

II. PARTIE SCIENTIFIQUE II. SCIENTIFIC PART

HYDROLOGY DURING THE HELLENIC CIVILIZATION

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INTRODUCTION

The pre-Hellenic civilizations, as discussed in a previous paper, grew up mainly on the banks of the three major river basins of the Nile, the Tigris-Euphrates, and the Indus. The Hellenic civilization started around 600 B.C. with the birth of the Ionian school in Asia Minor and here for the first time people were engaged in the pursuit of knowledge for its own sake. The Greek science was certainly indebted to older civilizations — and possibly most to the Egyptians. Reymond stated that “compared with the empirical and fragmentary knowledge which the peoples of the East had laboriously gathered together during long centuries, Greek science constitutes a veritable miracle. Here the human mind for the first time conceived the possibility of establishing a limited number of principles, and of deducing from these a number of truths which are their rigorous consequence.”⁽¹⁾

The failure of the Greek philosophers in establishing some basic principles of water sciences was not due to neglect of facts as they certainly noted carefully certain aspects — but they were too few. Also they did not consider all the facts in their possession simultaneously but only small and definite portions at a time. In fact, later Aristotle recommended it. Hence it is not surprising to find a whole number of conflicting theories on every subject under the sun (including the sun itself!) and in this respect it is worthwhile to quote Rapin who summed up the position as follows:

“All the powers of ancient philosophy was not able to settle any one principle of nature. Thales maintain’d that the water was the great source of all things; Heraclitus declar’d for the fire; Anaximenes for the air; Pythagoras for numbers; Democritus for atoms; Museus for unity; Parmenides for infinity. Protagoras affirmed that every thing was really true which appear’d to be so. Aristippus allow’d nothing to be true but what men are thro’ly convinc’d of by inward preswasion of the mind. Chrysippus declares, that the senses are always in the wrong; Lucretius contends, that they are always in the right.”⁽²⁾ Rapin concluded charmingly: “And it must be confess’d that there’s nothing so certain in nature, but what may be made the subject of dispute.”⁽²⁾

THALES — THE ANCIENT HYDROLOGIST

On the threshold of the Ionian philosophy stands out the semilegendary and yet very real figure of Thales of Miletos (624? - 548? B.C.). Very little is known about Thales (fig. 1) — and whatever we can credit him with comes mainly from Aristotle and Herodotus. Even during the 4th century B.C. — during the time of Aristotle — Thales was on his way to become a legendary figure. Sarton speaks of Thales as a sort of early Franklin — both had open mind, curiosity to

learn about new elements and then used their knowledge to practical problems. Like Franklin's visit to England, Thales made a sejourn to Egypt and both were impressed with what they saw.

Thales was universally acknowledged as one of the seven wise men of the ancient times (fig. 2) and it is amusing to note that statement of Demetrios Phalereus that Thales "received the title of sage" — as if it was sort of an honorary doctorate! The uncommon fame of Thales and the esteemed title of "wise man" did not come from the fact that he was the first Greek astronomer or the first Greek mathematician but on the contrary from his concept of using his knowledge to practical advantage. Aristotle's charming anecdote about the olive press (³) is just one such example.

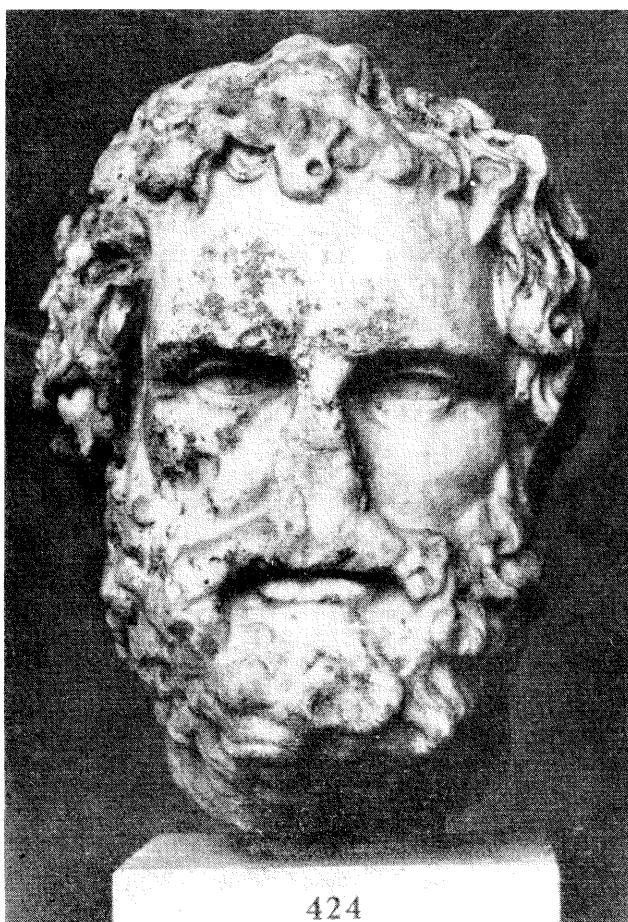


Fig. 1 — Thales — the "founder-member" of the Seven Wise Men (Courtesy — Ny Carlsberg Glyptotek, Copenhagen).

On a dissertation on the history of hydrology, we are interested in two statements which according to Aristotle can be attributed to Thales. They are:

- (1) The earth floats on the water (⁴).

(2) Water is the original substance and hence material cause of all things. (5)

The first of the two statements was quite common in Egyptian and Babylonian cosmogonies. The Egyptian priests believed that the earth originated out of the primordial waters of Nūn and they were still everywhere below it. (6) According to the prevailing Babylonian legend of that time — “All the lands were sea Marduk bound a rush mat upon the face of the



Fig. 2 — Mosaic of the Seven Sages from Torre Annunziata near Pompeii. Identification is rather difficult, but the third from the left pointing to the celestial sphere is probably Thales and the man standing to the left of the sundial could be the inventor Anaximander. (Courtesy — National Museum, Naples).

waters, he made dirt and piled it beside the rush mat.” (7) Marduk was the creator of the Babylonian and since Thales travelled extensively he must have been aware of the legends. Thus all he did probably was to leave Marduk out. It is also possible that Thales might have obtained his idea from Homer who thought that the earth was surrounded by the ocean. It was thought to be a vast expanse of water beyond the sea — having no source or origin. Thales could have possibly tried to rationalize Egyptian and Babylonian cosmologies and ended up with the concept that the earth floated on water like a flat disc.

The second statement that water is the fundamental or primary matter may sound foolhardy at first reading but will appear quite reasonable on close scrutiny and indeed very far from being nonsense. When he visited Egypt, he must have observed the almost legendary river — the Nile. It was a common belief that Egypt was created out of the Nile and Thales would also have seen the process of delta building before his own eyes. Thus he could have reasoned that the land was created out of water. The Egyptians depended exclusively on the inundation of the Nile and even though their survival depended on the regular rise of the river they had no rational reason or explanation for it. It could have only had added mystery — though latter the Ionian did offer an explanation for the phenomenon. Water again is the only liquid that was well known in its three physical states — liquid, vapour, and solid. The transformation from one state to another occurred easily and water can be seen in nature in all three states. Water came down from above as rain, hail, or dew, and early cosmologists believed that it turned into earth by some mysterious process. The possibility of connecting the origin of streams and rivers with precipitation was almost unthinkable at that time. However more about that will be discussed in later papers. It was also erroneously believed that the fire of the heavenly bodies was kept up from the moisture drawn from the rivers and the seas by the process of evaporation. (8) Probably one of the major factors which made Thales to reason that water was the primary element was that no life can exist without it. It must have been driven home rather forcefully when he visited the arid country of Egypt.

Some like Oswiecimski have tried to justify Thales' concept on different grounds. He argued that the "essence of water is, of course, what is most obvious in water, i.e., humidity or fluidity which can be easily identified with humidity. It was easy for Thales to observe that such a solid and "dry" body in its normal state as iron even in its liquid condition (e.g. when melting ore) is not only water, but even, under the influence of heat, cannot contain any water in the usual sense of the word. Yet it is a liquid, and, liquid in general is easy to be identified with humidity. So if iron is really, according to Thales theory, one of the forms of water or — what is the same — arose from primitive water, it is not the form of water itself but of its essential part, of its essence: humidity — fluidity which he understood in a material sense: not as a quality but rather as a concrete matter". (9)

Situated at the dispassionate distance of some 2500 years, it is futile to argue the actual contention of the founder of the Milesian school. A woman wearing her grandmother's dress may look like her grandmother but her thoughts will be different. Hence we return to Aristotle to get some insight into Thales' reason for proclaiming water was the primary substance.

Aristotle provides three reasons for Thales' philosophy. They are: (1) nutriment of all thing is moist, (2) heat is generated from moist and also kept alive by it, and (3) seeds of all things have a moist nature.

Like all ancient philosophers, Thales was also probably fascinated by the River Nile. He tried to reason the cause of the regular inundation of the River. He believed that the Etesian wind opposed the flow of the river to the sea and thus the water swelled up and flooded the banks of the river.(10) Etesian is the northerly wind which blows during summer with reasonable accuracy.

The Etesian wind concept of the rise of the Nile is not mentioned by Aristotle at all. Herodotus, as it can be seen from a previous paper(10), mentioned it as one of the three existing reasons but according to his practice he mentioned no names. It comes(11) from a pseudo-Aristotelian treatise on "The Rise of the Nile"(12) which according to Sarton is post-Eratosthenian(13, 14).

After Thales, the search for the primary substance or *arche* continued. Heraclitus thought it was fire and the priests of magi broadened the concept by including both fire and water. Euripides considered the primary substances to be air and earth. He believed that the generation of mankind and all the animals was because the earth was impregnated by the seeds contained in the precipitation(15) from the heavens. When all the living things were destroyed by time, they returned again to their point of origin — the heaven. Empedocles of Agrigentum (490-430 B.C.) postulated that there were four primary elements or roots (*rhizomata*) — fire, air, water, and earth from which all the materials of the world were constituted by their combination in different

proportions.⁽¹⁶⁾ For example bones were made of two parts of earth, two of water and four of water. This concept of constitution of materials by different ratios of the four 'elements' was probably due to the mathematical influence of Pythagoras.

ANAXIMANDER TO XENOPHANES

Anaximander of Miletos (610-545 B.C.) was a contemporary of Thales and hence it is not surprising to find that he was influenced by Thales to a certain extent. He considered the Thalesian concept of water as the primary substance too tangible and hence he opted for something intangible which he called *apeiron*. The word when translated means infinite, indefinite, undetermined or even unexperienced. Since only fragments of Anaximander's works are available to the present historians of science, considerable controversy has raged over the actual meaning of the word *apeiron*.⁽¹⁷⁾ Like Thales, Anaximander believed that in the beginning life — human as well as animal — originated in water. With the gradual but continuous evaporation, land emerged where once was the all-engulfing sea.⁽¹⁸⁾ Aristotle also discussed his views: "But those who are wiser in the wisdom of men give an origin of the sea. At first, they say, all the terrestrial region was moist; and, as it was dried up by the sun, the portion of it that evaporated produced the winds and the turnings of the sun and the moon, while the portion left behind was the sea. So they think the sea is becoming smallest by being dried up, and that at last it will all be dry."⁽¹⁹⁾ According to Hippolytos, Anaximander believed that the precipitation was caused due to the moisture being drawn up from the earth by the sun.⁽²⁰⁾

Anaximenes (d. 528/525 B.C.) believed that when rain is frozen while falling it resulted in hail where as snow was due to the imprisonment of air within the water.⁽²¹⁾

Xenophanes of Colophon lived somewhere within the period 570 to 470 B.C. He believed that the "sea is the source of water, and the source of wind. For neither could (the force of the wind blowing outwards from within come into being) without the great main (sea), nor the stream of rivers, nor the showery water of the sky; but the mighty main is the begetter of clouds and winds and rivers."⁽²²⁾ Thus Xenophanes put forward an argument of purely tautological character to prove his point. Clouds, rains, springs and streams all originate from the sea⁽²³⁾. If there was no sea, none of these would have existed but since there is sea, they do exist! He also observed that the presence of shells on high mountains and fossils of marine animals at various parts of the earth. Thus he reasoned that the land must have been under the sea at one time and on this basis he may be called the earliest geologist and the earliest paleontologist.⁽²⁴⁾

ANAXAGORAS AND HIPPON

Anaxagoras of Clazomenæ (500-428 B.C.) was endowed with a spirit of enquiry and was the last of the renowned Ionian philosophers. He offered an explanation for the regular rise of the river Nile — which was almost a correct explanation — but more about it have already been discussed in a previous paper.⁽¹⁰⁾ The main principles of Anaxagoras concerned with hydrology are the following.

"Of the moisture on the surface of the earth, the sea arose from the waters of the earth, and from the rivers which flow into it.

"Rivers take their being both from the rains and from the waters in the earth, for the earth is hollow, and has water in its cavities. And the Nile rises in summer owing to the water that comes down from the snows in Ethiopia."⁽²⁵⁾

Anaxagoras also stated that as the reflection of the sun on the clouds is known as rainbow and it is a sign of the storm because the water which flows round the cloud produces wind or forces out of rain.

Hippón of Samos flourished around the middle of the 5th century B.C. He said that: "All water that is drunk comes from the sea; for of course the wells from which we drink are not deeper than the sea, for in that case the water would not be from the sea but from elsewhere.

But in fact the sea is deeper than the water. It follows therefore that all water that is above the sea comes from the sea."⁽²⁶⁾

CONTRIBUTION OF HERODOTUS

Herodotus of Halicarnassus (484-425 B.C.) considered all knowledge to be within his jurisdiction and pursued his enquiries with great enthusiasm into a host of different things. He was curious about many hydrological events and he diligently searched for explanations and whatever reasons he could dig up — rational or irrational — were carefully noted in his book. He described three reasons of the regular inundation of the River Nile which began with the commencement of the summer solstice. These were all given by the Greeks and he noted that the Egyptians had no explanation at all. However he dismissed all three reasons with equal disdain and went on to offer a fantastic theory of his own. More about it have already been discussed in a previous paper.⁽¹⁰⁾

Herodotus studied the Nile with the greatest interest. He said that any one with "only common powers of observation" could see that Egypt was an acquired country and hence a gift of the river. The alluvial land was gradually built up by the sedimentation of silt brought by the river.⁽²⁷⁾ If one was away from the coast by a day's sail and dropped a sounding line, he would find mud at a depth of eleven fathoms.⁽²⁸⁾ It indicated that soil eroded by the river extends to that distance. With a brilliant piece of geological reasoning almost unparalleled in the ancient history, Herodotus opined that the Lower Egypt was once under the sea. Like the Red Sea, the Nile valley was once an arm of the sea but the silt carried by the river was gradually deposited in the sea-basin between Thebes and Memphis⁽²⁹⁾ and the delta was formed as it was gradually filled up. It was filled up in the "ages that passed before I was born by the great River Nile which works great changes."⁽³⁰⁾ Presence of sea shells on the hills and high salinity of the land confirmed his deductions.

The Egyptians were amused and horrified to learn that Greece has no such river as the Nile for their annual inundation. Consequently the Greeks had to depend on the rainfall as their only source of water. They thought that if God decided not to send rainfall to Greece, the poor Greeks would become wretchedly hungry — but the father of history must have chuckled to himself. According to the 'strong evidence' available from the priests at Heliopolis the Nile overflowed, during the reign of King Moeris, all Egypt below Memphis as soon as the river stage rose only to eight cubits (12ft). However, 900 years later when Herodotus was visiting Egypt, the river had to rise to sixteen cubit (24 ft) to achieve the same results.⁽³¹⁾ If the land went on increasing in height at the same rate as it had done in the past, it was obvious that a time will come when the Nile would no longer be able to flood the banks. Without the annual inundation in an almost rainless country, reasoned the astute historian, the chances were that it was the Egyptians who were more likely to go hungry — not the Greeks.

Like the Nile, Herodotus was also fascinated by the Ister (Danube) — but not as much. Contrary to the Nile which overflowed its banks with almost unbelievable regularity, the Ister remained at the same level during both the summer and the winter.⁽³²⁾ The Ister flowed at its "natural height" during the winter as there was scarcely any rain during that period — only snow. During the summer, the snow melted and there was also the rainfall and hence it all brought extra water to the river. But as the sun's power of attraction was greater during the summer the two causes counterbalanced each other and hence the flow in the Ister remained at the same level as in the winter.⁽³²⁾ But from where did the Ister get its supply of water during the winter to maintain its flow? The historian did not tell us and it is futile to speculate what reason or reasons he could have attributed to the fact. According to Whewell the statement of Herodotus that "the sun *draics*, or attracts, the water; a metaphorical term, obviously intended to denote some more general and abstract conception than that of the visible operation which the word primarily signifies. This abstract notion of 'drawing' is, in the historian, as we see, very vague and loose; it might, with equal propriety, be explained to mean what we now understand by mechanical or

chemical attraction, or pressure, or evaporation."⁽³⁴⁾ Was Whewell correct? We can only conjecture but who can say?

Herodotus was interested in various rivers and described in great details⁽³⁵⁾ the river systems of Scythia (fig. 3). He also noted that when the Nile was about to rise, the hollows and marshy spots near the river were flooded due to percolation of water through the riverbanks.⁽³⁵⁾ But the historian's worst error were undoubtedly on the general course of the Danube and of the Nile. He believed that like the Danube which flows across Europe from west to east, the upper Nile also flowed in the same direction.⁽³⁷⁾ He also confused the great river "containing crocodiles" with Niger. Later Juba II, the King of Mauretania, and Pliny made the same mistake.⁽³⁸⁾ However, considering that these erroneous ideas continued in one form or another for nearly the next 2,200 years, perhaps the historian can be excused.⁽¹⁰⁾

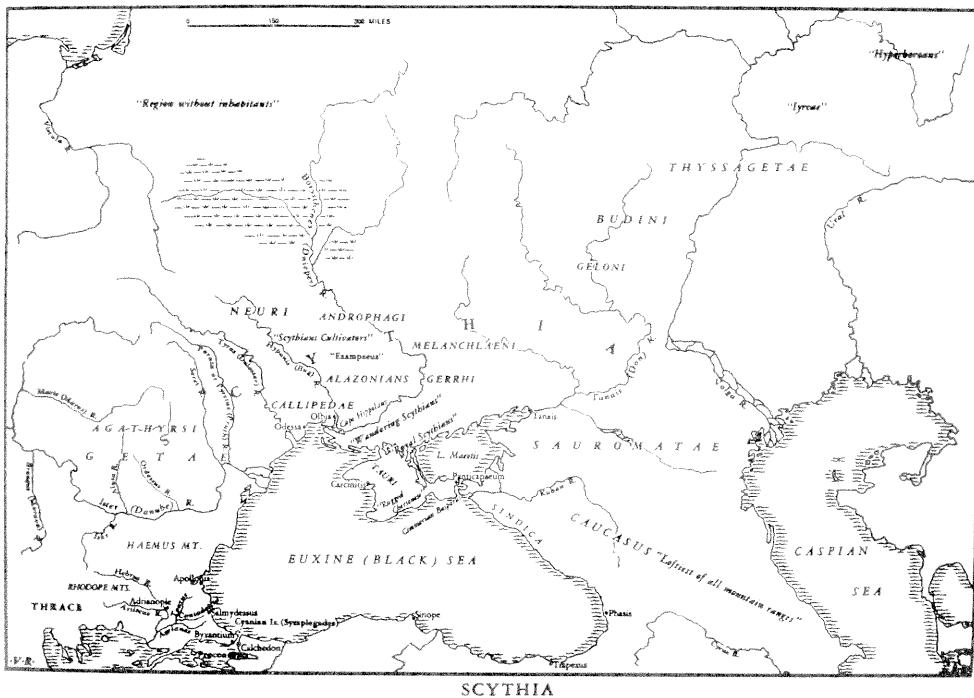


Fig. 3 — River system of Scythia according to Herodotus.

HIPPOCRATES' CONCEPT OF WATER

It is difficult to believe that the concepts of the Ionian philosophers were based on observed facts or even limited experimentation. With characteristic aplomb they decided that the ultimate constituents of all material things of the universe were water or air or atoms or four elements — as if the whole process of evolution had taken place before their very eyes. Plato later qualified the concepts as no more than a 'plausible tale'. However things were different with the medical science.

Hippocrates (460-400 B.C.?), the father of medicine, had some definite idea about the constitution of water.⁽³²⁾ He thought water contained of two parts: one part was thin, light, and clear

and the other was thick, turbid, and darkish. The sun attracted and raised only the lightest and the thinnest part of water — as is obvious from the saltish part which was always left behind. It was abstracted from all things which contained humidity and there was humidity in everything. Thus, he declared, the rain water was the lightest, sweetest, thinnest, and clearest.

"When attracted and raised up, being carried about and mixed with the air, whatever part of it is turbid and darkish is separated and removed from the other, and becomes cloud and mist, but the most attenuated and lightest part is left, and becomes sweet, being heated and concocted by the sun, for all other things when concocted becomes sweet. While dissipated then and not in a state of consistence it is carried aloft. But when collected and condensed by contrary winds, it falls down wherever it happens to be most condensed. For this is likely to happen when the clouds being carried along and moving with a wind which does not allow them to rest, suddenly encounters another wind and other clouds from the opposite direction: there it is first condensed, and what is behind is carried up to the spot, and thus it thickens, blackens, and is conglomerated, and by its weight it falls down and becomes rain."⁽³⁹⁾

Hippocrates conducted an experiment to show that some quantity of water (which according to him was the thinnest and lightest) was lost due to the process of evaporation. A measured quantity of water was poured into a vessel and was exposed to the open air in winter till it was frozen. The following day it was brought into a "warm situation" till the ice melted — whereupon it was measured and found to be much less than the original quantity. Thus he contended that if it was "a proof that the lightest and thinnest part is dissipated and dried up by the congestration, and not the heaviest and thickest for that is impossible."⁽³⁸⁾ Some hundred years ago Anaximenes had asserted his concept on the effect of reduction of temperature on the density, i.e., the hotter, the thinner; the colder, the denser.⁽⁴⁰⁾ Had he tried a simple experiment like Hippocrates he would have thought twice before propounding such a general and universal concept. Water when heated does become vapour and expands — but what happens when it is frozen? Does it contract into a smaller volume as anticipated by his theory? Had he kept a jar of water outside on a wintry night, he would have seen that instead of contracting, it expanded and possibly could have even split the jar. Thus the simple experiment of Hippocrates was a major development and undoubtedly a step forward in the right direction — towards the evolving of methods for scientific investigations.

ARISTOPHANES

The Athenian playwright Aristophanes (445? - 385? B.C.) ridiculed the then prevailing concept that rain is sent by the almighty god Zeus. The dialogue between Strepsiades and Socrates from his play "The Clouds" is worth quoting.

"Strepsiades.

No Zeus up aloft in the sky!
Then, you first must explain, who it is sends the rain:
or I really must think you are wrong.

Socrates.

Well then, be it known, these send it alone:
I can prove it by arguments strong
Was there ever a shower seen to fall in an hour
When the sky was all cloudless and blue?
Yet on a fine day, when the Clouds are away,
he might send one according to you.

Strepsiades:

Well, it must be confessed, that chimes in with the rest:
your words I am forced to believe.
Yet before, I had dreamed that the rain-water streamed
from Zeus and his chamber-pot sieve."⁽⁴¹⁾

CONCLUSION

The tradition of free enquiry started with the Milesian school — notably from the time of the 'first philosopher' Thales — and every physical phenomenon was subjected to discussion and criticism. It was during the time of the hellenic civilization, man first tried seriously to understand nature and tried to substitute natural causes in places of divine ones. Thales was the first man to give water much importance and his thoughts were echoed later by Pindar who in the 5th century B.C. flatly stated that the best of all things is water. It was here, for the first time in history, man pursued knowledge for its own sake, and, it was during this period the seeds of hydrology as a science was sown only to flower some 2,200 years later — during the seventeenth century with the experimental works of Pierre Perrault, Edmé Mariotte and Edmund Halley.

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