

FIFTEENTH CENTURY EARTH SCIENCE

EVELYN STOKES

University of Waikato

Abstract

The earth science content of two late medieval encyclopedias, the *Mirrouir of the World* and Higden's *Polychronicon*, both printed by William Caxton in the 1480's, is examined in relation to fifteenth century ideas about the physical nature of the earth and the universe. Such topics as the four elements, the earth and the spheres, location of Hell and Paradise, the arrangement of continents and oceans, the unity of waters, earthquakes and volcanoes, erosion, fossils and mountain building, climatic zones and weather phenomena are summarized and reference made to the Biblical and Classical Greek sources of these ideas.

INTRODUCTION

Earth science did not exist as a distinct field of study in fifteenth century Europe nor was there any attempt to consider earth phenomena in terms of scientific method. However, in the literal sense of science as knowledge, but not necessarily obtained by observation and experiment, a good deal of information, and some speculation, about earth phenomena can be found in the encyclopedic works of the late medieval period. The purpose of this paper is to summarize some of the dominant ideas about the physical nature of the globe, its rivers, volcanoes and earthquakes, its lands and seas, and its climate, in the fifteenth century. The basic 'text' used is the popular encyclopedia *Mirrouir of the World*, published in London in 1480 by William Caxton, but reference is also made to other writings known in the period, particularly Book I of Higden's *Polychronicon*.

William Caxton's *Mirrouir of the World* was both the first work printed in England with illustrations and one of the earliest encyclopedias in the English language, (the usual language of scholarly encyclopedias was Latin). Caxton translated the French work *Image du Monde*, a prose version of a long encyclopedic poem written during the 13th century by one Gossouin of Metz about whom little is known. The original work was a compilation from various classical and medieval Latin sources, often copied word for word, and deliberately designed to popularize scientific and geographic knowledge of the world, within the bounds of orthodox religious teachings. Caxton's English version of *Image du Monde*, was just as popular as its French original and ran through several editions (Prior, 1913).

In Part I Gossouin describes the power of God in a homily which takes up the first five chapters. He then goes on to describe some classical writers, and the seven liberal arts which were taught in the School at Alexandria. The final section deals with his ideas of God and Nature. Part II contains largely geographical material, a neat summary of the physical and regional geography of the known world. It is from this section that most of the ideas on earth science discussed here are derived. Part

III contains largely astronomical information derived from the *Almagest* of Claudius Ptolemaeus, with digressions on the writings of various classical authors, notably Virgil, and a final dissertation on the joys of heaven.

Ranulph Higden was a monk of St. Werburg's Abbey in Chester, England. He was born during the last twenty years of the 13th century, took his vows as a monk c. 1299 and died c. 1363. He did visit other parts of England but otherwise few details of his life are known. His best known work was the *Polychronicon*, or Universal History, designed to include the most important facts of history from the Creation to his own time, in chronological order. The geographical material quoted here is derived largely from Book I, The Map of the World, a brief description of all the known regions of the world, particularly Britain. Higden wrote in Latin, but the work was translated into English in 1387 by John of Trevisa and became one of the most popular histories of the fifteenth century. William Caxton printed Trevisa's version in 1482 (Babington and Lumby, 1865-86).

There was usually little original material in the medieval encyclopedias. The authors rarely left their monasteries to observe for themselves. Mostly, their works were compilations from Greek and Latin writers, and their commentators, and the encyclopedic works of the Church fathers, such as the Venerable Bede and Isidore of Seville. Plagiarism was not a crime and the same sources were used over and over, with or without acknowledgement.

By the mid-thirteenth century, the writings of the better classical authors, notably the works of Aristotle, which had been preserved by the Arabs but ignored by medieval Europe, were again made available to scholars in Western Europe. The revival of classical learning which blossomed during the early Renaissance served to emphasise the authority of the classical writers. It is not surprising, therefore, that Aristotelian ideas on what we now call earth sciences should be paramount in the fifteenth century. However, Aristotelian views were dominant only where there was no contradiction with theological doctrine, or when Biblical references failed to give any guidance in explaining natural phenomena.

One of the main features distinguishing medieval from modern scientific writing is the preoccupation with religious interpretation of natural phenomena. The more marvellous the phenomenon, the more noteworthy it was as an example of the power of God and the greatness of His manifold works. There was little attempt to explain in terms of any scientific theory; it was sufficient to describe, and comment, and wonder at the works of an omnipotent and omniscient God. Humble man was not expected to know or understand more than a tiny fraction of the wonders of Creation. It was good for man to seek to learn more, but he must not expect to find all the answers and must confine his researches within the bounds of theological doctrine. The following passage from the *Mirroure of the World* summarizes this attitude toward scientific enquiry:

And do not wonder at the things which you have found written in this book and seem to you very strange, diverse and difficult to believe. For Our Lord God who is the Almighty Maker and Creator of all things and in whom there is all power and good, has, by his own will and pleasure, made many marvels in this earth and many works to be wondered at because no man knows the reason why or wherefore. Therefore we ought not disbelieve in any way what we read here, or are told, about the wonders of the world until such time as we know whether they are true or not. The works of Our Lord are so high, and to men so complex and difficult, that every man may take these works for granted, though a man does no harm if he disbelieves, sometimes, things about which he knows nothing,

provided that he does not thereby err against the faith. For it is a good and profitable thing for every man to understand and remember, so that he may learn and not be abashed when he hears talk of such things, and can answer for the truth. Just as to us some of the things I have related seem to be great marvels, so it seems to them, that we, and the things found in these countries about us, seem very diverse and strange. They marvel greatly because they have seen little of us and our works. Therefore, a man ought not to wonder if he sometimes hears something although he can not understand the reason behind it. A man ought to be always ready to learn. There is no man who knows everything, except God alone, who sees all and knows all.

THE EARTH AND THE SPHERES

There was no doubt about the sphericity of the earth in the late medieval period (Taylor, 1931 and 1935), Gossouin wrote: "We have understood that the earth is round on all sides like an apple." He explained in some detail that because the earth is spherical, a man could journey right round it, if there could be land all the way, "as a fly goes round about an apple". (Fig. 1). He would reach a point where:

It should seem to him that we were under him, just as to us he would seem to be under us, for he should place his feet opposite ours and his head toward heaven, no more nor less than we do, and his feet toward earth.

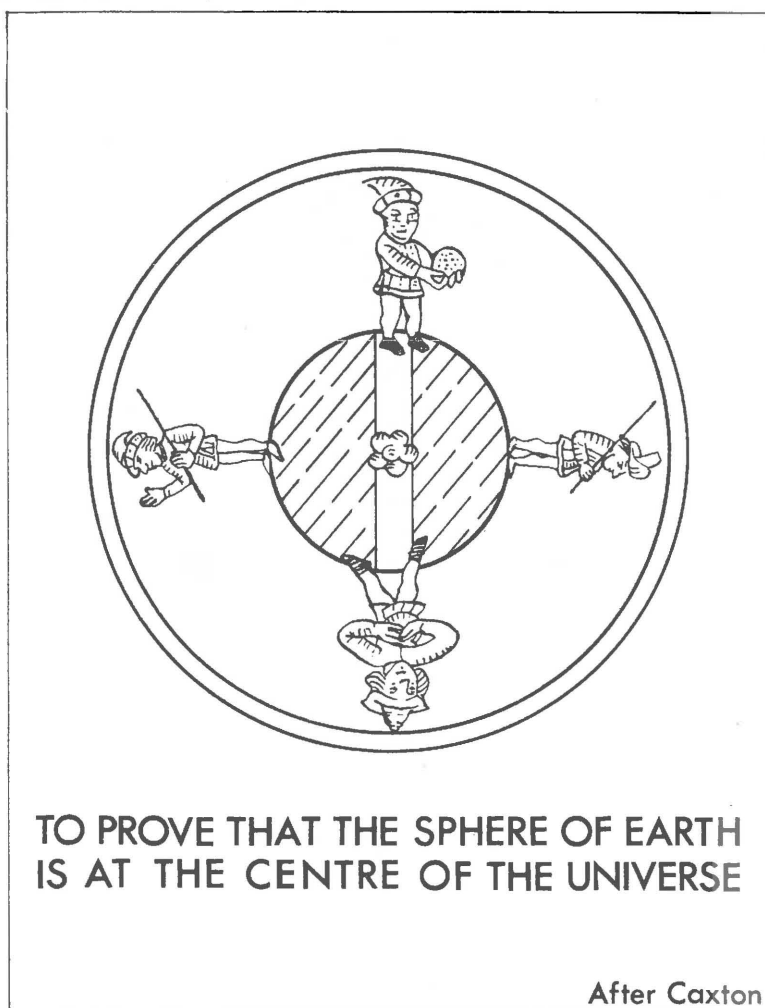


Figure 1

Rudimentary ideas of gravity are introduced in elaborating the description of the earth's roundness:

If the earth were parted right in the middle, in such a way that heaven might be seen right through it, and if one threw a stone, or heavy plummet of lead, when it reached the middle, half way through the earth, it should abide fast there. Even, if in falling it went further than the middle,

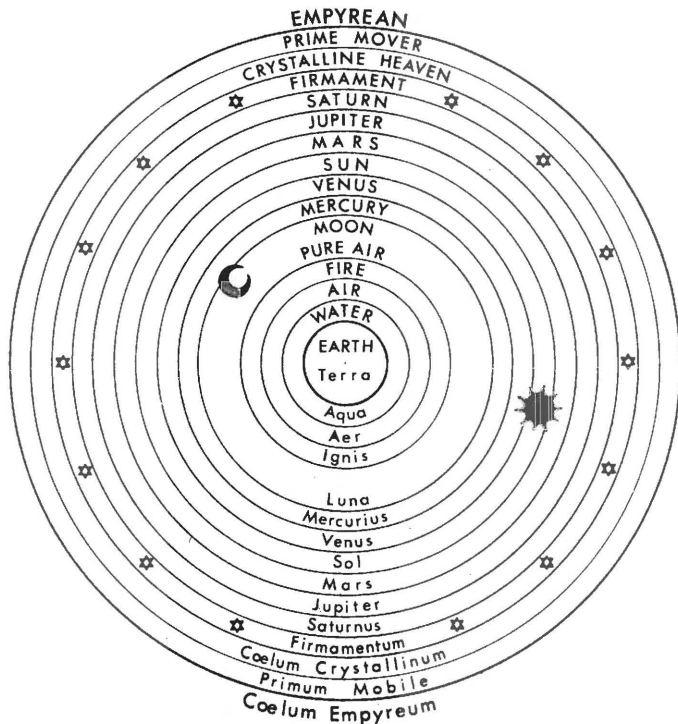
it should rise again in such a way that it will remain in the middle of the earth, and should never move from thence, for then it is at an equal distance from the firmament which turns night and day. By the virtue and might of its turning, nothing that is heavy may approach the firmament, but always falls away beneath it.

The earth, being the heaviest body in the universe, was therefore at the centre.

God formed the world all round, because of all the figures there be, and of what diverse kinds, may none be so full, or contain so much by its nature, as the round figure, for the circle is the most ample of all figures that can be used as an example.

The advantages of the circle or sphere in moving and turning, and the disadvantages of the rectangular figure are outlined. "And therefore God made the world round to this end, that it might best be filled on all sides, for He will leave nothing void". Since the firmament, the sun and moon and planets turned about the earth, the earth must be spherical.

This spherical earth was the centre of a concentric series of spheres, a system based on Aristotle's cosmology outlined in the *De Caelo* (Ross, 1931). The innermost spheres were those of the four elements: earth,



THE EARTH AND THE SPHERES

Figure 2

water, air and fire (Fig. 2). Ideas about the nature of phenomena occurring in these spheres will be considered in more detail below. Beyond the sphere of fire was the sphere of pure air:

The pure air is above the fire and extends to heaven.

In this air is no obscurity nor darkness, for it is made of clear purity. It is so resplendent and shining that nothing can be compared to it.

In this air are seven stars which make their course around the earth. These are very bright and clear and are named the Seven Planets. One is set above the other, so ordered that there is more space between them than there is between earth and moon, and this distance is fifteen times the diameter of earth. Each one runs by a miracle in the firmament . . .

These "seven planets" consisted, firstly, of the moon which "because it is nearest the earth it appears the largest and most obvious of all". The reflected nature of its light was understood:

But the clearness and light that we see is derived from the sun, just as a mirror, when the sun's rays strike it, casts a reflection on the wall which lasts as long as the sun shines on the glass. In this manner the light of the moon comes to us. The moon is a fair polished body, like a finely burnished knob on a sword hilt which shines and reflects light and brightens when the rays of the sun strike it.

Some say that the little clouds or patches of darkness seen on the moon are reflections of the earth. The areas of water appear white, just as a mirror reflects various colours when it is turned.

Others think otherwise, and say that it happened when Adam was deceived by the apple he had eaten — the sin which has burdened all his human descendants — the moon was damaged and its clarity reduced.

The other six planets were in order away from the earth: Mercury, Venus, Sun, Mars, Jupiter and Saturn. The sun, because of its size and obvious source of heat, is singled out for special comment: ". . . the sun which is so clear, fair and pure that it radiates light and clearness to all the world." However, all seven planets exerted considerable influence:

The character of these planets is such that they have power over things that grow on earth and are more abundant in virtues than all others in the firmament and their influence is more obvious, as the ancient and wise philosophers have discovered in their researches.

Beyond the seven spheres of the planets was the firmament which contained the 'fixed stars' as opposed to the planets which moved in their own spheres. No further distinction was made between stars and planets in the modern sense.

Beyond Saturn, which is the last planet and the furthest from us of all seven planets, is the heaven which men see so full of stars in clear weather, as though they were seeds scattered on the ground. This heaven which is so starred, is the firmament which revolves. In this movement there is such joy, and such a fine, sweet melody, that no man, should he hear it, would ever after have the power or will to do anything whatsoever against Our Lord; so great would be his desire to go thither, that he might forever be where he could hear such sweet music. It is sometimes said of it that little children hear this music when they laugh in their sleep, for it is said that they hear then the Angels of Our Lord singing in heaven and this is why they feel such happiness in their sleep.

But the truth of this no man knows, except God who knows all, who set the stars in heaven and gave them such powers, for there is nothing within the earth, nor within the sea, however diverse, which is not accounted in heaven and compassed by the stars, whose number no one knows, except God, who, at his pleasure, numbers them, and knows the name of every one of them, by reason of his knowing all and having created all . . .

For there is no star, however tiny, which does not possess some powers over things on the earth, whether herb, flower, or fruit, whether its form, colour or other characteristic. There is nothing which ought to be in the earth, nor growing on it for which some star has not power and influence of its own nature, whether good or otherwise, as God has bestowed on it.

Beyond the firmament was the "crystalline heaven" and beyond this the "primum mobile," the source of movement and music created by the motion of all the concentric spheres. Beyond the realm of the spheres was the Empyrean, the dwelling place of God and His hierarchies of angels, the primal source of all power. (Adams, 1938; Ch. III).

The Four Elements

According to Aristotle (*De Generatione et Corruptione* and *Meteorologica*) all matter was made up out of the four elements earth, water, air and fire. None of these existed in a pure form, but in a combination of at least two elements. None of the elements was immutable, but could be transformed from one to another. Aristotle also recognized 'contraries' of tangible qualities of matter such as hard-soft, heavy-light, rough-smooth, and so on. Of these, the primary contraries were hot-cold and dry-moist. There were four possible combinations of these qualities, and these attached themselves to the four elements as follows: fire is hot and dry; air, being a sort of aqueous vapour, is hot and moist; water is cold and moist; earth is cold and dry. (*De Gen. et Cor.* Book II).

There was constant interaction and transmutation between the elements, although one element was always dominant, and it is on this basis that the four 'earthly' spheres (as opposed to the 'heavenly') were defined. In Gossouin's words, the heavenly spheres

environ all about the world the four elements which God created and set one with the other. Of these, one is fire, the second is air, the third is water, and the fourth is earth; each is fastened within the other, and one sustains the other in such a way that the earth is held in the middle . . . for as much as the earth is heavier than any of the other elements, it is therefore held in the middle, and that which is most heavy abides about it.

All the sublunary spheres were under the influence of the heavenly bodies and interaction with the transmutable elements of the earthly spheres produced all the physical phenomena of the atmosphere, sea and land. This Aristotelian idea was the basis of all attempts to explain nature, although there was often little agreement about the manner of manifestation and a great variety of interpretations resulted. (Wright, 1925, pp.19-20).

Hell and Paradise

Both regions were given definite locations within the sphere of earth. Ranulph Higden describes the location of Hell:

Thus it is estimated that the circumference of the earth is approximately 20,040 miles. If we divide this sum into three and a seventh part of three, the thickness through of the earth is almost 6,500 miles . . . then half the thickness of the earth is a little over 3,245 miles. Therefore, if hell is in the middle of the earth right below us, we know how many miles it is to hell.

The writer of *Mirror of the World* explains why hell must be in the centre of the earth:

To my way of looking at it, it seems that that which is surrounded by, and enclosed within the earth is hell. I say this because hell cannot possibly be in the air which is such a noble place. Also, I may freely maintain that it is not in heaven for that place is so clear, pure and excellent that hell could not be endured there because hell is so horrible, stinking, foul, and dark. Also, it is more weighty than anything else and for this reason it can be clearly understood that hell must exist in the lowest places, the darkest and most vile places of the earth. Thus I have here explained to you the reasons why, in truth, it may not be in the air, even less in heaven, for in all aspects it is the opposite of heaven above in as much as these two places are contrary to one another. In the one is found all glory and consolation: that is heaven. In the other is nothing but all tribulation: that is hell. And therefore its location is as far away from the other as can be and that would be the middle of the earth. . . .

He goes on to describe in lurid detail the torments to be found in this "abyss or hollow of perdition":

This much I say to you of this place, that it is full of fire and burning sulphur. It is always hideous, stinking, full of ordure and all evilness. It is very wide within but presses down low.

The sulphur continually burns, destroys and consumes all that falls therein. And everything that enters will never be finished, or have any end, but will burn ceaselessly. And none who enter will ever die, for one of the characteristics of this place is that the more anything burns the longer it endures. . . .

Death holds them there at his command. This is the very pit of burning fire. Just as the stone is drowned in the sea when it is thrown in and sinks and is never seen again, so the souls sink to the bottom where they burn continually and are drowned there. But for all that, they are not diminished, nor have any end, but in such misery endure their follies night and day. And so they shall endure perpetually, without ending. For whatsoever is spiritual may never die in such a way that it is completely dead. But that death would they prefer, and they long for it incessantly. . . .

This is the land of oblivion and forgetting, for all who are there will be forgotten, just as in this world they forgot their Maker who is full of pity and mercy. Therefore He has placed them in oblivion, where they shall never receive any mercy or pardon. In this land so shadowy, hideous, full of all stenches, and of sorrow, anguish, heaviness, hunger and thirst, no creature shall ever feel gladness or joy. This is the terrible, stinking Gehennu. And there is the fire blazing so much, so hot and searing, that our fires and their heat are as little in comparison with hell, as a fire painted on the wall is in comparison with the heat of our fires.

There too are the perilous floods of fire and ice, so hideous, horrible, full of poison and foul beasts, that make so much noise, cause such grief, pain and irritation to the dolorous souls in this abyss, that no creature can attempt to describe but one hundredth part of it.

Further evidence that hell was located in the centre of the earth was provided by active volcanoes, the gates of hell, in certain regions of the earth:

In this region there are plenty of other places which are perilous and horrible. Of these, some are in the sea as well as in the earth. In many islands by the sea there is a terrible stench of sulphur burning in a great fire, which is very painful. There are many great mountains of sulphur that burn night and day, where so many souls are gathered together and burn continually, in order to purge their sins and iniquities.

Paradise was the complete antithesis of hell. Here was all sweetness and light, and medieval writers, basing their information on the Biblical account given in Genesis Ch. 2, waxed lyrical in elaborating this description. The main elements included a garden with an abundance of trees, fruits, and flowers which in some accounts are unfading, in others have medicinal qualities; in some, the fragrance of fruit and flowers is emphasised, and there are frequent references to birds and animals. The climate was always temperate, the air clear and agreeable as though eternally spring. The Tree of Life and Tree of Knowledge were to be found there, and also the fountain from which flowed the four rivers: Ganges, (Pison or Phison), Nile, (Gihon), Tigris and Euphrates, often interpreted in allegories as the four streams of the Gospel. Many precious stones, were to be found in the banks of these streams and elsewhere in Paradise (Patch, 1950).

Since the Nile was one of the rivers flowing out of Paradise, some writers advocated a location in Africa above the headwaters of this river. Higden commented on an alternative explanation of the Nile:

And though men read in books that the Nile flows out of Paradise, yet some affirm that the Nile rises in the west of the land of Ethiopia, not far from the mountains called Atlas and flows around Ethiopia and then through Egypt. (See also Crawford: 1949).

The orthodox location of Paradise was in eastern Asia, beyond the dwelling places of man, cut off by an ocean barrier, or a fiery wall, or a combination of both. Higden argued against a location "separated from the earth and high as the moon. This is not true for both nature and reason contradict this. . . ." He argued that the weight of Paradise could not be supported by the spheres of air and water; that nothing can live in the sphere of fire between the sphere of air and the moon; that if Paradise were so high it would sometimes shade the moon: "But of such an eclipse we have never heard;" and finally, "if Paradise were as high and separated from the earth and all its lands how should the four rivers which spring out of Paradise pass through air and the wide ocean and flow into the lands where men dwell."

The east Asian location of Paradise was demonstrated in the medieval T-O maps, such as the Hereford Map, where Paradise was prominently drawn in at the top of the map, often with pictures of Adam and Eve, and the garden, and the four rivers shown flowing out across Asia. The three divisions of earth: Asia, Africa and Europe were entirely surrounded by ocean so that, the earth being a sphere, it was theoretically possible to sail west from Europe to reach Paradise (Fig. 3).

Gossouin of Metz followed the orthodox view of Paradise.

The first region of Asia the great is terrestrial Paradise. This is a place which is full of solace, of pleasures and delights, so that no one therein may be grieved or endure any kind of evil of this world. In this paradise is the tree of life; and he who has eaten of this fruit shall not die as long as the world endures. But no living man may come thither unless Our Lord God or his Angel guide and bring him thither; for all around it is enclosed with burning fire which flames up into the clouds.

The problem of the Nile was explained by having it flow underground somewhere in Paradise to reappear in Ethiopia and flow through Egypt to the Mediterranean Sea. No explanation is given why the Indus should not also have its source in Paradise.

The Arrangement of Continents and Oceans

One of the basic problems was to reconcile the relation between the spheres of earth and water. Theoretically, the sphere of water should completely surround the sphere of earth. This obviously was not so in reality. Typically, recourse was made first to the Bible and the following passage from Genesis 1:9-10 satisfied most as an explanation.

And God said, Let the waters under the heaven be gathered together into one place and let the dry land appear: and it was so.

And God called the dry land Earth: and the gathering together of the waters called The Seas: and God saw that it was good.

The area of the Oecumene, the inhabited earth, was defined on the T-O maps and divided into three parts: Europe, Asia and Africa, completely surrounded by ocean (Fig. 3). However, speculation on the relation of oceans and continents also involved discussion of the Antipodes, the southern continent cut off from the Oecumene by the fiery heat of the Torrid Zone which began in the Sahara. Theological arguments had been advanced by St. Augustine and others against an inhabited Antopodes even if such a land mass did exist. All men being descended from Adam, it was argued, the Antipodes could not be inhabited by man because the Torrid Zone made it inaccessible to man. This did not preclude conjecture about the nature of a semi-human Antipodean people.

Some non-theological ideas were advanced in the early fifteenth century, concerning the relation of continents and oceans. John de Fundis

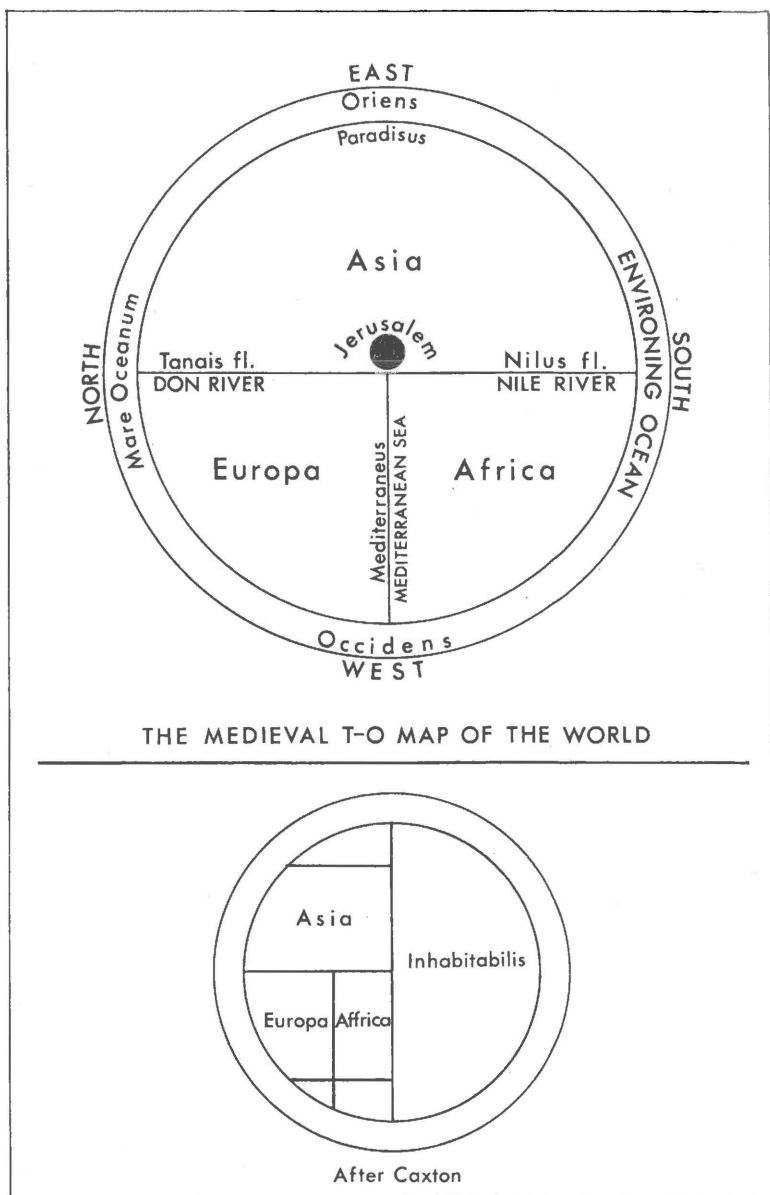


Figure 3

postulated that three-quarters of the globe was under water which surrounded the inhabited quarter; the antipodes were uninhabited. The land area moved in relation to an imaginary fixed point in the firmament, the western coast eroded while new land emerged in the east, making a complete circle of the earth in approximately 100,000 years (Thorndike, Vol. IV, p.239). John Calderia used the stock astrological argument that the antipodes were covered with water because the influence of the stars was weaker there. While conversion of air into water continued in the north, as elsewhere, certain stars near the North Pole were strong enough to hold back the water which continually flows south and prevent the

submergence of the Oecumene (Thorndike, Vol. IV, pp.165-6). Giovanni da Fontana thought that part of the earth's sphere was above that of water because the earth had two centres: the centre of gravity coincided with the centre of the universe but its centre of magnitude, or circumference, did not correspond, thus allowing part of the heavier earth to appear above water as dry land. This was a notable exception to the accepted concentricity of the spheres. Therefore, the antipodes of the Oecumene would be more deeply submerged in water. (Thorndike, IV, 176; Moody, 1941).

Gossouin of Metz was unconcerned with any speculation about the relation of earth to other spheres and preferred to attribute it all to the divine will of God.

The earth, which is very heavy in nature, holds itself in the air without pillar or foundation, but that is its character. And therefore he is a fool who wonders at the things that God makes, for no creature has the power to show reasons why they should or should not be. For there is nothing, however small, about which all truth is known except only as much as it pleases Our Lord God to let us know. In order to be well schooled in the Church, men may know and understand the reason for some things and also know other things by their properties which can not be comprehended by reason. Though a man enquire any length of time about that which is wrought in the earth, he shall not attain any further knowledge about how and why they are made. This may no man know for certain, except God alone who knows the reasons why and comprehends them all.

THE SEAS

Higden wrote: "The water of the ocean encompasses the earth like a garland and at certain times comes and goes, ebbing and flowing. . . ." In the second century B.C. Posidonius had correlated tides with phases of the moon and throughout the medieval period they were commonly attributed to lunar influence. Some writers combined astrological with physical explanations involving the action of great whirlpools, or the impact of ocean currents, or the Aristotelian theory of exhalations and vapours being drawn up from the sea floor by the moon and thus raising the sea level in a cyclical way. Apart from speculation of this sort there was no unified theory of tides or ocean currents. However, a good deal of practical information was known about different coasts. Higden noted that the tidal range was greater on West European and British coasts than in the Mediterranean. Certain marvels, often derived from classical mythology, such as Scylla and Charybdis in the Straits of Messina, were commented upon but left unexplained.

The salinity of the sea, in contrast with fresh water on land, was the source of some speculation. The writer of the *Mirror of the World* described saline mountains on the sea floor as the cause of this saltiness:

It is caused by the sun on high for in some places it gives out so much warmth that the sea is heated so much that it draws from the earth underneath a bitter moisture which takes away all its savour. For in the sea there are great mountains and deep valleys which are infected and full of grievous bitterness. The heat of the sun above is felt on the earth in the bottom of these valleys and it mixes deep water and earth in such a way that the salt is drawn upward by the heat of the sun until it is all mixed up with the water. Thus the sea water becomes salt like the sea bottom.

The usual explanation was based on the Aristotelian belief that water in its purest form has an insipid taste, but is thickened and rendered salt by the sun's heat in the torrid ocean zone whence it is distributed by currents to other seas.

The Unity of Waters

"All the waters run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again." Ecclesiastes 1:7

This was the Biblical basis for hydrological theory as expressed in this passage from the *Mirroure of the World*:

The water forms the deep sea which surrounds and flows right round the world and from this sea come all streams and rivers that run through the earth. They run so far in their courses until they return from whence they departed, that is the sea. Thus the sea is continually moving and flowing, for water is lighter than earth, and thus it is mostly above, but next to the earth. It divides the continents and spreads around the whole earth.

The water flows continually into the sea and is continually spread over the land in rivers and streams. It flows in the earth by veins from one place to another. Just as the blood of a man runs through the veins of the body and issues forth at a particular place, so the water runs through the veins of the earth and comes to the surface in springs and fountains. From this it follows that if one digs deep in the earth, in mountain or valley, one finds water, whether salt, or sweet or some other kind.

Gossouin goes on to discuss the different kinds of waters and springs to be found in the earth and offers an explanation for some of these:

All waters come from the sea; both sweet and salt, or whatever they are, all come out of the sea and thither they all return. Whereupon some may ask: "Since the sea is salt, how is it that some water is fresh and sweet?" One authority answers this and says that water that has its course through the sweet earth is fresh and sweet, and it becomes sweet through the sweetness of the earth which has the property of taking away its saltiness and bitterness. . . . Thus water which was formerly bitter and salt becomes sweet and fresh.

Other waters spring forth bitter and black, which some men drink instead of poison, in order to be cured of their maladies. These often make good purgatives for some people. This water wells up black and clear and runs through the earth which is bitter and black, and it is full of filth. Wherefore men are astonished that it may be wholesome to the body of a man. In another place there are springs of hot water, in which a pig or goose may be scalded. These are called baths or natural baths. Such baths there are in Germany in the city of Aachen, and in England at Bath; another is in Lorraine at the abbey of Plombières, [in Vosges area] and also at Ays in Gascony [either Ax in Ariège or Dax in Landes]. These occur because there are many caves within the earth which are hot and burning like fire. And the earth has plenty of veins which are full of sulphur. Sometimes a wind, great and strong, comes with the flowing water, and it rushes forward so strongly that the sulphur catches fire and burns just like a blazing furnace. The water which flows in a course near these veins also becomes as hot as fire. If it should happen that the water should gush out of the earth right there, it issues forth all steaming and boiling as if it were over a fire. But as the distance along its course decreases from thence, so the water decreases in heat and is less burning. It may run so far that it eventually cools down again, for there is nothing so hot that it does not cool some time, excepting only the fire of hell which continually burns and shall burn unceasingly.

Within the earth there are plenty of places which are full of foul and venomous beasts, in such a way that the water that runs through them is all infected when it springs forth in some places of the earth. He who drinks of these springs is looking for his death.

Further discussion of "the diverse wells and springs that form in the earth" is confined to a catalogue of their location, their magical and medicinal properties, and other curiosities.

The doctrine of 'congregatio aquae' or unity of waters was the nearest to any general theory reached in the late medieval period. The Greeks had speculated about the sources of ground water and noted that rain which was irregular, particularly during the long, hot Mediterranean summer, could not be the sole source of river flow. Since water was one of the four elements which made up all matter, it was not surprising that it should pour out of the earth. In the limestone regions of Greece and

the Adriatic coast this was a fairly common phenomenon. However, speculation continued through the medieval period on the nature of the process, whether water formed from air in cavities in the mountains, whether there were direct underground connections with the sea, and whether rain and snow were really sufficient to maintain an even flow in the rivers. In the fifteenth century, an elementary hydrologic cycle was generally accepted. The rivers ran into the sea, but evaporation by the sun prevented the ocean from increasing in size from the river water flowing into it. River water came from rain and snow and in addition, in some mysterious way, as yet undemonstrated, but sanctioned by the references from Ecclesiastes and similar references to the dividing of the waters in Genesis, all waters were one unit and must inevitably make their way back from the sea to the river sources. (Darby, 1933).

Apart from specific references to particular rivers, notably the Nile, the behaviour of rivers was not studied in a comparative way. The Nile flood was frequently commented on, with the usual Christian interpretation thrown in. In this extract from Higden's Polychronicon, the Biblical references can be found in Amos 4.13, and 7:4-13.

The Nile flows around Ethiopia and down into Egypt; and because of the silt carried in it makes the land fat and good for raising grain and fruit. Thus says Hieronymus, concerning the prophet Amos, that by God's own ordinance, the Nile overflows and waters all the land of Egypt, for heaps of gravel stop its course that it cannot fall into the Mediterranean. But after it has overflowed and watered the land, the heaps of gravel wash away, and the river returns to its channel again and runs into the sea. Nevertheless, Isidore says that the Nile is driven back and hindered by the north wind and so the water rises and floods. But Bede says that this wind blows in May and stops the course of the water of the Nile with heaps of gravel, and so the water rises and overflows the land. But when the wind ceases, the gravel falls away, and the water flows into its channel and turns toward the Mediterranean.

Apart from the interesting explanation of the annual Nile flood, this passage is a fine example of the usual medieval scholar's reliance on earlier authoritative writers rather than on field observation. However, Higden also commented on the behaviour of the River Dee which runs through the city of Chester where he lived, and formed the boundary between England and Wales. But he interpreted the changing course of the river as a portent that the English or Welsh would have the upper hand that year, according to whether the river shifted toward England or Wales, rather than presenting scientific observations on its behaviour.

THE SPHERE OF EARTH

Earthquakes and Volcanoes

The following explanation from *Mirroure of the World* is the orthodox one, derived from ancient Greek writers and given a Christian interpretation.

Now you must comprehend what is meant by the moving of the earth how it quakes and shakes. Some people call this "an earthquake" because they feel the earth move and quake under their feet. Sometimes it quakes so terribly and moves so much that cities sink into the earth never to be seen again.

This is the result of the large streams of water within the earth which sometimes hollow out caverns below the surface. Air is shut fast within these, under great pressure. If the earth's crust is weak, it may not be able to retain it all and is forced to crack open and the air rushes out. It is then that it often happens that towns, cities and castles sink down into the chasm.

If the earth is sufficiently strong that it does not crack open with the pushing and heaving of the wind within, then it trembles and quakes so astonishingly that great walls and high towers suddenly fall down in destruction

and kill the people inside them when they are not advised or warned of such dangers. This is a cause of much sorrow for the poor people who dwell where such misfortune occurs, when they are not warned of the advent of such a cataclysm so that they may avoid it.

But wise men who fear death, arm themselves, and make themselves ready in case of death. They very diligently seek conciliation with their sovereign judge for their sins and defaults in law, and believe that they must live as though they had no more hours of life, and thus they put their minds at ease.

Thus the water and the wind cause the very quaking and trembling when the earth splits open and shakes.

The greatest earthquake known in history, the destruction of Atlantis, was frequently described with the usual moral overtones:

This island is so large that it occupies more space than Europe and Africa together. But since Plato's time it was destroyed and broken as it pleased Our Lord, for it came down into the abyss because of the great sins committed by the inhabitants.

Atlantis itself seems to have been invented by Plato, possibly inspired by an Egyptian legend, and used for purely pedagogic purposes in the *Critias* and the *Timaeus* (Jowett, 1953). Nevertheless, the story was seized upon, and given a Christian moral in medieval Europe.

Earthquakes and volcanoes were associated phenomena. Volcanoes occurred when the subterranean winds and torrents of wind and water, rock and gravel, fire and brimstone derived from hell reached the surface. Higden's description of the Sicilian volcanoes is most graphic, although he himself had not been there and obtained his information from the writings of the Venerable Bede and Isidore of Seville.

The land of Sicily is hollow and full of caves and has much brimstone and bitumen so that air and fire can make a way through it. Fire, enclosed within the caves and cracks in the earth, strives with the air, and other things which oppose fire, and causes it frequently, and in many places, to break out into smoke and burning flame. And sometimes the strength of the wind within the earth causes breaking and great heaps of stones and gravel are cast out. It is because of such activity that the burning on Mount Etna has endured so long. Mount Etna, and south of it, has many clefts and hollow caves within the earth, full of brimstone, that engender much wind and fire and smoke. In that place are seen diverse figures and shapes and are heard rueful voices and groaning. Therefore, some people believe that there are souls in pain there. . . .

Higden goes on to describe the island of Eola. In Greek mythology the Aeolian Islands, (Lipari Islands off the north coast of Sicily) were the abode of Aeolus, god of the winds. This was consistent with the Greek idea that earthquakes and volcanoes were caused by subterranean winds and therefore it was fitting that the dwelling place of the god of the winds should be in a group of volcanic islands.

Erosion, Fossils and Mountain Building

While the obviously marvellous, and sometimes catastrophic, phenomena such as earthquakes and volcanic eruptions were frequently described, the normal processes of erosion generally went on unheeded. There was no scientific study of rocks and minerals, or of rock strata and their relations to each other on which to base any theories of earth history. Systematic studies of this sort awaited the keen field observations of sixteenth century miners such as George Bauer (Agricola), or the Huguenot potter Bernard Palissy, and naturalists such as the Swiss Conrad Gesner.

Such information about rocks as was available in the late medieval period was contained in books of stones called lapidaries. These were a remarkably popular form of medieval writing whose origin can be traced to later classical authors such as Pliny or Solinus. Although they can be

described as the earliest treatises on rocks, few detailed descriptions of the stones, beyond remarks on their colour and possible original locations were provided. The main purpose was to set out the supposed 'virtues' of each stone, particularly the magical and medicinal qualities with occasional comment on their beauty and symbolic significance. There was no attempt to study rock structures scientifically or connect these with landform processes.

The chief obstacle to speculation on the role of erosion and formation of mountains was theological dogma. A number of writers had noted the effect of rivers washing away their banks, erosion along coastlines and so on. Any further enquiry was hampered by the literal interpretation of Genesis, the creation of the earth in six days, when the main outlines of land and sea were established. Further modification, notably the sculpturing of mountains and valleys, occurred during the Universal Deluge, or Noah's Flood. Any subsequent landform changes must be negligible, or they would contradict Biblical authority.

A further complicating factor was the controversy over the nature of fossils. These were variously explained as jokes of capricious Nature, the work of occult and evil forces, often meant to convey a hidden meaning, the discarded remains of preliminary attempts by God in the process of creation, the products of vapours, exhalations or lapidifying juices at work in the earth, or the results of spontaneous generation in the earth which failed and never became truly animal. It was simpler to assume a non-organic origin, and so avoid the theological problems of explaining an organic origin. Nevertheless, the similarity of many fossils to living forms was too remarkable and some writers reluctantly conceded an organic origin. (Adams, 1938; ch. VIII). The only permissible explanation then of fossils occurring far inland and high up in the hills was that they were washed there by Noah's Flood. (Adams, 1938; Darby, 1933; Geikie, 1905).

There were some non-theological arguments offered to explain fossils, such as the ingenious attempt of John Buridan in explaining the eccentricity of the spheres of earth and water. He accepted different centres of gravity and magnitude and argued that dry land continued to exist, despite the processes of erosion decreasing its volume, because it was thus made lighter, and change in the centre of magnitude was offset by an equal change in the centre of gravity, essentially an elementary form of isostasy (Moody, 1941). This also explained the formation of mountains and occurrence of fossils far inland. Leonardo da Vinci far outstripped his predecessors, and immediate successors, in his comprehension of the nature of fossils, erosion processes and implications for landscape evolution. But his ideas were too heretical for public consumption and he wrote his observations and speculations in code in his notebooks, and consequently had little effect on contemporary ideas about landforms. Theological doctrine was seriously challenged in the 16th century by field observers such as Fracastoro, Bauer and Palissy, and the controversy gathered momentum with the publication of the observations of Nicolaus Steno and others, and the pronouncements of Archbishop Ussher in the 17th century. But in the 15th century, most writers were still content to refer difficult and apparently inexplicable problems to the works of an all powerful Creator.

THE SPHERES OF AIR AND FIRE

Climatic Zones

There was no formal division of the world into climatic types beyond the Aristotelian zonation of Torrid, Temperate and Frigid. The Frigid

Zone was too cold to be inhabited; the Temperate Zone comprised the Oecumene; and the Torrid Zone was too hot for human habitation and effectively cut off human access to the Temperate Zone of the southern hemisphere. People who lived in Ethiopia on the margins of the Torrid Zone were burned black "because of the heat of the sun, for it is so hot in this region that it seems that the earth should burn". Aridity was associated with the Torrid Zone, but such regions were usually dismissed as uninhabitable wilderness.

Beyond Ethiopia is no land but desert, and land which brings forth no fruit, but is full of serpents, vermin and wild beasts. This land ends at the Great Sea.

It was widely believed, though not always expressly stated, that climate influenced the nature and character of man. Bartholomew Anglicus commented that because the north wind dries and cools the land, yet owing to its cleanness, is "pure and subtile"; in the north, men are tall in stature and fair in body. The south wind, being hot and moist, gave the people of the south a different appearance and they were not so bold, or wrathful or angry (Darby, 1933). It was this stock of ideas about climatic and astrological influences on man, his character and behaviour, which formed the basis of Jean Bodin's theories about the influence of climate on the natural aptitude of people and its relation to political theories in the 16th century (Tooley, 1953). Higden's comparison of Asia, Europe and Africa is typical:

Asia is the largest; Europe is less in area and with a similar number of people; but Africa is the smallest of all three both in size and population. Therefore, some people who know of men and lands describe only two divisions of the earth, Asia and Europe. They regard Africa as belonging to Europe for Africa is narrow in breadth, and evil doers, corrupt air, wild and venomous beasts are found therein. Therefore, those who regard Africa as a third division do so, not because of its area, the measure of its length and breadth, but because of its distinctive characteristics, good and bad, which divide Africa from Europe and Asia, just as a sore limb is distinguished from all the other limbs which are sound and healthy. Africa also takes up less space, and because of the inclemency of heaven, has more wilderness and wasteland because of the great burning heat of the sun, in contrast with Europe and all the chill and great cold that occurs there often. Indeed, all that lives and grows can endure cold better than heat. This is the reason that Europe nourishes and brings forth large men, greater in body, mightier in strength, more daring and bold of heart, and more handsome, than in Africa. For the sun's rays always shine on the people of Africa, and draw out the humours, and make them short in stature, blacken the skin, crimp their hair, and by drawing out their spirits, make them cowardly at heart. The contrary is true of northern men where the cold stops up small holes and pores, and holds in bodily heat, and thus makes them fatter, larger, white and hotter within, and therefore, hardier and bolder at heart.

Within the temperate zone, there was little generalization about climatic differences. Higden remarked, "Ireland is moist, rainy and windy," and "As France surpasses Britain, so Britain surpasses Ireland in fair weather and nobility, but nought surpasses Britain in health." But such comparisons were rare, and usually associated with national or parochial feelings about a region. Likewise, even the major generalizations about climate and character tended to eulogize western Europe and its inhabitants,

Weather Phenomena

Since the Bible was unspecific in its references to weather phenomena, there was no impediment to using the explanations of classical writers. Of these, the primary source was Aristotle's *Meteorologica*. The sphere of air was the most important region, but earth and water provided the raw material, and the sphere of fire influenced the development or dissipation of weather phenomena. (Heninger 1960, p.37).

According to Aristotle, all the elements were transmutable, and therefore weather phenomena consisted of various combinations of these, transformed by the influence of the heavenly bodies, most notably the sun. Within the sphere of air, the part nearest the earth is moist and warm because it contains both a moist vapour and a dry exhalation from the earth. The part of the air near the sphere of fire is warm and dry. (*Meteorologica* Book I). The most important cause of weather phenomena was evaporation by the sun's heat. Evaporation occurred in two forms: a moist vapour and a dry exhalation. The vapour in which moisture predominates was the cause of clouds, rain, snow, etc. while the dry exhalation was the cause of all winds, thunder and lightning. This evaporation continued uninterrupted, but differed in degree and quantity, hence the constantly changing pattern of weather conditions, of sunshine and cloud, of droughts and floods, wind and calm. (*Meteorologica* Book II).

The following extract from *Mirroure of the World* is based directly on these Aristotelian theories, with the occasional Christian moral interpolated:

Here follows a description of the air and its properties

The air is set above the water and is much more subtle and insubstantial than water or earth. It encloses the earth on all sides and extends high as the clouds. This air which surrounds us is very thick. We live by breathing it, just as the fish lives in the water and draws it inside its body and casts it out again. Likewise, air is very beneficial to us, for we inhale it and then cast it out. Thus it preserves life in the body. For a man without air would die, sooner than a fish without water, and even the life of a fish always finishes quickly when it is out of water.

The air maintains life in us by means of the moisture in it. Because of its thickness it sustains birds flying and moving their wings about them so much, disporting themselves and expressing their joy in the air. Thus birds live by flying, singing and praising their Creator, like fishes which go swimming around in the water.

You may perceive the air in this manner. Take a rod and wave it in the air. If you move it fast and violently it will bend. If the air were not thick, it would not bend, and would remain firm and straight, no matter how fast you moved it.

Evil spirits take their form from the air but sometimes they give their bodies the semblance of other things; for example, when they appear in some place to deceive some person, man or woman, or to make someone go out of his mind, for indeed they sometimes have the power to do this; or when by the arts of necromancy the spirit gives itself any form or likeness that it wills. But this is a science which brings death to anyone who gives himself over to evil by practising it. For if he does not take heed, he will be damned, body and soul. But we will now turn our enquiry to the things which come from the air to the earth.

How the clouds and rain commonly come

Now we shall talk of the clouds in order to know what they are and also the rain.

The sun is the fount of all heat and all time, just as the heart of a man is the fount, through the strength that is in him, of all his natural heat. For all that lives and grows on the earth derives life from the heat of the sun, as it pleases Our Lord and as will be described presently, if you will listen and retain in your minds the substance of this book. For the sun causes the clouds to mount up on high, and then it makes the rain and causes it to fall. And I shall show you, briefly, how this is done by its power. You must understand it in this way: When the sun spreads its rays over the earth and on the marshes, it dries them out and draws up the moisture which it raises on high. But this is a subtle moisture which can scarcely be seen and is called vapour. It rises to the middle of the air and there it is gathered together and remains. Little by little, it increases in quantity, until it shuts out the sight of the sun. This thing is the cloud, but it is not sufficient to obscure from us the brightness of daylight.

When it comes over thick, it becomes water which falls on the earth and the clouds remain white. Then the sun shines from on high through the cloud, if it is not too dark, as if through a glass, or like a candle in a lantern, which gives forth light, though we may not see the candle. Thus the sun shines through the cloud underneath it, and gives us the brightness of day, while it is making its circle above the earth. And the clouds always remain there and continue to draw up moisture until they become black and moist. Then issues forth the water which comes down to earth. Thus the rain is formed.

When it is all fallen to earth, all the moisture is dried up, and the cloud loses its dark colour that it had before and which obscured the day. Then the clouds appear clear and white. They are much lighter, and rise so far on high, that they falter, and are dispersed by the heat of the sun which dries them all up. Then the sky again becomes pure and clear and the heavens as blue as azure.

From the earth evolves the rain, and the clouds too, as a wet cloth, which is dried by the fire, gives off moisture like a smoke rising upward. Anyone who holds his hands over this smoke would feel a vapour which makes his hands moist and wet. If he kept them there longer he would soon find his hands all wet and drops of water would fall off.

And so I say to you now, that in this manner are formed clouds and rain, And Our Lord God increases them well, when it pleases Him, to make seeds and fruits grow on earth.

Of frosts and snows

The great snows and frosts come from the great coldness of the air which is colder in the middle than anywhere else. This you may see on mountains in high places, such as the mountains of Savoy, or Piedmont, or Wales, or in any other mountains, where there is usually more snow than in areas of low flat ground.

All this is the result of the coldness of the air which has less heat above than below, because the upper layers are much thinner than the lower. When the upper air is thinner it retains so much less heat. But the thicker the air, the warmer it is and the more quickly it heats up when the sun shines on it. In the same way iron and steel get hotter in the sun than stone because the harder and more solid a thing is, the more quickly and readily it takes up heat, compared with less solid things.

Thus I have outlined to you how the air which is above us on high, is colder above than below, because it is not so thick as that air which is close to the earth, and because of the wind which often makes the air move. For water that is running quickly heats less than still water. The upper air acts the same way. And thus develops the cold which freezes this moisture in the air as it rises on high, and it falls down again all frozen.

Of hail and of tempests

In this way there come in summer great hailstorms and tempests. For winds develop in the air, and are often very cold so that the moisture brought up in the air is frozen. It is gathered up and accumulates in the air, but heat is being applied to it. The sun causes it to loosen itself and fall to earth. But when it falls to the ground it is not as massive as when it is frozen on high because it breaks up as it falls. This is the kind of storm which often occurs in summer and which is very harmful and destructive to many things.

Of lightning and of thunder

Many things happen in the air which people do not happily talk about, for they do not care for such things that they can not easily find out about.

It is the air that makes the earthquake, that makes the clouds thunder, that makes the earth open up, and that makes the clouds sparkle and light up when thunder is heard. For thunder and lightning are the concussion and breaking away of winds that meet above the clouds, so swiftly and sharply that in their moving, a great fire often develops in the air. This is the thunderbolt which falls in many places when the winds are so terribly constrained that the clouds cleave and break. This is the cause of thunder and lightning, which falls down in such fury, and so swiftly, forced by the wind, that it confounds all that it strikes in such a way that nothing can survive. It is so heavy that sometimes

it pierces the middle of the earth. Sometimes it is quenched before it reaches the ground, if it is light in weight, and provided it is not too dense.

When the clouds are very thick and dark, and saturated with moisture, the fire does not pass through so quickly but is quenched in the cloud by the great quantity of water in it, before it passes right through, so it may not reach the earth. But in the straining and breaking which it makes in the cloud, it causes a sound so loud and great it is marvellous to hear. I declare to you for certain that this is the thunder which is so much to be feared and dreaded. The same thing happens when red hot iron is plunged in a tub of water, there is a great noise from it; similarly when burning coals are quenched.

But the lightning of the thunder flashes and can be seen before the noise is heard, because man's sight is much more subtle than his hearing. Similarly men can see from afar, across a lake, the beating of clothes, or smiting of hammers, but the pounding is seen before its sound is heard. Likewise, I can explain the thunder which people see before they hear it. And the further above us it is, so much longer is the time between seeing the lightning and hearing the thunder. The sooner that thunder is heard after lightning is seen, then so much closer the thunder is to us.

In order to explain how winds grow and come.

The behaviour of winds may be enquired from men who sail the seas. The winds move around the earth and frequently meet in some places so swiftly that they rise up so high that they lift the air up high. The air that is so raised and displaced, removes other air in such a fashion that, as it is restored to its former level, it wails and undulates like running water. For the wind is nothing but air that is moved until its strength is beaten out of it. Thus are caused clouds, rain, thunder, lightning and the things already mentioned.

Beyond the sphere of air, and below the sphere of the moon, was the sphere of fire. This warm dry element, according to Aristotle, was the most inflammable of all bodies, spread around the sphere of air like a kind of fuel, so that a little motion often made it burst into flame. Whenever the circular motion of the spheres stirred up this element in any way, it caught fire at its most inflammable point and the resulting phenomena differed according to the disposition and quantity of combustible material (*Meteorologica* Book I). This was the explanation of shooting stars, comets, thunderbolts and other fiery impressions occurring in the upper levels. At lower levels, such phenomena were the result of ignition of excessive amounts of the dry exhalation, which, being lighter than the moist vapour, could rise higher toward the sphere of fire and, without moisture to prevent it, be ignited.

Gossouin described such phenomena thus:

You should know that above the air is fire. This is a type of air that is resplendent and shining and very splendid. Because of its great fineness it has no moisture in it. It is much clearer than the fire that we use and of finer form than the air against water or the water against the earth.

This air, which has no moisture, stretches as far as the moon. Beneath this air, there are often some sparkles of fire which look like stars. Men say of these that they are falling stars which have moved from their positions. But this is not so. They are a kind of fire which grows in the air out of dry vapour from the earth. It is made to grow by the sun which draws it up higher, and when it is too high, it falls, and is set on fire, and looks to us like a candle burning. When it falls back into the moist air, it is quenched by the moisture in it. When the fire is large and all the air dry, it falls burning all the way to earth.

It often happens that sailors at sea, and travellers on land, have frequently seen them fall to earth all shining and burning. When they come to where they fell, they find nothing but a little ash or material like the wet, rotten leaves of a tree. They then perceive and believe that there was no star. For stars may not fall but must always remain in their circles and continually, both night and day, move in their ordered positions.

CONCLUSION

In the *Mirrou of the World* we have a summary of late medieval earth science. This knowledge of the natural phenomena of the earth and its atmosphere did not constitute science in its modern sense for European scholarship in the 15th century was still circumscribed by theological dogma and uncritical reliance on ancient authority. Few men questioned scholastic authority. Such a spirit of scientific enquiry was to be awakened in succeeding centuries by the widening horizons of discovery and exploration of the earth's surface, the development of scientific method and the dissociation of religious interpretation from scientific explanation. Meanwhile, it was sufficient to refer the inexplicable to the power of God and the authority of the Bible:

Then I beheld all the work of God, that a man cannot find out the work that is done under the sun: because though a man labours to seek it out, yet he shall not find it; yea farther; though a wise man think to know it, yet shall he not be able to find it. Ecclesiastes 8:17

REFERENCES

- Adams, F. D., 1938: *The Birth and Development of the Geological Sciences*, Dover, New York, reprint 1954.
- Babington, C. and J. R. Lumby, eds., 1865 - 86: *Polychronicon Ranulphi Higden Monachi Cestrensis*, London, Rolls Series, H.M.S.O., 9 vols., reprint 1964, Kraus. The quotations are taken from Book I, The Map of the World, and have been rendered into modern English by E. Stokes.
- Crawford, O. G. S., 1949: Some Medieval Theories about the Nile, *Geog. J.* 114: pp. 6 - 29.
- Crone, G. R., 1954: *The World Map by Richard of Haldingham in Hereford Cathedral circa A.D. 1285*, Royal Geog. Soc. Reproductions of Early Manuscript Maps III.
- Darby, H. C., 1933: Geography in a Medieval Text Book, *Scottish Geog. Mag.* 49: pp. 323 - 331. This article summarizes the main geographical ideas in the 13th century encyclopedia *De Proprietatibus Rerum* of Bartholomew Anglicus which was also popular in the 15th century: ten editions of the Latin text, and four of the French translation appeared before 1500 (Tooley, 1953)
- Geikie, A., 1905: *Founders of Geology*, Macmillan, London, 2nd ed. reprint Dover, New York, 1962, Ch. 1 and 2.
- Heninger, S.K. Jr., 1960: *A Handbook of Renaissance Meteorology*, Duke U.P., Durham, N.C.
- Jowett, B., trans. and ed., 1953: *The Dialogues of Plato*, Oxford U.P., 4th ed., 4 vols. Vol. III contains the *Timaeus* and the *Critias*.
- Kimble, G. H. T., 1938: *Geography in the Middle Ages*, Methuen, London.
- Moody, E. A., 1941: John Buridan on the Habitability of the Earth, *Speculum* 16: pp. 415 - 425.
- Patch, H. R., 1950: *The Other World According to Descriptions in Medieval Literature*, Harvard U.P. See especially Ch. 5, Journeys to Paradise.
- Prior, O. H., ed., 1913, *Caxton's Mirrou of the World*, Early English Text Soc., Extra Series CX. All quotations from this text have been rendered into modern English by E. Stokes.
- Ross, W. D., Ed., 1931: *The Works of Aristotle*, 11 vols. Oxford U.P. Vol. II contains the *De Caelo* (trans. J. L. Stocks) and the *De Generatione et Corruptione* (trans. H. H. Joachim). Vol. III contains the *Meteorologica* (trans. E. W. Webster).
- Taylor, E. G. R., 1931: Imago Mundi, *Scottish Geog. Mag.* 48: pp. 78 - 80.
- , 1935: Some Notes on Early Ideas of the Form and Size of the Earth, *Geog. J.* 85: pp. 65 - 69.
- Thorndike, L., 1929: *Science and Thought in the Fifteenth Century*, reprint 1963, Hafner, New York.
- , 1949: *The Sphere of Sacrobosco and Its Commentators*, Chicago U.P.
- , 1959 - 1964: *A History of Magic and Experimental Science* Columbia U.P., New York, 8 vols. Vols. 3 and 4 cover the 14th and 15th centuries.
- Tooley, M. J., 1953: Bodin and the Medieval Theory of Climate, *Speculum* 28: pp. 64 - 83.
- Wright, J. K., 1925: *The Geographical Lore at the time of the Crusades; a study in the history of medieval science and tradition in western Europe*, American Geog. Soc., New York.