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Author(s): F. von Richthofen

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THE IMPETUS AND DIRECTION OF GEOGRAPHY IN THE NINETEENTH CENTURY.*

By Baron F. von RICHTHOFEN.

I.

THE object of geography is the study of the Earth. Its data are obtained from observations of the Earth's surface. Its bounds widen with the area explored and with the intensity of investigation. Hence, at all times an extension of the field of vision has stimulated interest and promoted the collection of data, while impulses of quite another kind have determined progress in the deepening and exact comprehension of observations and in scientific work.

Various motives have been the basis of human activity, which in the long course of time have led to the widening and illumination of the field of vision, which in the past century embraced almost the whole surface of the Earth. The majority of these motives have always existed, and but few are due to the development of scientific methods. The most elementary is the spirit of adventure, forcing man by some unconscious inner power to fight the dangers of the unknown, and this has governed many from the days of Pytheas to the African explorers of recent years. The search for treasure is another motive which has led to the extension of the known. Of precious metals, stones, or spices, which have been lodestars to many adventures, gold has been the chief. Trade has been a less important factor, for from early times a knowledge of routes and markets has usually been confined to the interested parties (cf. the scanty knowledge of Phœnician routes and trade obtained by their neighbours). Trade has served to develop relations between peoples, and to bind together their reciprocal interests, but the trader himself has really never directly promoted the scientific study of the Earth. In opposition to this we may set the desire of civilized powers to acquire fertile lands within their ken or to control trade routes. This has been a powerful factor in extending the bounds of the known world and of throwing more light on the known part. History is filled with examples. Territorial expansion by war brings new lands into the new sphere of influence, and gives a new base from which to obtain information about the region beyond. Since the discovery of America, colonial expansion has brought an interest in the wider world to many a narrow home, but in counting the value of colonies such imponderable matters are too often left out of account. Special embassies have not infrequently extended and clarified geographical knowledge; for instance, those of Carpini and Rubruquis. Missionary travels have been of very varying significance from a geographical point of view, Livingstone's travels are among the best. Pilgrimages to religious sites and centres awaken and spread an interest in distant lands. Those to Mecca need only be cited. Mission work has been most valuable geographically when religious efforts have been combined with political ones, *e.g.* the Jesuits in China in the time of Louis XIV. Lastly, there is the desire for knowledge in the individual, which inspires an Ibn Batuta or a modern globe-trotter at the one end and the scientific explorer at the other.

II.

Almost up to the beginning of the nineteenth century knowledge of the Earth, whether personal or based on the growing information, was utilized in three ways.

* An abstract of the Inaugural Address by Baron F. von Richthofen as Rector of the University of Berlin. 'Zeitschrift der Gesellschaft für Erdkunde zu Berlin,' 1903, No. 9.

1. Practical considerations naturally led to the recording of visible lines, especially of the coast-line near harbours. The word "geography" was first used by the Greeks only in the sense of this graphic representation. The early development of mensuration and geometry helped. In view of the fact that by 200 B.C. Eratosthenes had calculated almost correctly the diameter of the Earth, it is astonishing that it took four hundred and fifty years—from 300 B.C. to 150 A.D.—to pass from the idea of drawing the parallel of Rhodes to the construction of a network. Then the progress of cartography was arrested. The Arabs did not reach as far as the Greeks. One thousand three hundred years after Ptolemy, his network was used again, and, with Marco Polo's tale and the utilization of the compass, led to the discovery of the New World. This gave a motive for a further advance. Yet in all the period of maritime discovery, the second phase of which ended with Cook's voyage in 1780, the old ways of map-making traced by the Greeks were followed. Greater exactness resulted from the development of astronomy, improved arts and instruments of navigation, the use of triangulation for land surveys, new map projections, the discovery of the polar flattening of the Earth, and improved processes of drawing and reproduction. In comparison with that of the Greeks, it was a rich and exact map which was available at the beginning of the nineteenth century, but it lacked a representation of relief, without which a map is a mere skeleton.

2. The *written records* are unequally imperfect, and show the effect of periodic extensions of the horizon of the known. We descry in Herodotus and in Strabo the practical importance of the information. The rapid extension of the political horizon of the Arabs gave rise to many encyclopædic geographical works, but they are not so philosophical or critical as those of Strabo. From the thirteenth century compendia of knowledge appeared among Christian peoples, containing many wonders, but little understanding. The general encyclopædias of Vincent de Beauvais (1250), Konrad von Megenberg (1349), and Petrus de Alliaco (1410), show improvements. Sebastian Münster's '*Kosmographie*' (1550) is characteristic, but a real step forward was made by Athanasius Kircher in the seventeenth century, while many dry *repertoria* appeared in the eighteenth.

3. Interpretation was begun by the ancients. The distribution of heat and cold in zones, winds, periodic floods and their connection with rainfall, the relations of rain to the ocean, alluvial deposits, coastal changes, and tides were taken into account. No further progress was made before the middle of the seventeenth century. It required such a man of genius as Bernhard Varenus, whose '*Geographia generalis*' appeared in 1650, to write this the first work on the subject, one of which Sir Isaac Newton thought so highly that he prepared an English edition. Humboldt was the first to step in his footprints. In the interval Halley drew a map of lines of equal magnetic declination in 1701, Hadley propounded the first wind-law for the trades, Bernouilly and Euler studied oceanic movements and applied mathematics to phenomena of physical geography.

The art of observation was gradually learned, but phantasy was rife in the *à priori* eighteenth century. Kircher's '*Mundus subterraneus*' (1665) gave the idea of an *ossatura globi* which prevailed for a century. Buache's (c. 1750) framework of the Earth has still its relatives in modern Germany, and influenced Humboldt. The catastrophe theory of Pallas and Buffon, and the fights of Neptonists and Plutonists, witness to the desire for explanation. Right observations were extended by theoretic extrapolation. The data for genetic knowledge was lacking.

In the last third of the eighteenth century, the philosophy of Kant, the development of natural philosophy and of chemistry, exhibited the intellectual progress. A

knowledge of the significance of questioning nature by experiment led to doing so by observation, as the work of Linnæus testifies. Celsius observed the movements of the Swedish coast-line, and about 1760 the Cosmographical Society was founded in that country, leading to the publication of Bergman's 'Physical Description of the Sphere.' About 1780, Zimmermann concluded, from his researches into the distribution of animals and man, that there had been changes in the distribution of land and sea. Deluc, in 1772, gave the means of using the barometer to measure heights. De Saussure observed the folding of strata in the Alps. Hutton indirectly arrived at the explanation of the chiselling of mountains by observation of actual dynamic operations; and Werner formed a school for the better ordering of the sequence of geological formation.

III.

With the nineteenth century came, in the person of Alexander von Humboldt, the man who first fully combined the scholar and the scientific explorer. He was the founder of geography as a natural science. Three hundred years after the discovery of America he discovered it anew for science. His aim was not simply to observe phenomena for themselves, but also to investigate their causal relations. He advanced not merely general geography, but all parts of geography. Land-forms, outer and inner structure of mountains, the way they are arranged, the trend of the coast, thermal conditions of the atmosphere both in horizontal and vertical planes, their relationship to the distribution of plant species and formations, terrestrial magnetism, internal heat, volcanoes, are among the problems he tackled; but his interest extended to the connection between surroundings and world situation to human distribution, settlements, and lines of communication. With a marked taste for comparative philosophy and history, he also, for the first time, studied the history of geography and of discovery in a truly scientific way.

As Humboldt taught for only a short time, he founded no school to carry on his work; only from 1833 to 1836 Friedrich Hoffmann lectured on physical geography in Berlin.

In spite of marvellous progress and division of labour, the content and method of geography are very closely related to the meaning given to them by Humboldt. Progress has been irregular, and more in illuminating than extending the field of investigation. In the scientific voyages of the first sixty years geography played a small part. Later the *Challenger* and other expeditions added more to our knowledge of the ocean in a few decades than had been previously acquired from ancient times to the middle of the nineteenth century. The exploration of the land was begun with great promise under such men as Hutton, Werner, de Saussure, and von Humboldt. Practical considerations led various states to inaugurate surveys, trigonometrical, topographical, and geological, and gradually the appreciation of the scientific value of this work increased.

From the middle of the century on, the interiors of the great continents were explored. Later the discovered lands were divided among Western nations, and some of them are now surveyed. International co-operation in investigations has come, *e.g.* in geodesy, terrestrial magnetism, seismology, meteorology. A vast literature has grown, and a knowledge of results has been spread abroad by academic and popular lectures.

As in olden times, this knowledge has been utilized in three ways, but they are otherwise grouped. Encyclopædic registration stands apart. Near it is general geography, which formerly had not found its true place, but now possesses a definite method and an extraordinary growth of contents. The highest problems of measurement, which formerly had a separate place, are now indissolubly associated with

geophysical problems to form a general science of the Earth which may be contrasted with descriptive or regional geography.

Regional geography at the beginning of the nineteenth century was a mosaic. Karl Ritter improved it in two ways, by methodical use of sources, and by the philosophical handling thereof, ever seeking the causal connection between Earth and man. He built up no school.

Division of labour was necessary for progress. Specialization took two directions, (*a*) studying a strictly limited area, or (*b*) limited phenomena universally. In chorology a new spirit of higher scientific treatment of the contents of any part of the Earth's surface has arisen.

IV.

General geography has also been subdivided. The major divisions are cosmic geography, which has as subject the Earth as a whole, and the science of the surface of the Earth, which investigates its crust and outer spaces.

The problems of cosmic geography have become so varied that further subdivision is necessary. One branch is geophysics, which cannot be considered apart from cosmic physics, for it is necessary to take heavenly bodies into account in discussing internal heat, mean density, surface gravity, terrestrial magnetism, deformation, and each of these problems has its bearings on both physical geography and geology. It is only necessary to mention such phenomena as volcanoes and hot springs, earthquakes, modifications of sea and atmosphere, the deformation of the Earth in the past, and subsequent alterations in the sea. The scientific consideration of most of these problems was begun, or at least took a definite form during some period of the nineteenth century. Another branch is the measurement of the shape and size of the Earth. Although the principle involved in calculating the size of the Earth was known to Eratosthenes, yet the discovery of the polar flattening fundamentally altered the problem. The most refined methods must be adopted to discover the deviation of the Earth from its spherical shape, and the still smaller regional variations from the normal spheroid. This leads to problems of variations in gravity. The simplification of the pendulum has given an impulse to this study, and has resulted in the discovery of unexpected connections between the inner structure of the Earth's crust, and the trend of magnetic lines, and, later, to newer problems, such as the movement of the poles.

Trigonometrical measurements are the basis of large-scale maps. Not merely are there better representations of the curved surface on the map, but the topographical maps are made the basis for the representation of relief and other conditions. Nearly two hundred years separate the attempt of the Italian Borri (1632) to draw magnetic lines from Humboldt's isotherms (1817). In the interval Kircher (1665) drew the first map of ocean currents, Halley (1701) produced a better map of magnetic lines of deviation, and Zimmermann (1780) attempted to make a world map of animal distribution. At Humboldt's instigation, the so-called Physical Atlas of Berghaus appeared in 1840. It was an epoch-making work, and led to wider use of the same methods.

Cosmic geography really pursues a deductive course, as it progresses from observations on the exterior of our planet to questions about its inner construction and internal forces. Observations leading to inductive methods deal with the solid crust, the ocean, and the atmosphere. To these may be added a fourth—the constantly varying water, rising from the ocean as vapour and passing through various stages on its cycle back to it, to do which it plays both an active and a passive rôle in the atmosphere, as moving ice or running water alters the solid surface, and in this way is a factor of the highest importance in its outer transformation. Without the water-cycle it would be possible to treat the other three elements separately.

By and through it they are bound in a great dissoluble unity which forms the basis of the general science of the Earth's surface, and so is to be distinguished from the science of the Earth's body. Both together form general geography or the science of the Earth.

The method of investigation is different for each of these elements. The land surface presents changing forms in changing relations from place to place, and also changes in time. Atmosphere and ocean resemble each other in filling of space, material composition, physical condition, and in local and spacial modifications of conditions and mass through motion. The methods of observation differ in that they proceed from the ground upwards in the case of the atmosphere, and from the surface downwards in the case of the ocean. In the latter, the form of the hollow filled by it, and other considerations, among which is the geomorphological rôle of organic life, must be considered. Solar radiations are the chief source of energy modifying substances and causing changes of condition and motion in both elements. It acts from the ground in the atmosphere, from the surface in the ocean. Solar energy is the source of the driving power in the water-circulation. Here the scope of observation is very great, as it touches those which concern the other three elements in many points.

Uncoordinated facts about the surface of the Earth have existed since the earliest times. Aristotle attempted to set them in order. Varenus formed logically derived categories. Slowly the methodical questioning of nature was developed, and led to further divisions within the field of study. The sciences of meteorology and oceanology, hydrodynamics and geology, arose. After their separation there remained to the science of the Earth's surface an extensive field of investigation based on the results of geophysics, geodesy, geology, meteorology and hydrodynamics, which considered the surface of the Earth and the phenomena of the atmosphere, ocean and water-cycle bound together with it, as a unity, and strove to interpret their causal connection on the lines laid down by Humboldt. This to-day is the field of labour of physical geography. Its efforts culminate in geomorphology, *i.e.* in the genetic knowledge of the forms of the Earth, arranged according to categories as well as localities, and the nature of their grouping in terrestrial space. This is based on a knowledge of the composition and structure of the land-form and the genesis of its formation through terrestrial forces, and strives through an investigation of chemical and mechanical activity which is continually going on through the action of external forces to trace the course of the evolution of its present form. Physical geography endeavours to become a science of the theatre of organic life and of human existence.

Physical geography and geology differ in their foundations. Both require physics and chemistry, but geology is based more on mineralogy and palæontology, physical geography on meteorology and hydrodynamics. It is not necessary to draw sharp divisions. The geographer cannot do without the rudiments of geology, and the geologist, in order to understand the past, must make use of the physical geography of the present. Whatever boundaries are chosen, there will remain a broad region common to both sciences. This approach of a subject from two different standpoints has had valuable results, *e.g.* in glaciology the close relations of the two subjects have often been shown. Distinguished geologists like Murchison or Hochstetter turned their interests in later life to geography, while others have been able to work harmoniously in both subjects, *e.g.* Suess.

In addition to the widening of the horizon, and the impetus given by Humboldt, physical geography has been stimulated by many other forces in the nineteenth century, many of which have also affected geology, *e.g.* the discovery of the former glaciation of much of Europe, Darwin's theory of coral reefs, the relations of

winds to the baric gradient, the exploration of the ocean, the study of mountain-building in the United States, the Alps, Scotland, and Scandinavia, the genetic point of view adopted in all branches of science.

Another stimulus to advance has been the governmental support of universities, especially in Germany. The value of this is not merely a function of the formation of laboratories and institutes, but is bound up with the freedom of teaching and learning. The professor is expected not merely to teach, but to increase the knowledge of his subject by research and the direction of research. Only through scientific study of the ground on which man is placed and the environments in which he lives can a foundation be prepared for the methodical development of anthropogeography. Anthropology and ethnology, also following scientific methods, come to meet it and give rise to many problems, such as the correlation of settlement, communications, productions and trade with the natural conditions studied by the geographer. The foundation of geographical chairs in technical and commercial universities will bring forth good fruit in the study of such problems.

ON A FLAT MODEL WHICH SOLVES PROBLEMS IN THE USE OF THE GLOBES.*

By Prof. J. D. EVERETT, F.R.S.

THE perusal of a pamphlet by Major Close, describing the system to be adopted in making a new map of the British Isles to a scale of one-millionth, has called my attention to the very great accuracy with which a region covering 10° or 11° in latitude, and a much greater distance in longitude, can be represented in the flat by a judicious use of conical projection. The errors, both as regards area and distortion, are so small as to be imperceptible to the unaided eye, and are much smaller than the inevitable errors introduced by the stretching and shrinking of the paper in printing a map.

Adopting a plan identical in its main features with that employed by Major Close, but simpler for calculation, I have computed the data for a complete series of maps of the world in 10° zones, and the result is embodied in the model which I now exhibit. This consists of eighteen pieces of thin pearwood, each representing a region extending 10° in latitude and 80° in longitude. The scale is the same as that of a 20-inch globe, or about one in twenty-five millions. Nine of the pieces are duplicates of the other nine.

The piece for lat. 0° to 10° is nearly straight, and its length along the edge that corresponds to 0° is equal to 80° of the equator on a 20-inch globe. Of the eight succeeding strips, taken in order from equator to pole, each is shorter and more curved than its predecessor, till we come to the piece next the pole, which is a sector of a circle whose centre is the pole. The other eight pieces may be described as segments of flat rings, all having the same breadth. The two arcs of circles which bound each piece are concentric, so that the breadth of the piece is the difference of their radii—a difference which is the same for all, namely, about $1\frac{1}{4}$ inch, this being the length of 10° of a great circle on the globe. The concave side is in every case turned towards the nearest pole, and the convex side to the equator. The ends of each piece are meridians, and all meridians are at right angles to the circular arcs, which represent parallels of latitude.

Every tenth meridian is made conspicuous, to facilitate rapid counting of 10° intervals in longitude. Actual counting is more convenient for my purposes than

* Meeting of the Research Committee of the Society, November 16, 1903.