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From 200 to 1500 A.D.

INTRODUCTION

The dawn of the third century of the Christian era revealed an extraordinary mixture of different religions, sects, and philosophies at Alexandria, the centre of learning. The Christian, Judaic, and pagan religions were not on friendly terms; the Alexandrian school as well as the schools of Plato and Aristotle were decaying fast; and the presence of Stoics and Epicureans tended to increase the difficulties. But there was one factor that was common to all elements of this curious conglomeration – it was a profound contempt for science.[1]

HYDROLOGY UNDER THE HOLY FATHERS

With the advent of power acquired by the Christian Church, the desire as well as the privilege of investigating natural phenomena gradually faded away, and with the exception of theology a great stagnation spread over all branches of knowledge. Knowledge was permissible only as a means of edifying the doctrines of the scripture, as interpreted by the Holy Fathers. The Christian faith became a matter of eschatology and honest criticism gradually disappeared. The supreme function of knowledge was the furtherance of salvation and the highest task of philosopher was still to use his knowledge in the service of theology, and to demonstrate philosophy's hand-maidenly accord with revealed Christian truth.[2] According to Dampier:

> 'The Roman empire died, but its soul lived on in the Catholic Church, which took over its framework and its universalist ideals ... Philosophically the Catholic Church was the last creative achievement of Hellenistic civilisation; politically and organically it was the offspring and heir to the autocratic Roman Empire.'[3]

Isidore of Seville

At the turn of the seventh century, when the desecularization process started by the Catholic Church in its determined effort to eradicate heresies and heathenism all over Western Europe was complete, there lived in Seville a Spanish bishop and scholar, Saint Isidore (570–636). He can favourably be compared with Pliny, and his approach to science was similarly encyclopedic. His twenty-volume work on *Etymologies or Origins* is not as systematic as the Roman's Natural history, but it is to be remembered that during Isidore's time science and scholarship were at their lowest ebb; and powerful members of the Church, like Pope Gregory, were outspoken opponents of all secular knowledge. When considered in that light, Etymologies was an outstanding accomplishment, and it was one of the most widely read books for the next one thousand years.[4] When looked at from any direction, that was no small achievement.

Isidore explained meteorological phenomena primarily from a basis of the four elements[5]. Like Aristotle, he also believed in the interconvertibility of air into water, or water into air.[6] He gave two different reasons for precipitation.

'Air being contracted, makes clouds; being thickened, rain; when the clouds freeze, snow; when thick clouds freeze in a more disordered way, hail; being spread abroad, it causes fine weather, for it is well-known that thick air is cloud, and a rarified and spread-out cloud is air.[17]

Later on in his book he said:

'Rains (*pluviae*) are so called because they flow, as if *fluviae*. They arise by exhalation from earth and sea, and being carried aloft they fall in drops on the lands, being acted upon by the heat of the sun or condensed by strong winds.'[8]

These concepts probably indicate that Isidore was aware of the meteorological works of the Greek and the Roman philosophers, perhaps through intermediaries.

Chapters 12 and 13 of Book XIII of *Etymologies* deal with water and their different qualities from distinctly theological viewpoints. Isidore describes water as the most powerful element because,

'the waters temper the heavens, fertilize the earth, incorporate air in their exhalations, climb aloft and claim the heavens, for what is more marvellous than the waters keeping their place in the heavens.'[9]

He then goes on to discuss the various springs and lakes of the world, especially their magical and therapeutical properties. In later chapters he describes the oceans, the Mediterranean Sea (the first recorded use of the word as a proper name), gulfs of the world, tides and straits, lakes and pools, the great subterranean abyss of water, various rivers of the earth, and finally the floods which, needless to say, were biblical, starting with Noah's.

Isidore believed that there is a huge abyss under the earth from which all the springs and rivers originate. The abyss is bottomless and all waters eventually return there through secret channels. This is almost a restatement of the Platonic concept of Tartarus but it is more likely to have come from the book of Ecclesiastes, chapter I, verse 7, which reads:

'All rivers run into the sea;
Yet the sea is not full;
Unto the place from whence the rivers come,
Thither they return again.'

Isidore assigned various reasons for the constant elevation of the surface of the sea. He claimed it was because:

‘its very greatness does not feel the waters flowing in; secondly, because the bitter water consumes the fresh that is added, or that the clouds draw up much water to themselves, or that the winds carry it off, and the sun partly dries it up; lastly, because the water leaks through certain secret holes in the earth, and turns and runs back to the source of rivers and to the springs.’[10]

Venerable Bede

Venerable Bede (673–735), like Isidore, was a devout Churchman and was interested in knowledge insofar as it is useful in propagating a Christian point of view. Intellectually Bede was superior to Isidore, and along with Boethius (480?–524?) he may be ranked as one of the two top intellectual figures of the Latin West during the early Middle Ages. He was the first Englishman to write about weather, and has sometimes been called the founder of English metcorology.[11] Bede was not an original observer of nature, nor was he a theorizer; but he was a compiler and extraordinary summarizer of the existing knowledge from classical sources. His book *De rerum natura* served as an elementary primer on Christian cosmography and astronomy for monks. He freely borrowed from the book Natural history of Pliny and even appropriated an entire chapter from it. He acknowledged the fact, however, and even referred his readers to Pliny for additional information.

His outlook on hydro-meteorology was traditional. For example, wind is the air in motion or disturbance of air; as can be proved with a fan.[12] Breaking of the clouds produces thunder; hail melts more rapidly than snow, and it falls more often during the day than during the night. Salt in the sea cannot be raised by the sun's rays, and hence sea-water is saline; whereas rain, rivers or lakes are not salty. It may be noted that sun’s rays which lack the power to lift the salt from the sea, are reported to be capable of stopping planets in their courses! He also proposed a theory about the origin of the Nile[13] which was a combination of the ideas of Thales and Lucretius. He said that the etesian winds are responsible for causing the sea waves to deposit sands at the mouths of the Nile. As the sands pile up, the exits become less free with the consequent rise of the water level.[14]

HYDRO-METEOROLOGY

After Bede there was no significant development in the field of hydrology until the time of the Italian master, Leonardo da Vinci, but that should not be taken to mean that there was no interest in hydro-meteorology. As a matter of fact, Hellman has shown[15] that there were twenty-six works dealing substantially with some aspects of that subject between the seventh and the fourteenth centuries (although they were just dreary variations of previous works with the probable exceptions of a tenth century encyclopaedia written in Basra by a secret society called ‘The Brethern of Purity’).[16] The vague discussion it contained about the role of cooling during the process of precipitation follows:

‘If the air is warm, these vapours [vapour from the sea and heated exhalation from the land] rise to a great height, and the clouds collect one above the other stepwise, as it is observed in spring and autumn. It is as if they were mountains of combed cotton, one over another. But if cold from the zone of ice comes in from above, the vapours collect and become water; then their parts are pressed together, and they become drops, increase in weight and fall from the upper region of the cloud down through its mass. These little drops unite with one another until, if they come out of the lower boundary of the cloud, they are large drops of rain. If they meet great cold on their way, they freeze together and become hail before they reach the ground. In consequence, those that come from the upper part of the cloud will be hail, but those from the lower boundary of the cloud will be rain mixed with hail ... So the lower boundary of the region of icy cold, and the high mountains round about the sea confine the two rising streams of vapour from which clouds and rain come; they scatter them and take them away, just like the walls and roofs of bath-houses.’[17]

Toward the end of the twelfth century, works of Aristotle (including *Meteorologica*) were again available to the western world through Latin translations made in Spain[18] from the Arabic versions thereof. The meteorological ideas of the great master were in vogue again with the scholars and universities, under the subjective of *Meteora*. The spirit of inquiry was rekindled, as will be obvious from the following questionnaire handed down to us by a Scotsman, Michael Scot (1175?–1232):

‘Likewise tell us how it happens that the waters of the sea are sweet although they all come from the living sea. Tell us too concerning the sweet waters how they continually gush forth from the earth ... where they have their source and how it is that certain waters come forth sweet and fresh, some clear, others turbid, others thick and gummy; for we greatly wonder at these things, knowing already that all waters come from the sea, which is the bed and receptacle of all running waters. Hence we should like to know whether there is one place by itself which has sweet water only and one with salt water only, or whether there is one place for both kinds, … and how the running waters in all parts of the world seem to pour forth of their superabundance continually from their source, and although their flow is copious yet they do not increase if more were added beyond the common measure but remain constant at a flow which is uniform or nearly so.’[19]

These questions went unanswered (in the sense correctly) for about half a millennium in spite of Scot’s promise to answer them all. In the thirteenth century Albertus Magnus (1206–1280) wrote two famous treatises entitled *De meteoris* and De *passionibus aeris* which relied heavily on the works of Aristotle. Then, or slightly later, Vincent de Beauvais in France, Thomas de Cantimpre in Belgium, Ristoro d’Arezzo in Italy, and Bartholomew Anglicus in England, wrote about physical science incorporating mainly Aristotelean ideas, all under the very convenient title, *De rerum natura*. Probably the first book in the English language dealing with the hydro-meteorological subjects was published in 1481. It was called *Mirrour of the World*,[20] and was an English version of the work *Image du monde* of the thirteenth century as 'translated out of frensche into English by me simple person Wyllm Caxton'. The book, reprinted in 1912, deals with clouds, rain, snow, frost, hail, tempest, the circulation of water and salinity of the sea – the same subjects written about so much by the Greek, Roman and the Medieval writers.

The Italian, Leone Battista Alberti (1404–1472), was said to have 'made so great a progress in the sciences that he outstript all the great men of that age who were most famous for their learning'.[21] A major portion of Book X of his treatise *Ten books on architecture*, is devoted to water, and it reminds one of the 8th book of Vitruvius' *Architecture in 10 books*. Alberti was much influenced by Vitruvius but he was better-read than his Roman counterpart. He summarized the properties of water as follows:

> 'We must not omit to take notice of what we see with our eyes, that water naturally tends downwards; that it cannot suffer the air to be anywhere beneath it; that it hates all mixtures with any body that is either lighter or heavier than itself; that it loves to fill up every concavity into which it runs; that the more you endeavour to force it the more obstinately it strives against you, nor is it ever satisfied till it obtains the rest which it desires, and then when it is got to its place of repose, it is contented only with itself, and despises all other mixtures; lastly, that its surface is always an exact level.'[22]

On the question of the origin of springs and rivers, Alberti discussed all the explanations that had previously been offered, and concluded that he could not pretend to determine the correct answer because there are 'so much variety among authors upon the subject, and so many different considerations offering themselves to the mind when we think upon it'.[22] But he thought that if somebody believed that rivers originated from rainwater he will 'not be much mistaken in his conjecture'. He had some ideas about ground water table, and said that if a well is dug, water will be found only if it is sunk to the level of the nearest river.

RAIN GAUGES IN CHINA AND KOREA

The problem of flooding of rivers and canals has always been serious in China and, hence, it is not surprising to find that rain gauges were used at least as early as 1247 A.D. It is to be noted that the previous precipitation measurements were made in Palestine some twelve centuries ago[23] (see chapter 5), but that quantitative hydrological observations were completely lacking during a substantial part of the intervening period.

The book *Shu Shu Chiu Chang* (Mathematical treatise in nine sections) by Chhin Chiu-Shao has a series of problems concerning the shapes of rain gauges, called *thien chhih tshe yü*. The rain gauges he described were of conical- or barrel-shaped vessels. There was one installed at every provincial and district capital. The book also deals with problems on snow gauges – *chu chhi yen hsüeh*. Those gauges, consisting of large cages made of bamboo, were placed at the sides of mountain passes and uplands. This is probably the very first use of snow gauges on record. Chiu-Shao also discussed a method of determining the amount of rainfall over an area from observations of point rainfalls.[24]

The need for regular rainfall during rice cultivation periods probably resulted in the introduction from China, of the practice, of obtaining rainfall measurements all over Korea during the fifteenth century. The very economy of the country depended on the annual production of rice; so much so, in fact, that from ancient times the Koreans prayed for rain to the saints of the mountains and rivers.

The first mention of rain gauges appeared during the reign of King Sejong of the Lee Dynasty in 1441 A.D.[25, 26] during the Golden Age of the Korean Civilization. Rain gauges of the type then describes (figure 1) were used throughout Korea until 1907 A.D. and later references to them occur frequently in the annals of Korean history. The earliest one reads:

> 'In the twenty-fourth year of the reign of King Sejo, the King caused an instrument of bronze to be constructed for measurement of rainfall. It was a vase 1 *shaku*, 5 *sun* deep and 7 *sun* broad, set on a pillar. The instrument was placed at the observatory and the officials of the observatory measured the depth of rainfall each time it rained. The results were made known to the King. Similar instruments were distributed to the provinces and the cantons, and the results of the observations were reported to the court.'[27]

Figure 1. Korean rain gauge of 1441 A.D. (by courtesy of Dr. C. Cook, Director Central Meteorological Office, Seoul).

The Korean rain gauges were about 30 cm deep and 15 cm in diameter. Early in the twentieth century, Wada, then the director of the Korean Meteorological Observatory, made a systematic search for those early rain gauges and for records of the observations made with them, but was unsuccessful.

Some 228 years after the time of King Sejong, rain gauges were mentioned as follows in books pertaining to Korean history:

> 'In the year 46 of the King Eijo [1770 A.D.], the King, following the ancient system of King Sejo, had numerous rain gauges constructed, and placed them, two at the Palace, by the side of the wind-vane, and the others in the chief places of the eight provinces. The rain gauges are placed on stone pillars, measuring 1 in height and 0.8 at the side, and on the upper surface is a hole 1 deep to receive the end of the instrument.'[28]

Wada did succeed in finding two rain gauges of this period – one in Seoul and the other at Taiku. The second one (figure 2) was still in actual use at the Observatory of Chemulpo.[29] On figure 2, the large three Chinese letters mean 'instrument to measure rain' and the smaller seven characters explain that it was 'constructed in the fifth month of the cycle of the year', during a date in the Chinese calendar which corresponds to 1770 A.D. Wada also found a cubical block of marble with a hole in the upper surface for holding a rain gauge, in the park of the Bureau of Registers at the Palace of the residence of H.M. Emperor of Korea. Some 360 Chinese letters are engraved in the pedestal saying that rain gauges were 'invented' during the reign of King Sejo and were later improved by King Eijo.

Figure 2. The rain gauge found at Taiku, 1770 A.D. (after Wada).

Figure 3. Plaster copy of an early Korean rain Gauge at the Science Museum, London (Crown copyright).

Unfortunately the report by Wada concerning the Korean rain gauges contained three errors. Such gauges were in use in Korea at least from 1441 A.D.[25, 26] and not 1442 A.D. The rain gauges were not first discovered by the Italian Benedetto Castelli in 1639 A.D., as supposed by him, but they were in use in India some two millenniums ago. Finally, like the majority of Korean astronomical instruments, the rain gauges were either imported from China or copied from the Chinese types.

Figure 3 shows a plaster copy of an early (1837 A.D.) Korean *tsche yu chhi* (rain-measuring instrument) now in the Science Museum, London.[30] Gauges such as this stood on *yun kuan thai* (cloud-watching platforms). The original rain gauge from which it was copied was the one at the Korean Observatory at Chemulpo described previously. Thus, the rain gauge of King Sejo was first copied in 1770 A.D. and recopied in 1837 A.D.

CONCLUSION

The science of hydrology did not advance much during the thirteen hundred years covered in this chapter. The scholars of this period believed or were led to believe that:

‘Science remains subordinate to theology, and the statements of Scripture represent equally unassailable truths in science as in theology, that they, too, are bent on treating all passages in the Bible in which something is said about nature as scientific enunciations and bringing them into agreement with the results of professional science, does not prevent there being a difference of nuance between their conception of the study of nature and that of the Church Fathers.’[31]

It is, indeed, fortunate that man’s inborn thirst for knowledge could not be suppressed by the admonition that its gratification was not conducive to his salvation. Hydrology, like any other science, suffered very badly from this intellectual suppression, but on the other hand, the general influence of people like Roger Bacon (*argumentum non sufficit, sed experienta*) must have indirectly affected the development of this particular branch of knowledge. In retrospect, the greatest achievement in the field of hydrology during these long thirteen hundred years were undoubtedly the redevelopment of quantitative measurement of precipitation in China and Korea.

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