geofiziki* [News of the Institute of Applied Geophysics] (Leningrad)
1925–1944	*Tōkyō Daigaku Rigakubu kiyō. Dai 2-rui, Chishitsugaku, kōbutsugaku, chirigaku, jishingaku* [Journal of the Faculty of Science, University of Tokyo. Section 2. Geology, mineralogy, geography, geophysics] (Tokyo)
1936–current	*Geophysics* (Tulsa)
1939–current	*Geofisica Pura e Applicata* [Pure and applied geophysics] (Milan)

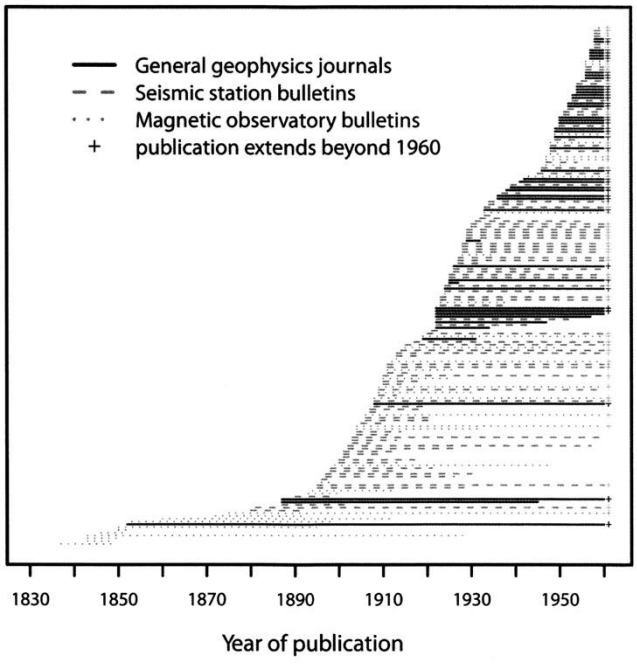

Figure 6. Timelines for 185 geophysical journals and other serial publications which began prior to 1960.

What can now be regarded as the first general geophysical journal, *Beiträge zur Geophysik* [Contributions to geophysics], began publication in 1887.[31] It was founded by the German philologist, anthropologist, geographer and, ultimately, geophysicist, Georg Karl Cornelius Gerland (1833−1919). He initially studied philology and anthropology in Berlin and Marburg, then taught in high schools in Kassel, Hanau, Magdebourg and Halle from 1856, until his appointment as Professor of geography and ethnology at the University of Strasbourg, France, in 1875, where he remained until his retirement in 1909. During that time, he lectured on theology, ethnology, cartography, mathematical and descriptive geography, biogeography and geophysics. Rejecting the established view that geography was the study of the surface of the earth because he believed that the surface could not be considered in isolation, he envisaged the subject as the study of the Earth in its totality, the result of interaction between interior and exterior forces: a complex of interactions which tended towards a stationary state. He regarded geography as a physical science, embodying the study of those interactions and the transformation of 'telluric' material as the result of their effect, whose basis was the 'physics of the globe'. Seismicity could be thought of as one manifestation of this interaction.

In 1887 Gerland established the *Bureau Central Météorologique d'Alsace-Lorraine* in Strasbourg, under the direction of his former pupil, the meteorologist Hugo Emil Hergesell (1859−1938), the *Kaiserlichen Hauptstation für Erdbebenforschung zu Strassburg* [Imperial main station for earthquake research at Strasbourg (KHES)] in 1900, and the *Bureau Central International de Sismologie* in 1901. Gerland undertook the roles of both director of the seismological station and editor of *Beiträge zur Geophysik* until 1909, when he retired as a result of his age and health (Vogt 1999).[32] At the Sixth International Geographical Congress, held in London in 1895, Gerland, supported by his fellow-countryman the seismologist, Ernst von Rebeur Paschwitz (1861−1895), put forward the case for the establishment of an international seismological association and, at the following Congress, held in Strasbourg in 1901, the International Seismological Association was formally established, and completed its organization in 1903. As a consequence, from 1895 to 1918, the front cover of the *Beiträge* included the subtitle *Zeitschrift für physikalische Erdkunde* [Journal of physical geography], to which was added in 1908 *Zugleich Organ der Kaiserlichen Hauptstation für Erdbebenforschung zu Strassburg* [also the mouthpiece of the KHES], but in 1911 it was renamed *G. Gerland's Beiträge zur Geophysik.* Following suspension of publication between the years 1919 to 1925, it resumed in 1926 as *Gerlands Beiträge zur Geophysik*, a title which it retained until it eventually ceased publication in 1990.

The earliest geophysical investigations were directed to unravelling the mysteries of 'physics of the Earth', embracing subjects such as the Earth's gravity and magnetic fields, seismicity related to earthquakes and volcanic activity, heat flow, geoelectricity and auroral displays, etc. However, as time went on, it was realised that geophysical methods could also be usefully applied to the search for minerals, oil and gas. Looking back over the initial period of growth in the geophysical literature from the perspective of the 1920s is made possible to some extent by means of the extensive bibliography in one of the first textbooks on applied geophysics, *Methoden der angewandten Geophysik* [Methods of applied geophysics], published by a leading German exponent of the science, Richard Karl Theodor Ambronn (1887−1954), in 1926 (English translation in Ambronn 1928). Ambronn began his own journal, *Zeitschrift für angewandte Geophysik* [Journal of applied geophysics] in 1922, which continued to the present day.

A frequency distribution of the years of publication of the works cited in Ambronn's bibliography (Figure 7) reflects steady growth in the field from 1870 onwards, apart from a brief downturn during the First World War. Taken together with the evidence of Figures 3-5, it suggests that geophysics really began as a discipline in the 1860s.

7. EARTH SCIENCE AND GEOSCIENCE

A definition of *earth science* in a 1990s encyclopedia reads: "earth science(s): dealing with the various aspects of the physical constitution of the earth, as geology, geophysics, oceanography, meteorology, etc." (Brown 1993, p. 775) but the word "geoscience" is not included in the dictionary. By way of contrast, a contemporary definition states that "earth science or geoscience includes all fields of natural science related to the planet Earth." These include: geology and subdivisions: environmental geology, Quaternary geology, planetary geology, petroleum geology, historical geology, hydro geology and structural geology, but also: geochemistry, geochronology, geomagnetics, geomicrobiology, geophysics, mineralogy, palaeontology, micropalaeontology and palynology, petrology, physical geodesy, sedimentology, seismology, stratigraphy and volcanology; but in addition: atmospheric science, geodesy, geography, glaciology, oceanography and planetary science.[33] Nevertheless, use of the terms *earth science* and *geoscience* can be traced back to 1852 and 1929 respectively (Figure 8). There is not space to go into detail here, but early examples include the occurrence of *la science de la terre* in de Nigris (1851), *Geowissenschaften* in Richthofen (1862), *earth-science* in Wilson (1883), and *geoscience* in Field (1941).

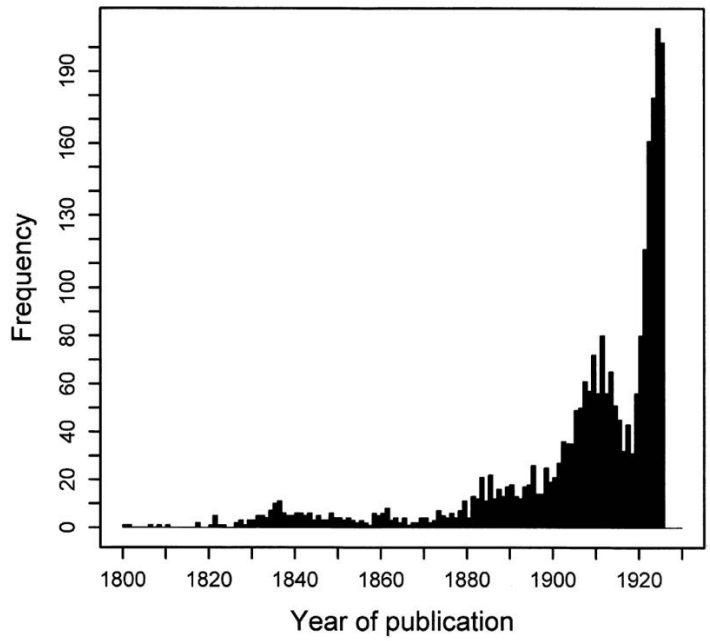

Figure 7. Frequency distribution of the year of publication of the 2475 works cited in the bibliography of Methoden der angewandten Geophysik *(Ambronn 1926).*

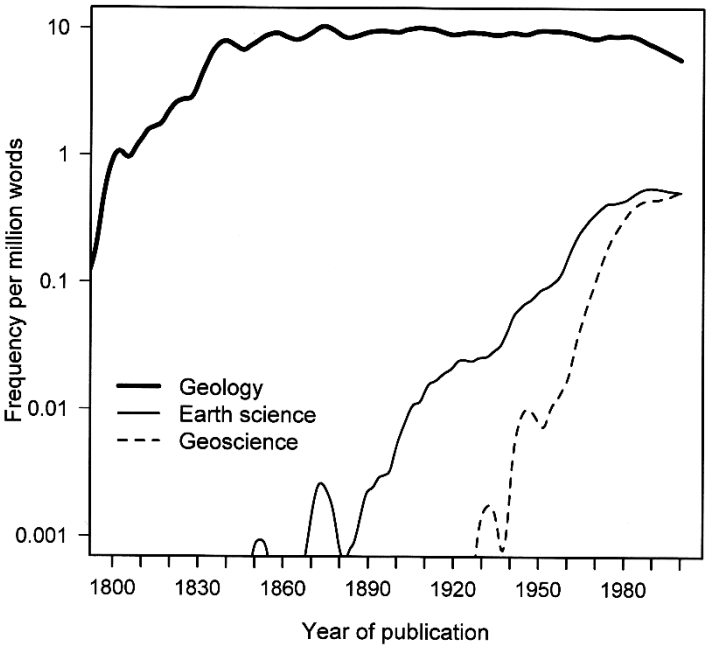

Figure 8. Relative annual frequency of the words 'geology,' 'earth science*' and '*geoscience*' (including their equivalents in French, German, Italian and Spanish) between 1800 and 2000 in the Google n-gram corpuses..*

8. CONCLUSIONS

Although there was some early criticism of the way the Google Books Ngram Corpus was compiled (*e.g.* Nunberg 2009), provided the data have been suitably normalized (Younes and Reips 2019; see f.n. 3 above), despite the exclusion of very low numbers of annual n-gram occurrences (which does not make it possible to identify the very earliest occurrence of a particular term in the corpus), graphs of the variation of normalized n-gram frequency through time have been found in this work to provide a useful aid to the study of the history of the geosciences. The time-trends summarised below are based on multi-lingual averages.

The idea that the word *geologia* was introduced by the Italian natural philosopher and mineral collector, Aldrovandi, in the late sixteenth century, rather than by the English cleric de Bury some 130 years earlier, is supported. The term entered the literature around 1700 and a major increase in its use, began in 1796 and lasted until about 1850, after which it remained levelled-off, although the exact meaning of the word *geology* changed during that time from

an all-embracing ‘philosophical View of the terraqueous Globe’ to a more focussed ‘account of all the stony masses which compose the crust of the earth.’ Usage of *geologist* followed a similar path.

The terminology introduced in Germany by Füchsel and Werner, who were trying to discriminate between what was based on observation and established facts from speculative theory: *geognosy* (what was *known* of the nature of the Earth), *geogony* (*theories* regarding the formation of the Earth) and *oryctognosy* (the identification of minerals) entered the literature in 1768 and reached their maximum usage in 1819, 1824 and 1826 respectively, after which time they progressively fell out of use. Reference to their followers, *geognosts*, followed a similar pattern, also beginning to diminish after 1825.

Following many years of observation of magnetic phenomena, gravity, and the occurrence of earthquakes (e.g. use of the term *Physik der Erde* goes back to the eighteenth century), the science of *geophysics* became properly established in the mid-nineteenth century and this was reflected in a steady growth of magnetic and seismic observatory bulletins after 1830. The term *geophysicist* began to appear in the German literature about 1860 and the first dedicated journal, *Beiträge zur Geophysik*, began publication in 1887.

Significant usage of our all-encompassing ‘modern’ terms *earth science* and *geoscience* began in 1852 and 1929 respectively.

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1 This term refers to the degree of flattening of the earth, regarded as an oblate ellipsoid.

2 This contains data from 8.12 million books, dating from 1500 to 2000. It comprises 4.54 million volumes in English; 0.79M in French; 0.85M in Spanish; 0.66M in German; 0.59M in Russian; 0.31M in Italian; 0.30M in Chinese; and 0.7M in Hebrew (Lin *et al*. 2012). Some of the 'books' are in fact bound volumes of journals.

3 The annual n-gram data were retrieved (ignoring case) from the various 2012 corpuses using Sean Carmody's *ngramr* package (https://github.com/seancarmody/ngramr, 2015) for the open-source *R* language developed under the *R*-project for Statistical Computing (see: http://www.r-project.org/). However, n-grams occurring less than 40 times in the corpus are not recorded in the publicly-available database (Michel *et al*. 2011). In order to take account of variation between the differing language corpuses, the raw data trend for each n-gram was first normalised relative to the average frequency of occurrence of a set of 'neutral' words (*i.e*. 'words with little or no specific meaning'): *the*, *of*, *and*, *in* , *a*, *is*, *was*, *not* and *other*, in English and their equivalents in the other languages, as advocated by Younes and Reips (2019). The general time-trend for a given n-gram was then obtained by first averaging the normalised relative frequencies for each year across all

corpuses used, and then smoothing the resulting average trend using robust locally-weighted regression (Cleveland 1979) with a 12-year moving window. This technique has been used to construct all the n-gram based figures in this paper. On account of the large variation in the frequency ranges of different n-grams, the results are displayed using semi-logarithmic charts. The advantages shown by this type of graph are discussed by Schmidt (1986): notably, an exponential increase or decrease becomes linear in a semi-logarithmic plot, which can cover a very wide range of values. Changes in the meaning of words cannot be taken into account. The Russian corpus has not been used here, as the average variation with time shown by some of the 'neutral' words was found to be very different between 1915 and 1925 to their relatively constant frequency in the other languages, and the reason for this is not clear.

4 Although the total sizes of each national corpus in the n-gram database are reported in Lin *et al*. (2012*)*, the sample sizes per decade are not given. However, some data are available from the Hathi Trust Digital Library website in which the Google-scanned 'books' are deposited; see: https://www.hathitrust.org/visualizations_dates. Social science users of the database have suggested that it is biased towards science and engineering (*e.g*. Pechenick *et al*. 2015), but that is not a difficulty in this study.

5 These first two volumes appear always to have been printed as one.

6 Koeberl (2018) and Klemun (2018) discuss two major collections from the 18th and 19th centuries. Bromhead (1945) is informative on geological investigators before 1600, suggesting that "by the opening of the seventeenth century in England and Wales, France, Germany and Italy the infant science of Geology had come to birth" (p. 129).

7 This term, meaning a magnifying-glass (Latin: *speculum comburens*), occurs earlier in the first (Latin) edition of Sir Francis Bacon's (1561–1626) *Novum Organum Scientarum* [New Instrument of Science] (1620) *e.g*. item 28 of his *Tabula Gradum, sive Comparativae in Calido* [Table of Degrees, or Comparison in Heat; pp. 189–203] begins: 'Fiat Experimentum per specula comburentia . . .' [Let a trial be made with burning glasses . . .] (Verulamio 1620, p. 198).

8 A similarly broad view of the scope of 'geology' was reflected in works by the German mathematician, astronomer and philosopher, Detlev Clüver (1645−1708) and by the theologian August Friedrich Wilhelm Sack (1703−1786) (Clüver 1700; Sack 1785).

9 Edmond (also spelled Edmund) Halley (1656–1742).

10 Known from antiquity; according to Gilbert (1600, p. 9) a loadstone (also spelt lodestone and load-stone; loadstone became the most common spelling after 1700) 'resembles unpolished iron and usually is found in iron mines' (English translation: Gilbert 1893, p. 18), its magnetic property being its notable feature. The earliest-known specimens were composed of iron-ore rich in magnetite which had become naturally magnetized as a result of lightning strikes on surface outcrops.

11 Abraham Gottlob Werner (1749−1817).

12 Oryktognosie occurs in the title of Werner (1792); and both oryctognosie and geognosie in the title of a multilingual dictionary (Reuss 1798) of the terms used in Werner's mineral classifcation scheme; for an English version of the scheme itself see Jameson (1830, vol. XIV, pp. 389-572).

13 Guntau (2009, p. 169) gives these English translations as they appear in vol. 10, pp. 68–70, of the 84 volumes of of Werner's handwritten papers in the Georgius Agricola Library of the Technische Universität Bergakademie, Freiberg. See also Werner (1791b, p. xiv; 1805, pp. 1-2; 1792), Reuss (1798). Weaver's translation (Werner 1805) implies that Werner used the term oryctognosy in his 1774 German text, but he does not appear to have done so.

14 Use of the term (in French) by Pott, is mentioned in Anonymous (1765, p. 120), where it is translated into English as *litho-geognosy*.

15 Very probably undertaken by Elizabeth Juliana Leeves (1807-1879), wife of the soldier and geophysicist Sir Edward Sabine (1788-1883); she later translated other works by Humboldt into English.

16 The English agriculturalist and geologist Robert Bakewell (1767–1843) was scathing regarding Werner's terminology: 'Geognosy, as defined by Mr. Jameson, "teaches us the relative position and mode of formation of the mineral masses, of which the crust of the earth is composed." Though the Germans, who delight in multiplying words, affect to make a distinction between geology and geognosy, according to this definition they are synonymous.' 'The term "well educated geognost" as used by some writers denotes a perfect disciple of Werner, who lost the use of his own eyes by constantly looking through the eyes of his master [?Füchsel].' (Bakewell 1813, p. 353) Again: 'Werner and his disciples, and also some of the French geologists, have changed the term [geology] into Geognosy; but for this change no sufficient reason can be assigned', 'Nothing can be more unmeaning than the apologies that have been offered for substituting γνώσεις (*gnosis*) "knowledge," for λογος (*logos*) "reason". By the same rule we ought to change meteorology, physiology, &c. into meteorogony, physiogony, &c.' (Bakewell 1828, p. 3).

17 In a passage which refers to "the *isochronism* of widely extended formations" [emphasis as in original], it continues: "The attempts which have been made by the Hebraic geologists to subject the epochas to absolute measures of time, and to connect the chronology of antient cosmogenic traditions with actual observations of nature, have proved fruitless." (p.28).

18 The slight increase in their usage after 1920 is presumably attributable to twentieth century publications concerning the history of geology.

19 Drawing in part on members of the Askesian Society (1796-1807), which was devoted to general scientific enquiry and the British Mineralogical Society (1799-1806); (Woodward 1908, pp. 6-18).

20 "Physique celeste, qui expliqera la nature des Cieux & des Astres, & en Physique Elementaire ou terrestre, qui examinera les corps sublunaires".

21 "*La Physique ou la Connoissance des Corps Naturels, & de leurs Proprietez. Livre quatrieme. De la Nature & des proprietez des Corps Terrestres en general".*

[22] La Physique terrestre, . . . demande cependant une étude assidue. L'intérieur de notre Globe fournit d'abord le spectacle des *Feux souterreins*, les *Tremblement de terre causes par l'Electricité,* les *Fossiles*, c'est-à-dire, les *Métaux*, *l'Aiman*, les *Pierres ordinaires* & *les pierres précieuses*, &c. [emphasis as in original].

[23] Luc (1792, p. 181); begun in 1773 under the editorship of Jean-François Pilâtre de Rozier (1754–1785), who taught chemistry and physics at the Academy in Reims.

[24] Part of the Holy Roman Empire until 1806, when it became part of France.

[25] Anonymous (1829, p. 94); almost certainly edited by the German surgeon and publisher, Ludwig Friedrich von Froriep (1799-1874) (Evenhuis 2015).

[26] die Wissenschaft der Geologie im weitesten Sinne des Wortes, als allgemeine Naturlehre der Erde (Physik der Erde; Geophysik; theoretische Erdkunde).

[27] Such as: Hansteen (1819), Reich (1834*a*,*b*; 1838), Gauss (1839; English translations in Gauss 1841 and Glassmeier & Tsurutani 2014), Erman (1835, 1841), Sabine (1838, 1840, 1841, 1842, 1843*a*,*b*,*c*; 1844, 1846*a*,*b*; 1849, 1851) and Humboldt (1845−1862; English translations in Humboldt 1855−1858, 1868).

[28] Such as: *Philosophical Transactions of the Royal Society* (established 1665); *Comptes rendus de l'Académie des Sciences* (1666); *Göttingischen Gelehrte Anzeigen* (1739); *Journal de physique, de chimie, d'histoire naturelle et des arts* (1787); *Annuaire de la Republique Française, présenté au Corps Législatif par le du Bureau des Longitudes* (1796); *The Quarterly Review* (1809); *Annales de chimie et de physique* (1815); *Annalen der Physik und Chemie* (1824); *London and Edinburgh philosophical magazine and journal of science* (1832); and *Resultate aus den Beobachtungen des Magnetischen Vereins* (1837).

[29] He also included *celestial mechanics*, as pioneered by Pierre-Simon Laplace (1749−1827), Joseph-Louis Lagrange (1736−1813), and Siméon-Denis Poisson (1781−1840) in France; *oceanography* by John William Lubbock (1803−1865) and William Whewell (1794−1866) in England and Matthew Fontaine Maury (1806−1873) in America; *meteorology* by Heinrich Wilhelm Dove (1803−1879) in Germany, Ludwig Friedrich Kämtz (1801−1867) and Adolf Theodor de Kupffer (1799−1865) in Russia, and Christopher Hendrick Dirk Buys-Ballot (1817−1890) in Holland.

[30] In 1829−1830, Johann Karl Eduard Schmidt (1803−1832), a German mathematician and astronomer, published a two-part work *Lehrbuch der mathematischen und physischen Geographie* [Textbook of mathematical and physical geography] (Schmidt 1829, 1830), the first volume of which, 'mathematical geography', was concerned with movement and positioning in relation to the Sun and 'fixed' stars; the mathematical projections used to represent the spherical earth on maps; and determination of the degree of flattening ('figure') of the earth from measurement of the lengths of a seconds pendulum at different latitudes. The second volume, 'Physical geography', included sections on the nature of the surface of the earth and its atmosphere; its surface and internal temperature; its geology and internal density; a surprisingly brief discussion of geomagnetism; and the ebb and flow of the seas. Schmidt subsequently became professor of mathematics at the University of Göttingen (1831−1832) and then professor of mathematics, astronomy and physics at the University of Tübingen, Germany, where unfortunately he died soon after his appointment. With the exception of the earth's flattening, the other topics, which we would now include within geophysics, were evidently considered to be part of physical geography.

[31] The first volume of the *Beiträge zur Geophysik* was devoted to *Abhandlungen aus dem geograpischen Seminar der Universität Strassburg* [Treatises from the geography seminar of the University of Strasbourg] and described work carried out by members of its research group. In his introduction, Gerland expressed the view that "the methods of geology, so far as they are founded on paleontology, [are not] the proper field of geographical studies", and he confined the latter "to the study of the problems of geophysics: *i.e.* the study of the physical and chemical forces as acting upon the earth" (Anonymous 1888, p. 203). However, a count of the types of articles in all the issues prior to World War I shows that about 60% of them were concerned with earthquakes and seismology; 10% with atmospheric physics and auroral phenomena; 7% with gravity measurements; 5% with the shape and constitution of the earth and aspects of terrain morphology; and the rest with vulcanology, geomagnetism, geothermy, etc.

[32] As he approached retirement, from 1899 Gerland shared the role of editor with Emil Julius Friedrich Rudolph (1853−1915), Professor of geophysics, seismology and vulcanology at the University of Strasbourg and from 1910, Rudolph shared his editorial role with the astronomer and geophysicist Oskar Hecker (1864−1938), who had previously worked at the Geodesy Institute in Potsdam and had just been appointed director of the KHES.

[33] Wikipedia definition at: https://en.wikipedia.org.wiki/Earth_science.