[AMERICAN JOURNAL OF SCIENCE, VOL. 265, JUNE 1967, P. 449-461]

American Journal of Science

JUNE 1967

THE FIRST, FIRST PRINCIPLES OF GEOLOGY

JOHN W. HARRINGTON

Wofford College, Spartanburg, South Carolina 29302

ABSTRACT. About 24 centuries ago Herodotus made some remarkable field observations on the work of the Nile River in Egypt. He understood enough of the first principles of geology to be able to communicate with us today on a scientific basis. Abstracted from his writing these may be thought of as the "First, First Principles of Geology".

Nature can be analyzed and understood by:

1. Collecting facts as field observatons, classifying them on a meaningful basis, and correlating them for use. This is possible through:
   A. Searching out the general or universal characteristics in nature and relating classes of phenomena rather than accepting a unique explanation for each separate item.
   B. Appreciating the "Wasness of the Is" by divorcing the existence of an observation from the restrictive limit of the "absolute now" and recognizing that it has had existence throughout a range of past time.
2. Understanding causality and realizing that properly assembled facts imply rational, inescapable conclusions that cannot be found as simple observations.

Unfortunately, it is one thing for an author to understand the principles on which his views are based and quite another for his readers to grasp them. For this reason Herodotus' contributions did not found a school of geologic study. All of it had to be rediscovered independently centuries later. This leads to the realization that it is most important to search out the general truths in any investigation, even though the immediate concern is the solution of some specific problem. A search for more first principles is suggested so that we may break away from our own limiting barriers.

INTRODUCTION

The basic presupposition of science is that nature can be understood. Armed with this emboldening thought we are free to search for the very roots of the universe, the "why and how" of the world as we find it. Behind this is the netherland of metaphysics in which philosophers have gnawed over the problems of reality for nearly three millenia without satisfying each other or disturbing the rest of us too much.

Geology is a very complicated field of science, part chemistry, part physics, part biology. But the story of this rocky planet, Earth, and the happenings that have occurred on it in space and time belong to Geology alone. Albritton's compendium, *The Fabric of Geology* (1963), shows the logical ties that interweave the different systems used to understand geological data. Is it possible to set out in brief the few first principles on which the whole fabric of analysis rests?

About 24 centuries ago Herodotus made some remarkable observations on the work of the Nile River in Egypt. I am going to attempt to show that Herodotus discovered and understood enough of the first principles of modern geology to be able to communicate with the

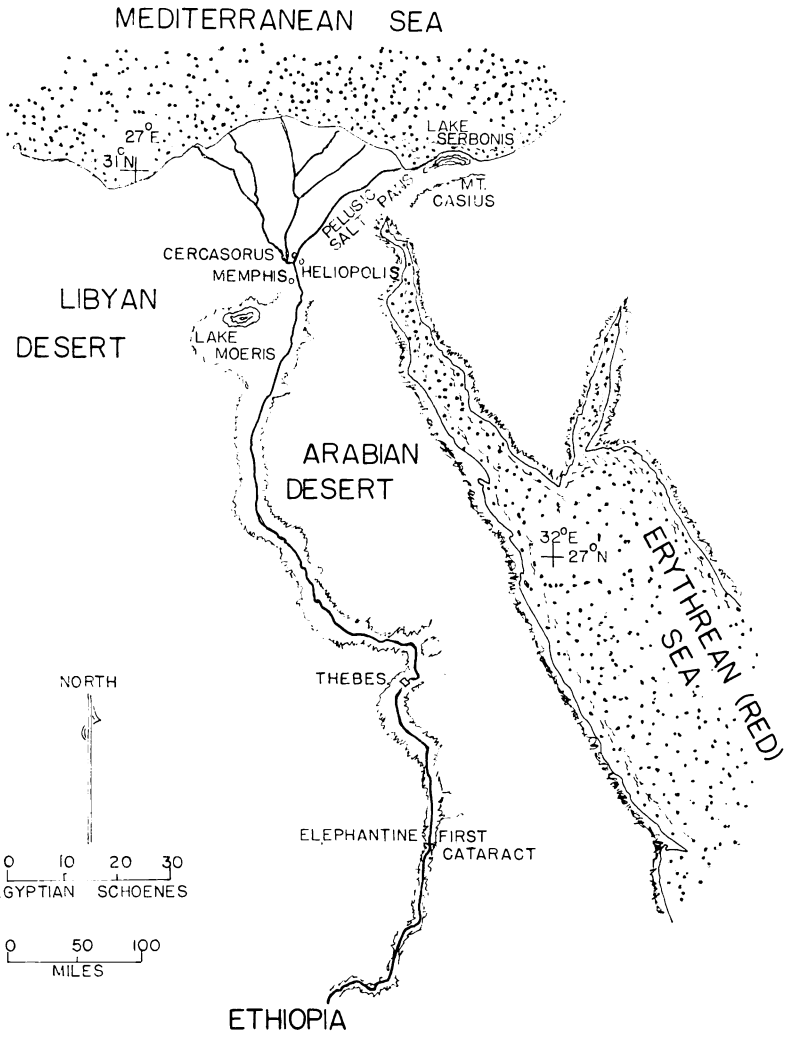

Fig. 1. Egypt as Herodotus must have known it, redrawn from Kiepert's "Atlas Antiquus" to emphasize the similar topography of the Nile Valley and the Red Sea. Herodotus only mentioned five mouths of the Nile. Apparently, he did not count some of the wanderings and canals that may have been in use.

geologist of today on a scientific basis. These might be called the First, First Principles of Geology. Unfortunately, he did not specifically separate them from the rest of the text, and for this reason they were overlooked until rediscovered independently many centuries later. The text will be familiar to all geologists as it has been quoted in part many times over the years. Adams (1938, p. 11) refers to the following passages by saying, "By far the most complete and striking account of the replacement of portions of the sea by land is the well-known description by

Herodotus, one of the most observant and least speculative of these wise men of Greece, of the origin of lower Egypt, which he gives for the purpose of showing that his portion of Egypt occupies what was formerly a gulf of the sea".

HERODOTUS LOOKS AT EGYPT (FIGURE 1)

These selections are taken from Book II as translated by Rawlinson and edited by Komroff (1928, p. 82 and following). The presentation is out of context and rearranged to the extent that extraneous material is deleted. In order to avoid confusing footnotes the text is irreverently interrupted to place the necessary explanations where they can be appreciated most. No attempt has been made to justify his references to authorities of the day or to dignify him as an historian. The point of real concern is how this first great geological genius managed to draw these magnificent conclusions from the field data.

". . . And they (Egyptian priests) told me that the first man who ruled over Egypt was Men, and that in his time all Egypt, except the Thebaic canton (area near Thebes about 400 miles inland), was a marsh, none of the land below Lake Moeris (modern Birket Qarum about 150 miles inland and well above Cairo) then showing itself above the surface of the water. This is a distance of seven days' sail from the sea up the river".

* * * * * * *

(This much may be thought of as instruction in geology, but here his genius begins to be seen!)

"What they said of their country seemed to me to be very reasonable. For anyone who sees Egypt, without having heard a word about it before, must perceive, *if he has only common powers of observation*, that the Egypt to which the Greeks go in their ships is an acquired country, the gift of the river. The same is true of the land above the lake to the distance of three days' voyage, concerning which the Egyptians say nothing, but which is exactly the same kind of country.

"The following is the general character of the region. In the first place, on approaching it by sea, *when you are still a day's sail from the land, if you let down a sounding-line you will bring up mud*, and find yourself in eleven fathoms of water, which shows that the soil washed down by the stream extends to that distance". (Herodotus must have been curious enough to do it.)

* * * * * * *

". . . From the coast inland as far as Heliopolis (very close to modern Cairo and at the head of the distributaries) the breadth of Egypt is considerable, the country is flat, without springs, and full of swamps. As one proceeeds beyond Heliopolis up the country, Egypt becomes narrow, the Arabian range of hills which has a direction from north to south, shutting it in upon the one side, and the Lybian range on the other. The former ridge runs on without a break and stretches

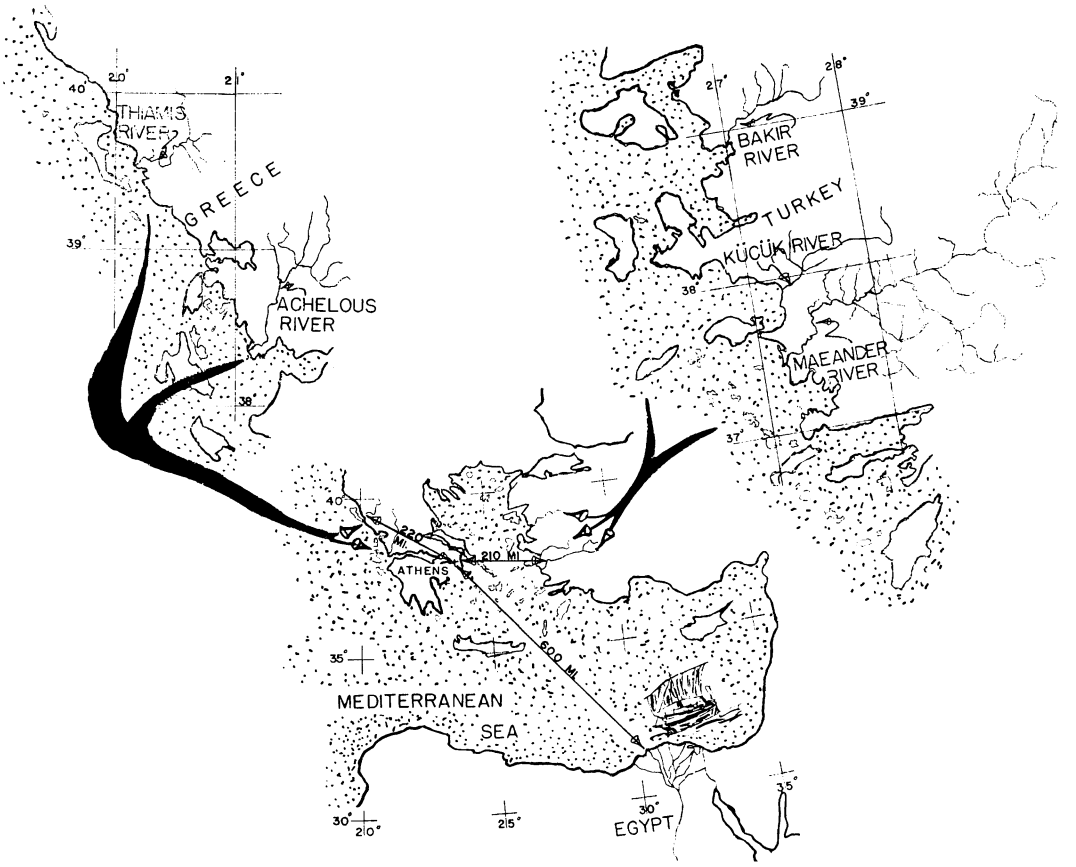

Fig. 2. The Mediterranean area with the field examples of other rivers Herodotus was able to cite in his search for the universal characteristics of nature.

away to the sea called the Erythraean (Red Sea); it contains the quarries whence the stone was cut for the pyramids of Memphis (Cheops and others); and this is the point where it ceases its first direction, and bends away in the manner above indicated.

". . . On the Lybian side, the other ridge whereon the pyramids stand, is rocky and covered with sand; its direction is the same as that of the Arabian ridge in the first part of its course. Above Heliopolis then, there is no great breadth of territory for such a country as Egypt, but during four days' sail Egypt is narrow; the valley between the two ranges is a level plain, and seemed to me to be, at the narrowest point, not more than 200 furlongs (about 25 miles) across from the Arabian to the Lybian hills. Above this point Egypt again widens.

". . . The greater portion of the country above described seemed to me to be, as the priests declared, a tract gained by the inhabitants. For the whole region above Memphis, lying between the two ranges of

hills, that have been spoken of, appeared evidently to have formed at one time a gulf of the sea. It resembles, to compare small things with great, the parts about Ilium and Teuthrania, Ephesus, and the plain of the Maeander. In all of these regions the land has been formed by rivers, whereof the greatest is not to be compared to any of the five mouths of the Nile. I could mention other rivers also far inferior to the Nile in magnitude, that have effected very great changes. Among these not the least is the Achelous, which after passing through Arcania, empties itself into the sea opposite the islands called Echinades, and has already joined one half of them to the continent".

(The range of field examples available to Herodotus is extremely interesting: they are shown in figures 2, 3, 4, 5, and 6. The Ilium area is on the west coast of modern Greece about 10 miles south of the Albanian border at approximately lat 39°30′ N. and long 27°15′ E. The Thiamis River is the depositing agent. Teuthrania is on the mainland of modern Turkey just east of the island of Lesbos at about lat 38°5′ N. and long 27°00′ E. The Bakir River is the one Herodotus knew. Ephesus is near the coast of modern Turkey just northeast of the island of Samos and on the Kucuk River about lat 37°50′ N. and long 27°15′ E. The Maeander is a larger river in the next drainage basin south of the

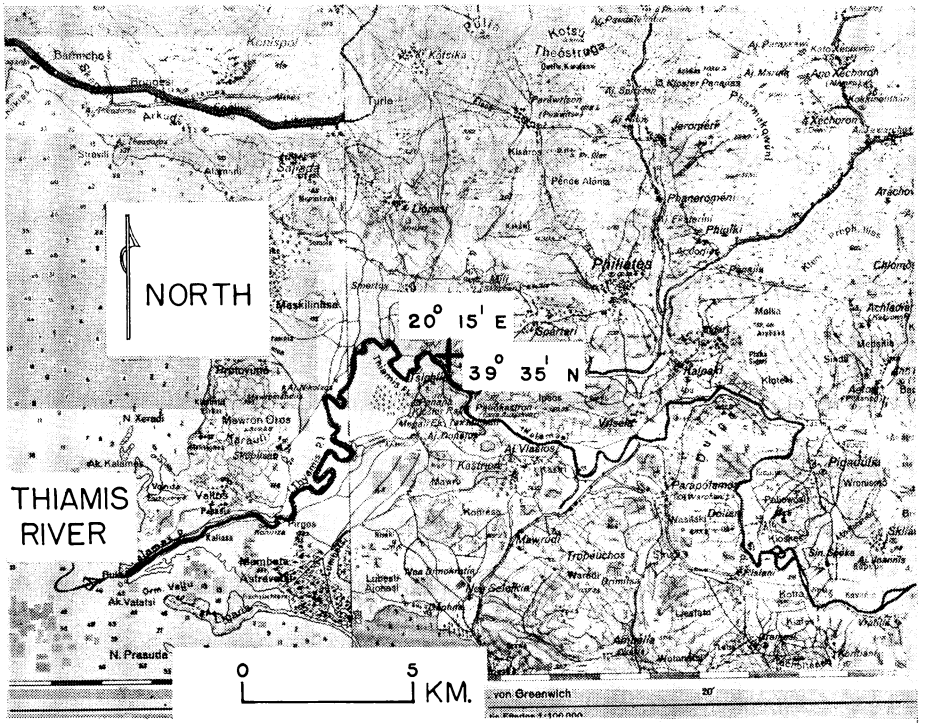

Fig. 3. The Ilium area of modern Greece, just south of the Albanian border, where the Thiamis River empties into the Adriatic Sea.

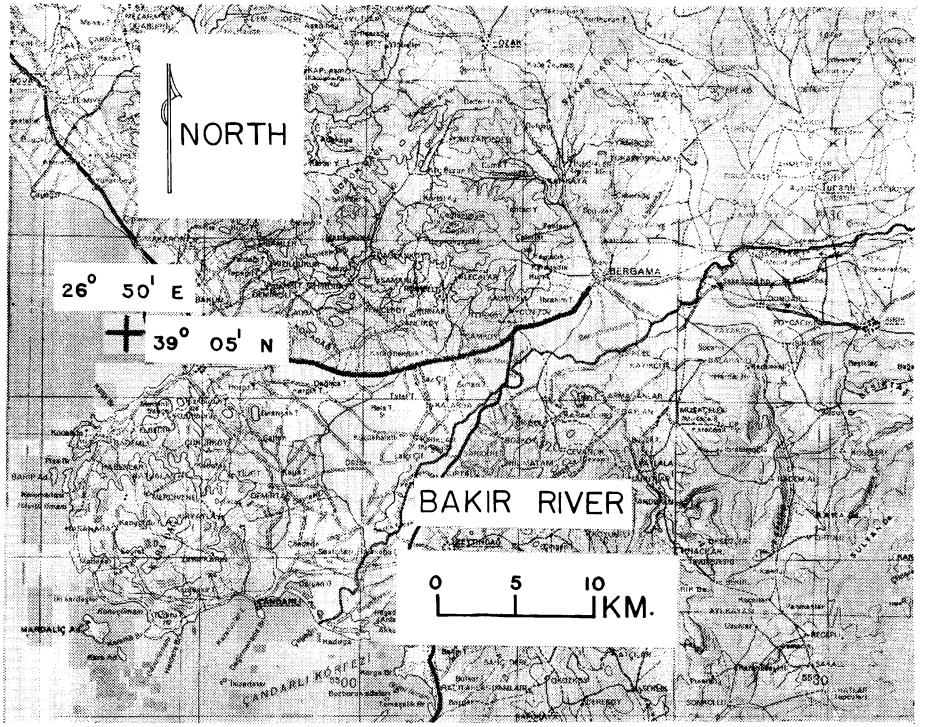

Fig. 4. The Teuthrania area in modern Turkey, just east of the island of Lesbos. The Bakir River flows on an alluvial plain into the Aegean Sea.

Kucuk. Its mouth is southeast of Samos at approximately lat 37°30′ N. and long 27°15′ E. Modern maps show the effectiveness of the deposition of the Achelous in tying the islands to the continent just as Herodotus described. The area is in central Greece at the mouth of the Gulf of Corinth about lat 38°20′ N. and long 21°7′ E.

(These points are hundreds of miles apart and emphasize the degree to which Herodotus put into practice the analogical method of reasoning. One of my own professors, John Huddle, used to say that every young geologist should work for the U. S. Geological Survey for a time in order to see different areas and different rocks. Apparently this aspect of geology will never change. This should encourage those who do not feel that the whole Earth will ever be contained in the laboratory.)

* * * * * * *

". . . In Arabia, not far from Egypt, there is a long and narrow gulf running inland from the sea called the Erythraean, of which I will here set down the dimensions. Starting from its innermost recess, and using a row-boat, you take forty days to reach the open main, while you may cross the gulf at its widest part in the space of half a day. In this sea there is an ebb and flow of the tide every day".

(At this point it is very important to be sure what places Herodotus had in mind. The data are a little contradictory. Webster's International Dictionary assures us that the Erythraean Sea is the Red Sea citing the Greek root word for red as evidence. Other authorities differ and identify it as the Arabian Sea, but that does not fit the description. The real problem concerns the dimensions. The Red Sea is between 100 and 200 miles wide and 1200 to 1300 miles long. No one could row across in half a day. The Gulf of Suez is only 30 miles wide, but it is 180 to 200 miles long. Perhaps, anyone who rowed across half the first day would take 40 days to finish up and row the length. We shall postulate that Herodotus was confused with hearsay evidence and meant the Gulf of Suez and some portion of the northern end of the Red Sea. This is an attractive idea because the dimensions of the landform are not unlike those of the narrow part of the Nile Valley and the more open delta country he has already described. As the comparison is quite apt (fig. 1), it is interesting to see what he does with it.)

* * * * * * *

". . . My opinion is, that Egypt was formerly very much such a gulf as this—one gulf penetrated from the sea that washes Egypt on the north, and extended itself towards Ethiopia; another entered from the southern

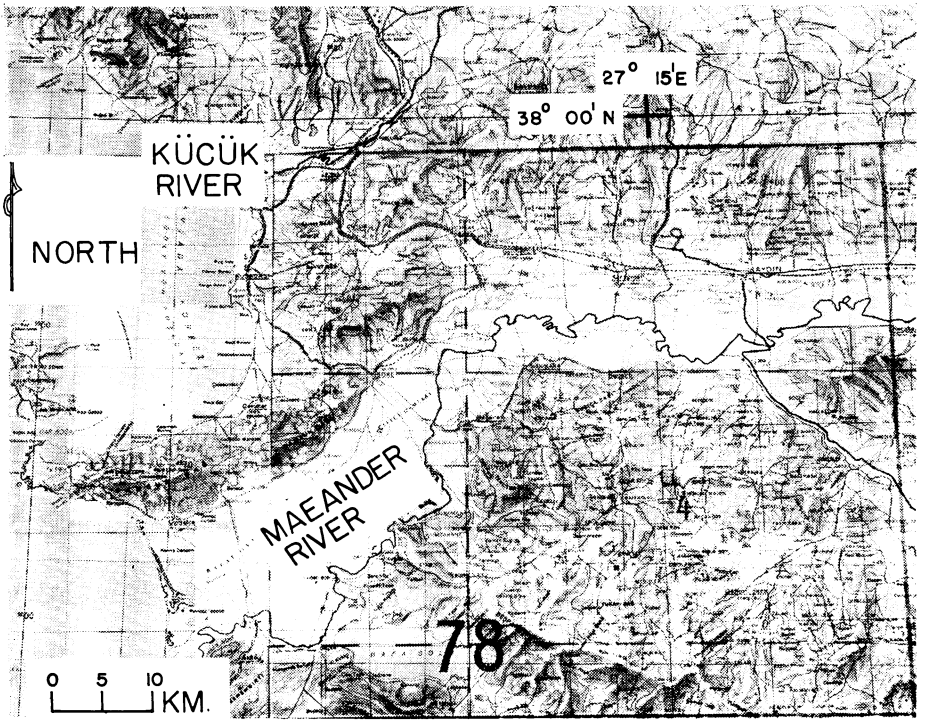

Fig. 5. The Ephesus area with the Kucuk River and the plain of the Maeander River in modern Turkey.

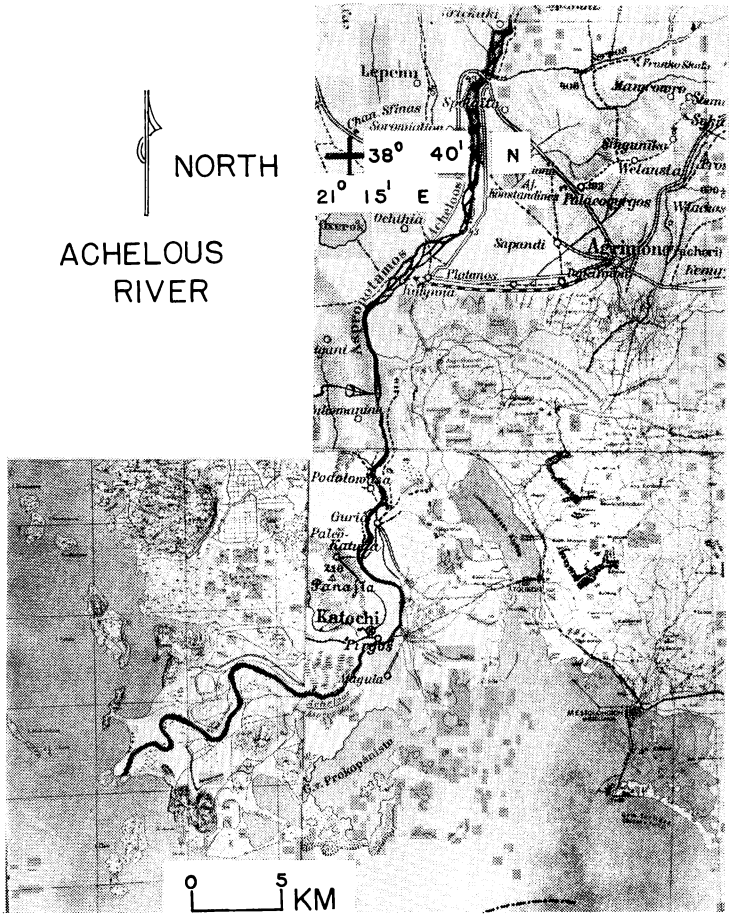

Fig. 6. The Achelous River in modern Greece entering the Adriatic Sea north of the Gulf of Patras.

ocean and stretched towards Syria; the two gulfs ran into the land so as to almost meet each other, and left between them only a very narrow tract of country. Now if the Nile should choose to divert his waters from their present bed into this Arabian gulf, what is there to hinder it from being filled up by the stream within, at the utmost, twenty thousand years? For my part, I think it would be filled in half the time. How then should not a gulf even of much greater size, have been filled up in the ages that passed before I was born, by a river that is at once so large and so given to working changes"?

(In a logical sense Herodotus is a little guilty of begging the question, but his grasp of the nature of change with time and the vastness of time is astounding.)

* * * * * * *

". . . Thus I give credit to those from whom I received this account of Egypt, and am myself, moreover, strongly of the same opinion, since I remarked that the country projects into the sea farther than the neighboring shores, and I observed that there were shells on the hills, and that salt exuded from the soil to such an extent as even to injure the pyramids; . . .".

(These are famous lines and often quoted, as, for example, by Leggett (1963, p. 243) asking the question, "Was he the first paleontologist"? It is even more interesting to note how he tests his hypothesis of river deposition against further observation.)

". . . and I noticed also that there is but a single hill in all Egypt (speaking of the confined Nile Valley) where sand is found, namely, the hill above Memphis; and further, I found the country to bear no resemblance either to its borderland Arabia or to Lybia—nay, nor even to Syria, which forms the seaboard of Arabia; but whereas the soil of Lybia is, we know, sandy and of a reddish hue, and that of Arabia and Syria inclines to stone and clay, Egypt has a soil that is black and crumbly, as being alluvial and formed of the deposits brought down by the river from Ethiopia.

"One fact which I learnt of the priests is to me strong evidence of the origin of the country. They said that when Moeris was king, the Nile overflowed all Egypt below Memphis, as soon as it rose so little as eight cubits (12 feet). Now Moeris had not been dead 900 years at the time when I heard this of the priests; yet at the present day, unless the river rises sixteen or at least fifteen cubits (22.5 to 24 feet), it does not overflow the lands. It seems to me, therefore, that if the land goes on rising and growing at this rate the Egyptians who dwell below lake Moeris, in the delta, as it is called, and elsewhere, will one day by the stoppage of the inundations, suffer permanently the fate which they told me they expected would some time or other befall the Greeks." (Famine by drought)

(Herodotus speaks of time with the ease of a modern geologist. His reference to "900 years" is comparable to one of us saying, "The Norman conquest had been over only 900 years when I heard about it". It is difficult to know just how seriously to take his depositional rate. Nevertheless, the statement is recognition of the reality of the change in the past and expectable in the future. The accuracy of the change may be quite another matter.)

* * * * * * *

". . . If then we choose to adopt the views of the Ionians concerning Egypt, we must come to the conclusion that the Egyptians had formerly no country at all. For the Ionians say that nothing is really Egypt but the Delta, which extends along the shore from the Watch-tower of Perseus (?), as it is called, to the Pelusaic Salt-pans (just east of modern Port Said), a distance of forty schoenes (about 300 miles by Herodotus'

conversion factors), and stretches inland as far as the city of Cercasorus (near modern Cairo), where the Nile divides into two streams which reach the sea at Pelusium and Canobus (near modern Alexandria) respectively. The rest of what is accounted Egypt belongs, they say, either to Arabia or Lybia. But the Delta as the Egyptians affirm, and as I am myself persuaded, is formed by the deposits of the river, *and has only recently, if I may use the expression, come to light.* If, then, they had formerly no territory at all, how came they to be so extravagant as to fancy themselves the most ancient race in the world? . . . But in truth I do not believe that the Egyptians came into being at the same time with the Delta as the Ionians call it; I think they have always existed ever since the human race began; as the land went on increasing, part of the population came down into the new country, part remained in their old settlements . . .".

* * * * * * *

(Herodotus' geologic essay continues with an attempt to explain the source of the Nile. A great, through flowing stream in an arid region seemed to him to present a real problem. I do not believe he can be criticized too severely as he simply did not have the data on which to base a judgment. What is important is that he searched for a rational explanation.)

THE FIRST, FIRST PRINCIPLES OF GEOLOGY

Herodotus accepted the idea that nature can be analyzed and understood. He looked for a reasoned explanation of the origin of the Egyptian countryside rather than a magical one. There was no appeal to faith or the supernatural. This is how he did it.

1. *He carefully collected facts as field observations and then classified them.* River sediments were not confused with the sandy soils of Lybia or the stone and clay of Syria. He recognized that the sounding of mud in 11 fathoms of water in the Mediterranean Sea was quite different from the normal sea floor sediment. He must have been able to distinguish between sorted and unsorted materials. These were, in fact, acts of correlation which could serve today as a basis for determining a mappable unit.

Classification is a difficult task. Herodotus had a remarkable command of two profund concepts:

A. *He searched for the general or universal characteristics in nature that related classes of phenomena rather than accepting a unique explanation for each separate item.* He did not compare rivers by size or locality but by the common factor of the work that rivers are able to do. His sense of scale is interesting. There was no other river in the world that Herodotus knew that approached the dimensions of the Nile, but this did not stop him from finding adequate parallels in lesser streams hundreds of miles from Egypt and hundreds of miles apart from one another. In modern geology scale model study is an accepted form of

analogy. Hubbert (1937, p. 1461) states, ". . . often, however, the thing studied is too large to be experimented with. Under these conditions, where mathematical analysis is inadequate, and where for one reason or another direct experimentation is precluded, the best remaining alternative is to construct and study a scale model". Herodotus put it more simply, "to compare small things with great". Physically, of course, there is a difference between these views, as Herodotus chose models having the same dimensional units and Hubbert was concerned with scaling down all dimensions in proportion.

B. *He appreciated the "Wasness of the Is" by divorcing the existence of an observation from the restrictive limit of the "absolute now" and recognizing that it has had an existence throughout a range of past time.* The separation of these ranges of time presents the only knowledge of an ordered antiquity. The whole fabric of modern time stratigraphy rests on the acceptance of the prior existence of some piece of evidence that can be observed today. The rock, or fossil, that originated some time in the past serves as a measure of some part of the time continuant. It required the insight of true genius for Herodotus to have grasped this principle. This made classification of relative time units possible.

2. *Herodotus understood causality and realized that properly assembled facts imply rational, inescapable conclusions that cannot be found as simple observations.* His reasoning was much like that of Sherlock Holmes:

Fact 1 + Fact 2 + Fact 3 + Fact N implies inescapable conclusion(s). It would be idealistic to claim that Herodotus anticipated Chamberlin's (1897) system of "Multiple Working Hypotheses". However, in an unquoted part of the text, he tried to explain the source of the Nile and its tendency to flood by selecting between hypotheses. Unfortunately, his knowledge of science was too inadequate to serve as a basis for further argument. Yet he was able to present the work of the Nile in depositing the delta with the full understanding that there was no other acceptable explanation for the land form.

Taken all together these points constitute the first, first principles of geology and are timeless enough to permit Herodotus to speak to us across the ages as one scientist to another.

UNIFORMITARIANISM AND MORE MODERN FIRST PRINCIPLES

Geologists still reason with implied but hopefully inescapable conclusions as goals. Since most geologic phenomena are rooted deep in the past we attempt through uniformitarianism to establish analogies in the more accessible present. Quite frequently the principle has become so much a part of us that we forget the built-in uncertainties of reasoning through analogy. Its meaning should be kept in perspective with Webster's definition . . . "analogy: a form of inference in which it is reasoned that if two (or more) things agree with one another in one or more respects they will *probably* agree in yet other respects". Through

uniformitarianism geologists hope to maximize the probability of a conclusion, applying logical simplicity or Occam's razor.

Herodotus had a most uncertain appreciation of uniformitarianism. His observations on the work of rivers lie well within the scope of the principle, but he had no knowledge of the full range of phenomena that is included today. As a result his work seems both remarkably limited and remarkably profound.

CONCLUSION

Unfortunately, Herodotus did not separate his first, first principles of geology from the rest of the text. For this reason his contribution did not found a school of geologic study. All of it had to be rediscovered independently by other workers centuries later. This leads to the realization that it is most important to search out the general truths of any investigation, even though the immediate concern is the solution of some specific problem.

I think that this paper is a clear illustration of what Krynine (1960) had in mind when, as his second "moral conclusion", he urged us to restudy the Greek philosophers.

ACKNOWLEDGMENTS

Some years ago I discovered Herodotus in random reading. I realized that he was able to communicate on a scientific basis, but I never understood why. In 1965 Professor John Hill, of Wofford College, conceived the idea of an interdisciplinary faculty seminar to examine the few basic first principles on which each of our disciplines was founded. Dr. Dan Olds pointed the way in his discussion of Physics concluding that the first principle of science is that nature can be understood.

In preparing for the geology discussion, I realized that these same first principles must have been grasped by Herodotus. Henry Johnson, State Geologist of South Carolina, encouraged me to publish my notes. A few weeks later Kirtley F. Mather visited Wofford on a lecture tour. He spent some time with me reviewing the manuscript and tightening up the ideas. When he too felt that Herodotus was probably the first systematic geomorphologist and historical geologist his added encouragement was most appreciated. Herodotus is well known, and one does not want to present redundant material. The contribution of each of these men is gratefully acknowledged.

Finally, Claude C. Albritton, Jr., examined the concepts from the standpoint of an historical geologist and encouraged me to publish for the historians of science as well as for geologists.

REFERENCES

Adams, F. D., 1938, The birth and development of the geological sciences: Baltimore, Maryland, Williams and Wilkins Co.; New York, New York, Dover Ed., 506 p.

Albritton, C. C., 1963, The fabric of geology: Reading, Mass., Palo Alto, Calif., London, Addison-Wesley Pub. Co., 372 p.

Chamberlin, T. C., 1897, The method of multiple working hypotheses: Jour. Geology, v. 5, p. 837-848.

Hubbert, M. King, 1937, Theory of scale models as applied to the study of geologic structures: Geol. Soc. America Bull., v. 48, p. 1459-1520.

Kiepert, Henry, (date unknown), Atlas Antiquus, Twelve Maps of the Ancient World for Schools and Colleges, 11th ed.: Boston, New York, and Chicago, Leach, Shewell, and Sanborn.

Leggett, R. F., 1963, Geology in the service of man, *in* Albritton, C. C., ed., The fabric of geology: Reading, Mass., Palo Alto, Calif., London, Addison-Wesley Pub. Co., p. 242-261.

Komroff, Manuel, ed., 1928, The History of Herodotus (George Rawlinson, translator): New York, Tudor Pub. Co., 544 p. (1956, Dial Press Copyright).

Krynine, P. D., 1960, On the antiquity of "sedimentation" and hydrology: Geol. Soc. America Bull., v. 71, p. 1721-1726.