Greek Seismology

Being an Annotated Sourcebook of Earthquake Theories and Concepts in Classical Antiquity

By

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v. 2.0

To Janet

For Her Love, Patience and Understanding

"The ancients attributed earthquakes to supernatural causes..."

K. E. Bullen (*An Intro.* To The Theory of Seismology,
Camb. Univ. Press, 3rd ed. 1963, p.1)

"It will help also to keep in mind that gods cause none of these things and that neither heaven nor earth is overturned by the wrath of divinities. These phenomena have causes of their own..."

Seneca (Natural Questions, c.62 AD, Book 6.3)

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PREFACE

This book was written some years ago. It was the outgrowth of my interest in seismology, Greek civilization, and the history of science. I wrote it for myself, and perhaps as something to leave my children (who came later). There were occasional attempts to publish the work, but these were feeble and found no success. However, one of these attempts led to my column "Seismos" in The Leading Edge, a publication of the Society of Exploration Geophysicists. In fact, two of the early columns dealt with subject matter mined from this book. One was the unique reference in Herodotus to the earliest known instance of reflection seismology.

The present book is largely unchanged from the original version of 1985, although II have taken a few opportunities to extend the text. Also, the text has been completely ported to new software by Ms. Inta Arpandi, to whom I am very grateful.

Finally, I greatly appreciate the efforts of Dr. J. Scales, and others, for conceiving and maintaining Samizdat free press. It has allowed me to share this work with others.

I hope those of you reading this will feel some of the fascination and joy which I find in the subject.

C.L.L
Tulsa, Oklahoma
10 October, 1997

Preface to the original version

I set out some time ago to research a history of seismology.

It is always a question as to where such a history should begin. The modern reflection seismologist might want it to begin with the advent of electronic computers in the 1950's and the ensuing near-miraculous explosion of theory and technology. This alone would be sufficient material for a lengthy history. Or, he might want the history to begin with the first reflection seismic experiments by Karcher around 1916. The period since 1910 would also be important to the earthquake seismologist. But, he would probably feel shorted unless the history included the pioneering work of Milne, Rayleigh, Lamb and

Oldham in the period 1880-1910. And to be thorough the work of Robert Mallet would have to be discussed taking the history back to 1850. To cover the beginnings of observational seismology would push it back a few years further, the first electro-magnetic seismometer dating from about 1841.

The trail might end there so far as modern observational seismology is concerned, but this seismological work was possible only because a certain level of theoretical understanding had been achieved concerning the physics of mechanical wave propagation in continuous media. The theoretical seismologist, whether earthquake or reflection, could argue that this prerequisite fundamental work should also be included in a history of seismology. In 1861 Maxwell established the electro-magnetic theory of light, but for the previous 30 years many of the best physicist and applied mathematicians in the world had attempted to derive an elastic wave theory of light (perhaps the most ambitious was the brilliant 1849 memoir by G. G. Stokes called *The Dynamical Theory of Diffraction*). Much of this theory was of direct use later in seismology. Including this work pushes the history back to 1828 when Poisson established the theoretical existence of the two kinds of elastic waves, or, finally, back to 1821 when Navier derived the fundamental equations of motion for an elastic solid.

This is the beginning of true elastic theory in the modern sense of a solid supporting both normal and tangential stresses. However, as early as 1687 work had been done by Newton concerning wave motion in media supporting only normal stresses, e.g. acoustic media. There was also earlier experimental work by Hook, Galileo and others going back to 1631 on the flexures and elasticities of different substances. Now, hopefully, all of our modern seismologists with their varied interests would be satisfied with the point of departure.

This was to be the extent of my history of seismology. I did plan, for completeness, to include the standard brief paragraph on ancient Greek understanding of earthquakes; basically concerning Aristotle classification of earthquake motions which I had seen in

Bullen's book and elsewhere. In preparation for this paragraph I began reading the ancient works. In Plutarch I found a page concerning earthquake theories (I now know this to be Pseudo-Plutarch), in Ammianus Marcellinus two or three pages, and in Seneca thirty. All this before I even *got* to Aristotle. It soon became apparent that this called for more than a cursory paragraph.

The present work is the result of merely locating, organizing and annotating this material. If my own ignorance was any indication, it is a project whose time has come.

I wish to acknowledge the assistance given by Prof. David Furley of the Classics Department, Princeton University concerning text and translations of the *Placita* ; C. B. F. Walker of the British Museum's Department of Western Asiatic Antiquities for correspondence concerning earthquake references contained in Babylonian tablets; D. H. D. Roller of the University of Oklahoma's History of Science Collection for allowing access to the collection and conversations concerning reference works on Pre-Socratic philosophy; and Prof. Jack Catlin of the Classics Department, University of Oklahoma for information related to Greek literature.

My wife, Janet, was more than patient in proof reading much of the manuscript.

Finally, I wish to extend a special acknowledgment to my friend Mike McGowan who also proofed the manuscript. He was always anxious for discussions concerning the progress and direction of the study. His feedback was constructive, useful and enjoyable, and his encouragement was always appreciated.

C. L. L.
Oklahoma City, Oklahoma
11 March 1986

Introduction

Scope and Purpose

References to earthquakes abound in the ancient Greek and Roman literature. From the earliest works to those of the Christian era we find them mentioned in many contexts. There may be a simple statement that an earthquake occurred, perhaps giving the time and place. Sometimes there is a graphic description of a particular earthquake, detailing the effect it had on cities, buildings and people; or, an ancient writer may give 'signs' that tell of an impending earthquake. This sort of information is relatively common.

There is another kind of information, which only rarely occurs. There are a few writers who give the *causes* of earthquakes--actual earthquake theories. These theories of the natural philosophers are interesting in their own right, and important to the history of science as the faintest beginnings of what has become modern seismology. The word seismology itself is Greek; '*Seismos*' meaning earthquake, and '*logos*' to speak of, or reason about.

The present study gathers together full quotations from all ancient works containing such theory references. In this way, the reader may peruse, study and directly compare the theories themselves. Much work remains to be done on the meaning and interrelationships of the various theories; this is not attempted in the present study.

This is basically a sourcebook of quotations from the ancient literature. Explanatory text and footnotes are supplied only as necessary to render the quotations more understandable and/or meaningful.

To my knowledge this information has never been gathered into a single volume. It is hoped that the accessibility this affords will encourage a more widespread familiarity with and appreciation of the subject.

Natural Philosophy Vs Natural Science.

Many of the ancient Greeks were keen observers of nature. This is seen, for example, in the descriptions of earthquakes and their effects, which are the basis of our study. But were these same men *scientists*? If the difference between natural philosophy and natural science lies in the distinction between 'mere observation' and 'experiment', then the answer is no. An excellent summary of this question by Lee[1] is worth quoting at length.

"...the main interest of the work [Aristotle's *Meteorologica*] is to be found not so much in any particular conclusions which Aristotle reaches, as in the fact that all his conclusions are so far wrong and in his lack of a method which could lead him to right ones. In this he is typical of Greek science. The comparative failure of the Greeks to develop experimental science was due to many causes, which cannot be considered here. They lacked instruments of precision--there were, for instance, no accurate clocks until Galileo discovered the pendulum. They did not produce until a comparatively late date any glass suitable for chemical experiment or lens making. Their iron-making technique was elementary, which precluded the development of the machine. Their mathematical notation was clumsy and unsuited to scientific calculation. All these things would have severely limited the development of an experimental science had the Greeks fully grasped its method. But the experimental method eluded them. They observed but they did not experiment, and between observation and experiment there is a fundamental difference, which it is essential to recognize if the history of Greek thought is to be understood. This difference can be clearly seen in the *Meteorologica*. There is plenty of observation: Books 1-3 are full of it, and Book 4 shows a keen observation of the processes of the kitchen and garden in terms of which Aristotle tries to explain chemical change in general. But there is practically no experiment, and in those experiments which Aristotle does quote the results given are wrong. A good example of his attitude and method is the theory of exhalations, which plays so prominent a part in Books 1 and 2. It has a basis in observation: Aristotle had obviously observed the phenomena of evaporation. Yet not only has it no basis in experiment but it is not designed to be verified experimentally, nor is it easy to conceive any experiment which could either confirm or invalidate it. It is this absence of the awareness for the necessity of an experimental test that is the mark of thought that is rational but not yet scientific, of the natural philosopher rather than the natural scientist. And of Aristotle's natural philosophy and of Greek natural philosophy in general it is true that it remained rational without being scientific, that it never passed from natural philosophy to natural science. There are, of course, exceptions both in Aristotle and elsewhere in Greek thought. Greek medicine comes very near to being scientific, so also do Aristotle's biological works; and the Greeks made further progress in astronomy than in any of the other physical sciences, though this was just because their astronomy involved no experiment, but only observation and mathematical calculation. But these are exceptions. Of the more general tendency the *Meteorologica* is typical; it is the product of the natural philosopher and not the natural scientist..."

Little needs to be added to this account except to say that we should not ignore the ancient theories simply because they were 'unscientific'. They represent the beginnings of

[1] Intro. to Aristotle's Meteorologica, pp. xxvi-xxviii

science because they asked the questions which science was ultimately invented to answer. This discussion may properly be concluded with the following quote from Seneca[2]:

"Before anything else, I must say that the old theories are crude and inexact. Men were still in error about the truth. Everything was new for men who were making the first attempts. Later these same theories were refined. Yet, if anything has been discovered, it none the less ought to be acknowledged as having been received from them. It was the achievement of a great spirit to move aside the veil from hidden places and, not content with the exterior appearance of nature, to look within and to descend into the secrets of the gods. *The man who had the hope that the truth could be found made the greatest contribution to its discovery*. And so the ancients must be listened to, indulgently. Nothing is completed while it is beginning. This is true not only in this subject (which is the greatest and most complex of all), but in every other business as well. Even though much will have been done on the subject every age will none the less find something to do. As in every other subject, the first beginnings have always been far away from the completed knowledge."

Historical Outline of Greek Philosophy

Greek philosophy began in Greek colonies along the West Coast of Asia Minor in the seventh century BC. The first philosopher we hear of is Thales of Miletus (640-546 BC) who was renowned as an astronomer, mathematician and sage, as well as being a philosopher. There followed a progression of philosophers in Miletus and the surrounding region from his time until 494 BC, when the city was destroyed by war. Following this event philosophy spread throughout the rest of Greece.

Socrates (469-399 BC) is a key figure in the history of Greek philosophy; in fact, it is commonly split up into pre-Socratic and Post-Socratic. This division is a natural and important one. It is based on the fact that Socrates was the first philosopher to introduce the study of ethics. Earlier inquiry had been limited to the physical world, theology and mathematics.

Another distinction between pre- and post-Socratic philosophy is related to survival of written works. Basically, all the numerous philosophical treatises composed before the time of Socrates are lost. Socrates himself apparently wrote nothing, but many of the contemporary and later philosophers did, and much of that material is extant. These

[2] Natural Questions 6.5.2-3 (italics mine).

surviving works begin with those by Xenophon (445-355 BC) and Plato (427?-347 BC), both students of Socrates.

It is important to understand what is meant when it is said that a written work is "extant". In no case do we have the original manuscript of an ancient philosophical work. What we have are nth generation copies, which were written centuries after the original composition. As an example (and not an outlandish one), our earliest surviving copies of Aristotle date from the tenth century AD -- twelve to thirteen hundred years after the original composition.

While the pre-Socratic philosophical treatises as entities are lost, we do have some scattered information concerning their content from fragments (purported quotations) and notices (all information other than direct quotations) in the work of later writers. The first good source of such information is Aristotle, although some is also found in Plato. This kind of second-hand information is known collectively as "doxographic", a word meaning 'written opinions'.

We know of about 300 pre-Socratic philosophers, but often the information we have is limited to only a name. This is particularly true in the case of the 200 or so followers of Pythagoras, or Pythagoreans.

In the century following Socrates (fourth century BC), Greek philosophy reached its peak, both in terms of quality and quantity. This was the period of Plato, Aristotle, Xenocrates, Theophrastus and dozens more. Of their writings much has survived, but much more has been lost. For example, while we have all of Plato, we have less than half of Aristotle (39 of about 155 works), only the smallest bit of Theophrastus (3 of about 227), and none of Chrysippus (who composed 705 works).

An important concept in the history of Greek philosophy is that of the sect. Around a famous philosopher, a gathering of students and adherents would naturally accumulate. Sometimes this population took on an identity of its own and became a sect, propagating the doctrine long after the philosopher himself was gone. Some of the more important sects, together with the founding philosopher of each, are

Sect	**Founder**	**Date of Founding**
Pythagoreans	Pythagoras	c.530 BC
Academics	Plato	c.390
Peripatetics	Aristotle	c.340
Stoics	Zeno of Cittium	c.310
Epicurians	Epicurus	c.310
Sceptics	Pyrrho	c.310
Middle Academics	Arcesilaus	c.280
New Academics	Carneades	c.180
Eclectics	Antiochus	c.80 BC
Neoplatonists	Plotinus	c.240 AD.

These sects were much more than mere intellectual societies. They were more akin to political parties or religious factions. In fact, persecution between sects was not uncommon in late antiquity.

The vitality and originality of Greek philosophy slowly declined following the "golden age" in the fourth century BC. Eventually, it came to be studied by a few Romans, but it never enjoyed the popularity it had seen in Greece.

By the beginning of the Christian era, philosophy had become something of a hodge-podge of competing sects. Although there were still isolated examples of individual brilliance, Greek philosophy had seen its best days centuries before.

Sources and Theories

There are only seven surviving works, which give us actual information about earthquake theories of the ancient Greek natural philosophers. These works are, chronologically,

Author	**Title**	**Date of Work**
Aristotle	*Meteorologica*	fourth cent. BC
Lucretius	*De Rerum Natura*	first century BC
Seneca	*Natural Questions*	c.62 AD
Pliny	*Natural History*	c.77 AD
Pseudo-Plutarch	*Placita Philosophorum*	second cent. AD
Diogenes Laertius	*Lives of...Philosophers*	c.225-250 AD
A. Marcellinus	*The Roman History*	c.391 AD.

From these sources we find that twenty-one natural philosophers have theorized about the causes of earthquakes; Table I gives a cross-reference.

Greek and Latin words for earthquakes. The Greek word for 'earthquake' is seismos[3] , but there also occurs the phrase kinaseos ges[3] , 'earth tremor'. The first of these is far more common in Aristotle and elsewhere.

By contrast, there are at least six Latin terms meaning, loosely, 'earthquake'. The English word earthquake is an old English translation of the most common of the Latin terms, terrae motus , literally 'motion or movement of the earth'. The six basic Latin phrases which denote earthquakes are

Latin phrase	literal translation
terrae motus	motion or movement of the earth
orbis agitur	agitation of the world
terrae tremorem	trembling of the earth
terrae concuti	a shattering or impairing of the earth
terrae pulsibus	a beating or pulsation of the earth
terrae pulsu vibratum	a vibrating pulsation of the earth

[3] Aristotle's Meteorologica 2.7.365a14.

THEORIES \ SOURCES	Aristotle Meteorologica (fourth century BC)	Lucretius De Rerum Natura (first century BC)	Seneca Natural Questions (c.62 AD)	Pliny Natural History (c.77 AD)	Anonymous (Pseudo-Plutarch) Placita Philosophorum (second century AD)	Diogenes Laertius Lives of Emminent Philosophers (c.225-250 AD)	Ammianus Marcellinus The Roman History (c.391 AD)
Thales (640-546 BC)			3.14.1 6.6.1-4		3.15.1		
Anaximander (c.610-546 BC)				2.81.191			17.7.12
Pherecydes (600-550? BC)				2.81.192		1.116	
Anaximenes (585-524? BC)	2.7.365a17 2.7.365b7-20		6.10.1-2		3.15.3 3.15.8		
Anaxagoras (500-428? BC)	2.7.365a17 2.7.365a20-36		6.9.1		3.15.4	2.9	17.7.11 22.16.22
Parmenides (fl.475 BC)					3.15.7		
Diogenes of Appolonia (fl.460 BC)			4.2.28-30				
Archelaus (5th cent. BC)			6.12.1-3				
Antiphon (late 5th cent. BC)							
Democritus (460?-362? BC)	2.7.365a19 2.7.365b1-6		6.20.1		3.15.1 3.15.7		
Plato (427?-327 BC)					3.15.10		
Aristotle (384-322 BC)	(several)		6.13.1 7.28.3		3.15.5		17.7.11
Theophrastus (372-287 BC)			6.13.1 7.28.3				
Callisthenes (360-327 BC)			6.23.2 6.23.4 6.26.3				
Metrodorus (?-277 BC)			6.19.1		3.15.6		
Epicurus (342?-270 BC)		6.535 to 6.607	6.20.5		3.15.11		10.105
Zeno of Cittium (333-261 BC)					[3.15.2 "stoics"]		7.154
Strato (fl.288 BC)			6.13.2				
Posidonius of Apamea (135-51 BC)			6.21.2 6.24.6				7.154
Asclepiodotus (1st cent. BC)			6.17.3 6.22.2				
Seneca (4 BC-65 AD)			(several)				

Table 1. Cross-index of literary sources and earthquake theories.

Judging from the sources used in this study, by far the most common term *is terrae motus* , which occurs about 75% of the time. Lucretius, the earliest Latin author in this study, uses this term exclusively; later writers use progressively more diverse terminology. In Part I below, the Latin terms which have been translated as ’earthquake’ are footnoted.

It is quite clear that this diversity of terms does not represent a classification of earthquake motions or types. We do not see a writer referring to a *terrae concuti* type of event. Rather, the same event will be referred to in any of several ways indiscriminately. It would seem that the plethora of Latin terms for ’earthquake’ is related to literary style, and not any specific earthquake characteristics.

Earthquakes in the Bible

It should be emphasized that while the Greeks were the first to attempt the natural explanation of earthquakes, earlier earthquake references do exist in ancient Eastern and Near-Eastern literature. Only one example will be given.

To the modern western reader, the most familiar of this very early literature is the Biblical Old Testament. We find in the Old Testament[4] six references to earthquakes. These are

Book and Verse	Approx. Date of Composition[5]
1. Numbers 16.30-33	12th? century BC
2. Deuteronomy 11.6	12th? century BC
3. Amos 1.1	c.750 BC
4. Psalms 18.7	c.515 BC (date of coalescence)
5. Psalms 106.7	c.515 BC (date of coalescence)
6. Zechariah 14.4-5	c.270 BC

Numbers 16.30-33

"30. But if the Lord make a new creature, and the earth open her mouth, and swallow them up, with all that appertain unto them, and they go down quick into the pit; then ye shall understand that these men have provoked the Lord.

31. And it came to pass as he had made an end to speaking all these words, that the ground clave asunder that was under them:

[4] Although not of interest to us here, earthquake references also occur in the New Testament. These are: Math.27.52-54 & 28.2; Mark 15-38; Luke 23.45; Acts 16.26.

[5] Gathered out of Gethman.

32. And the earth opened her mouth, and swallowed them up, and their houses, and all the men that appertained unto Korah, and all their goods.

33. They, and all that appertained to them, went down alive into the pit, and the earth closed upon them: and they perished from among the congregation."

Deuteronomy 11.6

"6. And what he did unto Dathan and Abiram, the sons of Eliab, the son of Reuben: how the earth opened her mouth and swallowed them up, and their households, and their tents, and all the substance that was in their possession in the midst of all Israel."

Amos 1.1

"1. The words of Amos, who was among the herdsmen of Tekoa, which he saw concerning Israel, in the days of Uzziah king of Judah, and in the days of Jeroboam the son of Joash king of Israel, two years before the earthquake."

Psalms 18.7

"6. In my distress I called upon the Lord, and cried unto my God: he heard my voice out of his temple, and my cry came before him, even into his ears.

7. Then the earth shook and trembled; the foundations also of the hills moved and were shaken, because he was wroth."

Psalms 106.17

"17. The earth opened and swallowed up Dathan, and covered the company of Abiram."

Zechariah 14.4-5

"4. And his feet shall stand in that day upon the mount of Olives, which is before Jerusalem on the east, and the mount of Olives shall cleave in the midst thereof toward the east, and toward the west, and there shall be a very great valley, and half of the mountain shall remove toward the north, and half of it toward the south.

5. And ye shall flee to the valley of the mountains: for the valley of the mountains shall reach unto Azal: yea, ye shall flee like as ye fled from before the earthquake in the days of Uzziah king of Judah: and Lord my God shall come, and all the saints with thee."

All of these passages, except Zechariah, refer to the single event given in Numbers. This particular earthquake, at least, the ancient Hebrews obviously considered as supernatural in origin.

Earthquakes in Pre-Socratic Greek literature

As mentioned above the surviving pre-Socratic philosophical literature is incomplete. However, there does survive some non-philosophical Greek literature from that period. The earthquake references in this material are of interest since it gives us some idea of popular earthquake concepts. We will briefly consider the information in three of the earliest writers; Homer, Herodotus, and Thucydides.

<u>Homer.</u> The earliest extant Greek literature is that attributed to Homer; the *Illiad* and the *Odyssey*. The composition date for these epic poems is not known with any certainty. Nineteenth century scholars felt confident at placing them between 950 and 900 BC. Modern scholars are more cautious, generally attributing them to the eighth century BC. Some circumvent the question altogether, saying only that the first writer to mention Homer is Callinus of Ephesus (c.660 BC).

There are no actual earthquakes mentioned by Homer. However, throughout his work Poseidon, the god of the sea, is called either *enosichthon*, "the earth-shaker", or *gae-ache* , "the earth-enfolder". The same terms are found in Hesiod, who was perhaps a century later than Homer.

The implication is clear that Homer saw earthquakes as the supernatural work of Poseidon. Presumably, Homer saw the world as a flat disc floating in, and surrounded by, water; the element, which Poseidon ruled. Thus Poseidon was seen as the "earth-enfolder". When this water was disturbed, at Poseidon's bidding, earthquakes occurred. Except for the supernatural element, this scheme is identical to the earthquake theory of Thales; the earliest Greek philosopher.

Herodotus. Herodotus of Halicarnassus lived from about 484 to 425 BC. His *History* (composed c.445-425 BC) marks the beginning of real historical writing among the Greeks. Earlier writers, called 'logographers', had compiled information on individual towns or families, but Herodotus was the first to weave what we would call a true historical narrative.

There are two passages in Herodotus which mention earthquakes.

1. [Book 6. Sect. 98]

"98. This done, Datis sailed with his host against Eretria first, taking with him Ionians and Aeolians; and after he had put out thence to sea, there was an earthquake at Delos, the first and last, as the Delians say, before my time. This portent was sent by heaven, as I suppose, to be an omen of the ills that were coming on the world. For in three generations, that is, in the time of Darius son of Hystaspes and Xerxes son of Darius and Artaxerxes son of Xerxes[6], more ills befell Hellas than in twenty generations before Darius; which ills came in part from Persians and part from the wars for preeminence among the chief of the nations themselves. Thus it was no marvel that there should be an earthquake in Delos, wherein it was written:

'Delos itself will I shake, that never was shaken aforetime'."

2. [Book 7. Sect. 129]

"Now the Thessalians say that Poseidon made this passage whereby the Peneus flows; and this is reasonable; for whosoever believes that Poseidon is the shaker of the earth, and that rifts made by earthquakes are that god's handiwork, will judge from sight of that passage that it is of Poseidon's making; for it is an earthquake, as it seems to me, that has riven the mountains asunder."

It is interesting that Herodotus does not seem to flatly believe, as Homer did, in the supernatural origin of earthquakes. Rather, he appears to tolerate this view without actually being committed to it[7].

In addition to these interesting accounts of earthquake phenomena, the geophysicist reading Herodotus may be struck by the following passage[8] describing an event of c.580 BC that involves reflection seismology. Recall that Karcher in 1916 was the inventor the reflection seismic technique…

" Then the Persians besieged Barce for nine months, digging mines leading to the walls, and making violent assaults. As for the mines, a smith discovered them by the means of a brazen shield, and this is how he found them: carrying the shield round the inner side of the walls he smote it against the ground of the city; all other places where he smote it returned but a dull sound, but where the mines were the bronze of the shield rang clear.

[6] 522-424 BC.
[7] McGowan disagrees.
[8] Book 4, sect. 200

Here the Barcaeans made a counter-mine and slew those Persians who were digging the earth. Thus the mines were discovered and the assaults were beaten off by the townsmen."

In modern terms we would say the smith used his shield to perform a seismic tunnel detection experiment. While this application of reflection seismology had no influence on later developments in the science, it does predate Karcher by about 2500 years.

Thucydides. Thucydides of Athens was a younger contemporary of Herodotus, he lived from about 471 to 399 BC. His work *The History of the Peloponnesian War* is a narrative of the events of the war between Athens and Sparta (431-404 BC).

There are nine passages in Thucydides concerning earthquakes. Some of these only mention that an earthquake has occurred, but have been included here for completeness.

1. [Book 1. sect. 101]

"Meanwhile the Thasians being defeated in the field and suffering siege, appealed to Lacedaemon, and desired her to assist them by an invasion of Attica. Without informing Athens, she promised and intended to do so, but was prevented by the occurrence of the earthquake..."

2. [Book 2. Sect. 8]

"Everywhere predictions were being recited and oracles being chanted by such persons as collect them, and this not only in the contending cities. Further, some while before this, there was an earthquake at Delos, for the first time in the memory of the Hellenes. This was said and thought to be ominous of the events impending; indeed, nothing of the kind that happened was allowed to pass without remark."

3. [Book 3. Sect. 87]

"At the same time[9] took place the numerous earthquakes in Athens, Euboea, and Boetia, particularly at Orchomenus in the last-named country."

4. [Book 3. Sect. 89]

"The next summer the Peloponnesians and their allies set out to invade Attica under the command of Agis, son of Archidamus, and went as far as the Isthmus, but numerous earthquakes occurring, turned back again without the invasion taking place. About the same time that these earthquakes were so common, the sea at Orobiae, in Euboea, retiring from the then line of coast, returned in a huge wave and invaded a great part of the town,

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[9] 425 BC.

and retreated leaving some of it still under water; so that what was once land is now sea; such of the inhabitants perishing as could not run up to the higher ground in time. A similar inundation also occurred at Atalanta, the island off the Opuntian Locrian coast, carrying away part of the Athenian fort and wrecking one of two ships which were drawn up on the beach. At Peparethus also the sea retreated a little, without however any inundation following; and an earthquake threw down part of the wall, the town hall, and a few other buildings. The cause, in my opinion, of this phenomenon must be sought in the earthquake. At the point where its shock has been the most violent, the sea is driven back and, suddenly recoiling with redoubled force, causes the inundation. Without an earthquake I do not see how such an accident could happen."

5. [Book 4. Sect. 52]

"In the first days of the next summer there was an eclipse of the sun at the time of new moon, and in the early part of the same month an earthquake."

6. [Book 5. Sect. 45]

"When the envoys appeared before the people, and upon the question being put to them, did not say as they had said in the senate, that they had come with full powers, the Athenians lost all patience, and carried away by Alcibiades, who thundered more loudly than ever against the Lacedaemonians, were ready instantly to introduce the Argives and their companions and to take them into alliance. An earthquake, however, occurring, before anything definite had been done, this assembly was adjourned."

7. [Book 5. Sect.50]

"After the Olympic games, the Argives and the allies repaired to Corinth to invite that city to come over to them. There they found some Lacedaemonian envoys; and a long discussion ensued, which after all ended in nothing, as an earthquake occurred, and they dispersed to their different homes."

8. [Book 6. Sect.95]

"The same spring the Lacedaemonians marched against Argos, and went as far as Cleonae, when an earthquake occurred and caused them to return."

9. [Book 8. Sect.41]

"As he coasted along he [Astyochus] landed at the Meropid Cos and sacked the city. It was unfortified and had been lately laid in ruins by an earthquake, by far the greatest in living memory."

In these quotations of Thucydides we find no hint of a supernatural cause for earthquakes; we see no opinion put forward on the subject at all. He says that earthquakes (end of quotation 4) cause tidal waves, but he does not say what in turn causes earthquakes. Poseidon is nowhere mentioned.

Throughout the *History* Thucydides is a pragmatic, factual writer, not prone to speculation. His silence on the causes of earthquakes may be nothing more than an instance of his character.

Still, it is tempting to say that in Thucydides we have a rejection of the supernatural view.

Some Conclusions

As mentioned above, this is primarily a sourcebook and does not pretend to discuss the interrelationships and/or meanings of the various ancient earthquake theories. Such an analysis may be forthcoming in a later work. In the meantime, the following brief impressions and opinions developed in the course of compiling the present work may be of interest to the reader. Most of these are supported in the text of the present work; others are derived from notes, which were not included.

1. Homer and Hesiod (fl. before 700 BC) believed that earthquakes had supernatural cause; specifically the sea-god Poseidon (equivalent to the later Roman god Neptune).

2. The Babylonians kept track of earthquake occurrences in their astronomical calendars (beginning before 600? BC, perhaps long before), and believed they were caused by and predictable from the movements of the planets (i.e., astrology).

3. About twenty natural philosophers are known to have theorized on the causes of earthquakes. These range in date from Thales (640-546 BC) to Seneca (4 BC-AD 64).

4. The only individuals purported to have predicted a specific earthquake are Anaximander (c.610-546 BC) and Pherecydes (c.600?-550? BC). These predictions were undoubtedly based on mysticism since later writers, with a greater knowledge of natural philosophy, did not attempt the prediction of individual earthquakes. Rather, they frequently stated the conditions under which they believed an earthquake would, or might, occur; e.g., "...an earthquake sometimes occurs at an eclipse of the moon. ...the earthquake before the eclipse" (Arist. *Meteor*. 2.8.367b20-23).

5. The theories are derived from observation (not experiment) and proof consists of logical argument and analogy (often to processes in the human body).

6. There are no quantitative or mathematical earthquake theories, although there are a few quantitative statements (e.g., "...an earthquake does not extend two hundred miles." Seneca *Nat. Quest*. 6.25)

7. There is no "fault theory" of earthquakes equivalent to the modern view, but there are theories that involve large subterranean parts of the earth 'falling' in caverns. The modern fault theory could not have been derived in antiquity because they lacked the concept of a solid capable of infinitesimal deformation (i.e., an elastic solid); this concept arose only in the seventeenth century AD.

8. Of those philosophers who did original work in this field, only the earthquake work of Aristotle (*the Meteorologica*) has survived in full. [*Natural Questions* by Seneca (4 BC - 65 AD) also has survived, but his originality is questionable].

9. The Greeks had two words for earthquake, the Latin writers had several more.

10. Aristotle (384-322 BC) based his somewhat confusing theory on the concept of exhalations, a pre-Socratic concept he embellished and elaborated to an extreme. This theory seems to have enjoyed no special place in antiquity, but on the weight of his other work it became "the theory" in the Middle Ages and later. As late as the seventeenth century it was still necessary for serious writers to refute Aristotle on this subject. Popular conceptions, ultimately derived from the earthquake precursors and effects he listed, persisted well into the nineteenth century (e.g., in almanacs, etc.).

11. Metrodorus of Chios (4th cent. BC) based his theory on the (new?) concept that motion can be transferred from vibrations of the air (i.e., sound) to the solid earth. [This concept is familiar to the modern seismologist as coupling of atmospheric compressional waves to the surface of an elastic solid; a problem solved only in the 1950's.]

12. Classification of earthquakes by the nature of ground motion, which is commonly attributed to Aristotle, is actually to be found in a spurious work by "Pseudo-Aristotle" (date uncertain: between 50? BC and 150? AD) titled *On the Cosmos* . This classification of earthquakes into seven "types" is the most detailed scheme, which has come down to us from antiquity.

"There will come a time when our descendants will be amazed that we did not know things that are so plain to them."

Seneca *Natural Questions* 7.25.5

Part I: Full earthquake quotations in the seven sources.

Aristotle *Meteorologica*

Life[10]. Aristotle is considered to be one of the two greatest Greek philosophers, the other being his teacher Plato. The details of his life are well attested by many ancient authorities.

He was born in Stageira, a Greek colony in Thrace, in 384 BC. In 367 BC, following the death of his father, he went to Athens. There he became a pupil of Plato and stayed for twenty years. Toward the end of that period he worked as a teacher of rhetoric. He was an independent thinker more or less in constant disagreement with the details of Plato's philosophy. As a consequence, Plato compared him to a colt, which kicks its mother. Still, he had the greatest respect for Plato, and the two were good friends. Plato called him "the intellect' of the school, and "the reader" because of his incessant study. Coming from a wealthy family, Aristotle apparently had enough money to buy books, a luxury most philosophy students could not afford.

In 347 BC Aristotle left Athens. He traveled a bit and wound up in Macedonia at the invitation of Philip of Macedonia. There he undertook the tutorship of Philip's son Alexander (later Alexander the Great), then thirteen years old. There he remained for eight years, only returning to Athens in 335 BC when Alexander had set off to conquer the world. Aristotle lectured and taught in Athens until the death of Alexander in 323 BC, at which time all who had been associated with Alexander immediately became suspect. To avoid persecution, he retired to the small town of Chalcis and died there the next year in 322 BC.

Works. Aristotle's writing was prolific and original. About forty of his works have survived, and this only represents something less than half of what he wrote. The books he prepared for publication are all lost. What has survived are lecture-materials, notes and similar writings.

The extant works can broadly be grouped into four categories: logic, metaphysics, natural philosophy and ethics. In natural philosophy we have the following:

[10] From Sandy, pp.67-70.

Physics
On The Heavens
On Coming To Be
On Passing Away
On The Cosmos (spurious)
Meteorologica
Directions And Names of Winds (fragmentary)
Physical Problems
Mechanical Problems
On Indivisible Lines
History of Animals
Parts of Animals
Movement of Animals
Progression of Animals
and a number of works on psychology.

Earthquake References. Aristotle deals with earthquakes in the *Meteorologica* book 2, chapters 7-8. They are considered as intimately related in cause to several meteorological phenomena, including lightning, thunder and wind. In essence, Aristotle's theory is that earthquakes are caused by wind that is trapped in the earth. However, the issue is complicated by the fact that Aristotle's wind is not wind in the ordinary sense; it is not "moving air". His conception of wind, and thus earthquakes, is wrapped up in his "theory of exhalations." A brief account of this theory is given in Chap.12 of Part II, below. Listed separately in the same chapter are precursors, observations, etc., contained in the full quotations below.

Quotations. The quotations are taken from the *Loeb Edition* of Lee.

Quotation 1: Book 1. ch. 1, 338b26 - 339a3

"There follows[11] the investigation of the causes of winds and earthquakes and all occurrences associated with their motions. Of all these phenomena, some we find inexplicable, others we can to some extent understand."

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[11] In the section containing this passage Aristotle is giving a summary of topics treated in the Meteorologica, as well as an overview of his divisions of natural philosophy.

Quotation 2: Book 1. ch. 6, 343a34 -343b1

"Nor is it true that comets only appear in the northern part of the sky when the sun is at the summer solstice. For the great comet, which appeared about the time of the earthquake in Achaea[12] and the tidal wave, rose toward the equinoctial sunset[13]."

Quotation 3: Book 2. ch. 7, 365a14 - ch. 8, 369a9

"Chapter 7

We must next deal with earthquakes[14] and earth tremors[15], a subject which follows naturally on our last, as the cause of these phenomena is akin to that of wind.

Up to the present three theories have been put forward by three separate men. For Anaxagoras of Clazomenae and before him Anaximenes of Miletus both published[16] views on the subject, and after them Democritus of Abdera.

Anaxagoras says that the air, whose natural motion is upwards, causes earthquakes when it is trapped in hollows beneath the earth, which happens when the upper parts of the earth get clogged by rain, all earth being naturally porous. For he regards the globe[17] as having an upper and a lower part, the part on which we live being the upper part, the other the lower.

It is perhaps hardly necessary to say anything to refute this very elementary account. For it is very silly to think of up and down as if heavy bodies did not fall down to the earth from all directions and light ones (*e.g.* fire) rise up from it, especially when we see that throughout the known world the horizon always changes as we move, which indicates that we live on the convex surface of a sphere. It is silly, too, to think that the earth rests on the air because of its size, and that it is jarred right through by a shock from below. Besides, he fails to account for any of the peculiar features of earthquakes, which do not occur in any district or at any time indiscriminately.

Democritus says the earth is full of water and that earthquakes are caused when a large amount of rain water falls besides this; for when there is too much for the existing cavities in the earth to contain, it causes an earthquake by forcing its way out. Similarly, when the earth gets dried up water is drawn to the empty places from the fuller and causes earthquakes by the impact of its passage.

Anaximenes says that when the earth is in process of becoming wet or dry it breaks, and is shaken by the high ground breaking and falling. Which is why earthquakes occur in droughts and again in heavy rains: for in droughts the earth is dried and so, as just explained, breaks, and when the rains make it excessively wet it falls apart.

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[12] 373-372 BC. For other references to this comet in Arist. see Lee (p.45, note c).

[13] i.e., it rose toward the west.

[14] transliteration of the Greek word is ‘seismou[s]’.

[15] transliteration of the Greek word is ‘kinaseos ges’ (earth tremors).

[16] Arist. is apparently unaware, or unconcerned, with other theories not ‘published’. These include Thales (Seneca Nat. Ques. 6.6.1-4), Archelaus (Seneca Nat. Ques. 6.12.1-3) and others.

[17] globe = “sphaira” in transliteration, literally “a sphere”. But if this refers to the earth then Aristotle is mistaken; Anaxagoras thought the earth was a flat disc or squat cylinder. (Freeman, p.268). Recent scholarship raises the questions of whether the Ionian philosophers, including Anaxagoras, believed they were living on the cylinder.

But (i) if this is so the earth ought to be sinking obviously in many places, (ii) and why do earthquakes occur often in some places which, compared with others, are by no means conspicuous for any such excess of drought or rain, as on this theory they should be? (iii) Besides, on this theory it must be maintained that earthquakes are getting progressively fewer, and will some day cease altogether. For this would be the natural result of the packing down process it describes. But if this is impossible, then this account of their cause must be impossible too.

Chapter 8

Now it is clear, as we have already said, that there must be exhalation both from moist and dry, and earthquakes are a necessary result of the existence of these exhalations. For the earth is in itself dry but contains much moisture because of the rain that falls on it; with the result that when it is heated by the sun and its own internal fire, a considerable amount of wind is generated both outside it and inside, and this sometimes all flows out, sometimes all flows in, while sometimes it is split up.

This process is inevitable. Our next step should therefore be to consider what substance has the greatest motive power. This must necessarily be the substance whose natural motion is most prolonged and whose action is most violent. The substance most violent in action must be that which has the greatest velocity, as its velocity makes its impact most forcible. The farthest mover must be the most penetrating, that is, the finest. If, therefore, the natural constitution of wind is of this kind, it must be the substance whose motive power is the greatest. For even fire when conjoined with wind is blown to flame and moves quickly. So the cause of earth tremors is neither water not earth but wind[18], which causes them when the external exhalation flows inwards.

This is why the majority of earthquakes and the greatest occur in calm weather. For the exhalation being continuous in general follows its initial impulse and tends either all to flow inwards at once or all outwards. There is, however, nothing inexplicable in the fact that some earthquakes occur when a wind is blowing; for we sometimes see several winds[19] blowing at the same time, and when one of these plunges into the earth the resultant earthquake is accompanied by wind. But these earthquakes are less violent, because the energy of their original cause is divided. Most major earthquakes occur at night, and those that occur in daytime at midday, this being as a rule the calmest time of day, because when the sun is at its strongest it confines the exhalation within the earth, and it is at its strongest about midday; and the night again is calmer than the day because of the sun's absence. So at these times the flow turns inwards again, like an ebb as opposed to the outward flood. This happens especially towards dawn, for it is then that winds normally begin to blow. If, then, the original impulse of the exhalation changes direction, like the Euripus, and turns inwards, it causes a more violent earthquake because of its quantity.

Again, the severest earthquakes occur in places where the sea is full of currents or the earth is porous and hollow. So they occur in the Hellespont and Achaea and Sicily, and

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[18] Aristotle does not consider wind to be merely air in motion as expounded by some of his predecessors (Anaximander and Diogenes of Apollonia); this view he explicitly rejects.
(Book 1, Chap.13) Rather, he sees wind as "moving exhalation" (see Part II, chap.12 of the present work).

[19] Aristotle, and the Greeks in general, considered winds as discrete entities--the North Wind, South Wind, etc. see Meteor. 2.6

in the districts in Euboea where the sea is supposed to run in channels beneath the earth. The hot springs at Aedepsus are due to a similar cause. In the places mentioned earthquakes occur mostly because of the constricted space. For when a violent wind arises the volume of the inflowing sea drives it back into the earth, when it would naturally be exhaled from it. And places whose subsoil is porous are shaken more because of the large amount of wind they absorb.

For the same reason earthquakes occur most often in spring and autumn and during rains and droughts, since these periods produce most wind. For summer and winter both bring calm weather, the one because of its frosts, the other because of its warmth, the one thus being too cold, the other being too dry to produce winds. But in times of drought the air is full of wind, drought simply being an excess of dry over moist exhalation. In times of rain the exhalation is produced within the earth in greater quantity, and when what has been so produced is caught in a constricted space and forcibly compressed as the hollows within the earth fill with water, the impact of the stream of the wind on the earth causes a severe shock, once the compression of a large quantity of it into a small space begins to have its effect. For we must suppose that the wind in the earth has effects similar to those of the wind in our bodies whose force when it is pent up inside us can cause tremors and throbbings, some earthquakes being like a tremor, some like a throbbing. We must suppose, again, that the earth is affected as we often are after making water, when a sort of tremor runs through the body as a body of wind turns inwards again from without. For the force that wind has can be seen not only by studying its effects in the air, when one would expect it to be able to produce them because of its volume, but also in the bodies of living things. Tetanus and spasms are movements caused by wind, and are so strong that the combined strength and efforts of a number of men is unable to master the movements of their victims. And if we may compare great things with small, we must suppose that the same sort of thing happens to the earth.

As evidence we may cite occurrences which have been observed in many places. For in some places there has been an earthquake which has not ceased until the wind which was its motive force has broken out like a hurricane and risen into the upper region. This happened recently, for instance, in Heracleia in Pontus, and before that in Hiera, one of the so-called Aeolian islands. For in this island part of the earth swelled up and rose with a noise in a crest-shaped lump; this finally exploded and a large quantity of wind broke out, blowing up cinders and ash which smothered the neighboring city of Lipara, and even reached as far as some of the cities in Italy. The place where this eruption took place can still be seen. (This too must be regarded as the cause of the fire that there is in the earth; for when the air is broken up into small particles, percussion then causes it to catch fire).

And there is a proof that winds circulate beneath the earth in something else that happens in these islands. For when a south wind is going to blow it is heralded by noises from the places from which eruptions occur. This is because the sea, which is being driven forward from far off, thrusts the wind that is erupting out of the earth back again when it meets it. This causes a noise but no earthquake because there is plenty of room for the wind, of which there is only a small quantity and which can overflow into the void outside.

Further evidence that our account of the cause of earthquakes is correct is afforded by the fact that before them the sun becomes misty and dimmer though there is no cloud, and that before earthquakes that occur at dawn there is often a calm and a hard frost. The sun is necessarily misty and dim when the wind which dissolves and breaks up the air begins to retreat into the earth. Calm and cold towards sunrise and dawn are also necessary concomitants. Calm must usually fall, as we have explained, because the wind drains back as it were into the earth, and the greater the earthquake the more this happens; for the earthquake is bound to be more severe if the wind is not dispersed, some outside and some in, but moves in a mass. The reason for the cold is that the exhalation, which is by nature essentially warm, is directed inwards. (Winds are not usually supposed to be warm because they set the air in motion and the air contains large quantities of cold vapor. This can be seen when wind is blown out of the mouth: close by it is warm, as when we breath with open mouth, though there is too little of it to be very noticeable, while farther off it is cool for the same reason as the winds). So the warm element disappears into the earth, and wherever this happens, the vaporous exhalation being moist condenses and causes cold. The cause of a sign which often heralds earthquakes is the same. In clear weather, either by day or a little after sunset, a fine long streak of cloud appears, like a long straight line carefully drawn, the reason being that the wind is dying down and running away. Something like it happens on the seashore too. For when the sea runs high the breakers are large and uneven, but when there is a calm they are fine and straight [because the amount of exhalation is small]. The wind produces the same effects on the cloud in the sky as the sea on the shore, so that when there is a calm the clouds that are left are all straight and fine like breakers in the air.

For the same reason an earthquake sometimes occurs at an eclipse of the moon. For when the interposition is approaching but the light and warmth from the sun, though already fading, have not entirely disappeared from the air, a calm falls when the wind runs back into the earth. And this causes the earthquake before the eclipse. For there are often winds also before eclipses, at nightfall before a midnight eclipse, at midnight before an eclipse at dawn. The reason for this is the failure of the heat from the moon when its course approaches the point at which the eclipse will take place. Thus when the cause which held it quiet ceases to operate the air is set in motion again and a wind rises, and the later the eclipse, the later this happens.

When an earthquake is severe the shocks do not cease immediately or at once, but frequently go on for forty days or so in the first instance, and symptoms appear subsequently for one or two years in the same district. The cause of the severity is the amount of the wind and the shape of the passages through which it has to flow. When it meets with resistance and cannot easily get through, the shocks are severest and air is bound to be left in the narrow places, like water that cannot get out of a vessel. Therefore, just as throbbings in the body do not stop at once or quickly, but gradually as the affliction which is their cause dies away, so the originating cause of the exhalation and the source of the wind clearly do not expend all at once the material which produces the wind which we call an earthquake. Until, therefore, the rest of it is expended shocks must continue, their force decreasing until there is too little exhalation to cause a shock that is noticeable.

Wind is also the cause of noises beneath the earth, among them the noises that precede earthquakes, though they have also been known to occur without an earthquake following. For as the air when struck gives out all sorts of noises, so also it does when it is itself the striker; the effect is the same in either case, since every striker is itself also struck. The sound precedes the shock because the sound is of finer texture and so more penetrating than the wind itself. When the wind is too fine to communicate any impulse to the earth, being unable to do so because of the ease with which it filters through it, nevertheless when it strikes hard or hollow masses of all shapes it gives out all sorts of noises, so that sometimes the earth seems to bellow as they say it does in fairy stories.

Water has sometimes burst out of the earth when there has been an earthquake. But this does not mean that the water was the cause of the shock. It is the wind which is the cause, whether it exerts its force on the surface or from beneath--just as the winds are the cause of waves and not the waves of winds. Indeed one might as well suppose that the earth is the cause of the shock as that the water is; for in an earthquake it is overturned like water, and upsetting water is a form of overturning. But in fact both earth and water are material causes, being passive not active, but wind the motive cause.

When a tidal wave coincides with an earthquake the cause is an opposition of winds. This happens when the wind which is causing the earthquake is unable quite to drive out the sea which is being driven in by another wind, but pushes it back and piles it together till a large mass has collected. Then if the first wind gives way the whole mass is driven in by the opposing wind and breaks on the land and causes a flood. This is what happened in Achaea. For in Achaea there was south wind, outside a north wind; this was followed by a calm when the wind plunged into the earth, and so there was a tidal wave at the same time as the earthquake -- an earthquake which was all the more violent because the sea gave no vent to the wind that had run into the earth, but blocked its passage. So in their mutual struggle the wind caused the earthquake, the wave by its subsidence the flood.

Earthquakes are confined to one locality, often quite a small one, but winds are not. They are localized when the exhalations of a particular locality and its neighbor combine, which was what we said happens in local droughts and rainy seasons. Earthquakes are produced in this way, but not winds. For rains, droughts and earthquakes originate in the earth, and so their constituent exhalations tend to move all in one direction; the sun has less power over them than it has with the exhalations in the air which therefore flow on in one direction when the sun's movement gives them an impulse, differing according to the difference of its position.

So then, when the quantity of wind is large it causes an earthquake shock which runs horizontally, like a shudder: occasionally in some places the shock runs up from below, like a throb. The latter type of shock is therefore the rarer, for sufficient force to cause it does not easily collect since there is many times as much of the exhalation that causes shocks horizontally as of that which causes them from below. But whenever this type of earthquake does occur, large quantities of stones come to the surface, like the chaff in a winnowing sieve. This kind of earthquake it was that devastated the country round Sipylos, the so-called Phlegraean plain and the districts of Liguria.

Earthquakes are rarer in islands that are far out at sea than in those close to the mainland. For the quantity of the sea cools the exhalations and its weight crushes them and prevents their forming; and the force of the winds causes waves and not shocks in the sea. Again, its extent is so great that the exhalations do not run into it but are produced from it and joined by those from the land. On the other hand, islands close to the mainland are for all practical purposes part of it, the interval between them being too small to be effective. And islands out at sea can feel no shock that is not felt by the whole of the sea by which they are surrounded.

This completes out explanation of the nature and cause of earthquakes, and of their most important attendant circumstances."

Quotation 4: Book 2. ch. 9, 370a26 - 33

"Our own view is that the same natural substance causes wind on the earth's surface, earthquakes beneath it, and thunder in the clouds; for all these have the same substance, the dry exhalation. If it flows in one way it is wind, in another it causes earthquakes..."

Lucretius De Rerum Natura

Life[20]. Information concerning the life of Titus Lucretius Carus is very meager indeed. His own work contains no autobiographical material and he is mentioned only one time each by Cicero[21], Donatus[22] and St. Jerome[23]. The evidence for Lucretius' date is contained in the comments of St. Jerome and Cicero. St. Jerome wrote that in the year 94 BC[24], "The poet Titus Lucretius was born. He...committed suicide in his 44th year." Cicero, in a letter of 54 BC, merely alludes to Lucretius' *De Rerum Natura*[25]. Since it was not published until after Lucretius' death[26] the inference is that he did not live to 54 BC. Based on this and other minor evidence, the generally accepted dates for Lucretius are c.96-55 BC.

Lucretius was a Roman citizen and probably a well-educated aristocrat. He was an ardent member and promoter of the Epicurean philosophical sect[27]. As such, the philosophy, both ethical and natural, contained in his writing is considered to be that of Epicurus[28].

Works. *De Rerum Natura* is the only work Lucretius is known to have produced, but considered to be a masterpiece of Latin poetry. It is a poetical account, in six books, of the Epicurean concept of nature. Interlaced with this is a heavy dose of their moral philosophy. Despite all of this "Epicureanism", or perhaps because of it, Lucretius was a keen observer of nature. This is apparent in the earthquake-related quotations given below.

Manuscripts. The earliest complete copies of Lucretius which have survived are two manuscripts of the ninth century. Both are in the University Library of Leiden,

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[20] Information gathered from the introduction of Smith (pp. ix-lxii).
[21] Marcus Tullius Cicero, famous Roman orator and writer (106-43 BC).
[22] A grammarian of the fourth century AD.
[23] Latin father of the Church (340-420 AD), author of a Greek Chronology, the Vulgate version of the Latin Bible, and other works.
[24] Chron.p.149 Helm (Smith's note).
[25] Literally, "On the Nature of Things".
[26] Since the work is unfinished.
[27] Followers of the doctrines of the Greek philosopher Epicurus (342?-270 BC).
[28] For details see Smith (pp. xxviii-liv).

Germany. We also have two fragmentary manuscripts dating from the ninth or tenth century. These are in Copenhagen and Vienna.

Quotations. The quotations are taken from the *Loeb Edition* of Smith.

Quotation 1: Book 5, 104 - 108

"My words will perhaps win credit by plain facts, and within some short time you will see violent earthquakes arise and all things convulsed with shocks."

Quotation 2: Book 5, 1236 - 1241

"Then when the whole earth trembles beneath our feet, when cities are shaken and fall or threaten to fall, what wonder if the sons of men feel contempt for themselves, and acknowledge the great potency and wondrous might of gods in the world, to govern all things?"

Quotation 3: Book 6, 535 - 607

"Now attend and learn what is the reason for earthquakes. And in the first place, be sure to consider the earth below as above to be everywhere full of windy caverns, bearing many lakes and many pools in her bosom with rocks and steep cliffs; and we must suppose that many a hidden stream beneath the earth's back violently rolls its waves and submerged boulders; for the facts themselves demand that she be everywhere like herself.

Since therefore she has these things attached beneath her and ranged beneath, the upper earth trembles under the shock of some great collapse when time undermines those huge caverns beneath; for whole mountains fall, and with the great shock the tremblings in an instant creep abroad from the place far and wide -- and with good reason, since when wagons of no great weight pass, whole buildings hard by the road tremble with the shock, nor less do [the wagons themselves][29] jump [when a stone in the road][10] jolts up the iron tires of the wheels on this side and that.

Sometimes also, when from lapse of time a huge mass is rolled forwards from the earth into some great and wide pool of water, the earth also is moved and shaken by the wave of water: just as a vessel sometimes cannot remain still, unless the water within it ceases to be moved about in waves to and fro.

Besides, when a wind gathering together through the hollow places beneath the earth throws itself forward from one quarter, and bears hard, thrusting with great force into the lofty caverns, the earth leans over in the direction of the wind's headlong force. Then those buildings which are built up above the earth, and each all the more, the more they tower up towards heaven, lean suspended, pushing forward in the same direction, and the beams dragged forward hang over ready to go. And yet people fear to believe that this great world has waiting for it some period of destruction and ruin, although they see the earth's mighty mass leaning over! Yet if the winds should never abate, no force could curb the world back

[29] The manuscripts (line 550) are corrupted in this passage and thus the reading is uncertain. The general sense is not in doubt.

or hold it back in its rush to perdition. As it is, because in turns they abate and gather force, and rally as it were and come back and then are driven back in retreat, for this reason the earth more often threatens to fall than it does fall; for it inclines forward and then again springs back, and after tumbling forward recovers its proper place in equilibrium. This then is how all buildings totter, the top more than the middle, the middle than the foundation, the foundation the merest trifle.

There is also another cause of the same great trembling, when wind or a very great force of air, either from without or arising within the earth itself, has thrown itself suddenly into the hollow places of the earth, and there in the great caverns first growls tumultuously and is carried whirling about, afterwards the force thus excited and driven outwards bursts forth, and at the same time cleaving the earth asunder makes a great chasm. This befell at Syrian Sidon, and came to pass at Aegium[30] in the Peloponnese, when such an issue of air over threw those cities with the earthquake that followed. Many another city wall has fallen by great quakings in the earth, many cities have sunk down to the bottom of the sea along with their inhabitants.

But if there is no breaking forth, yet the impetuous air itself and the furious force of wind is distributed abroad through the many interstices of the earth like an ague, and thus transmits the trembling; just as, when cold penetrates deep into our limbs, it shakes them, making them tremble and quake against our will. Therefore men shiver in their cities with a twofold terror: they fear the houses above, they dread the caverns below, lest the earth's nature loosen all asunder in a moment, or torn asunder open abroad her own gaping jaws, and in confusion seek to gorge it with her own ruins.

Therefore let them believe as they please that earth and sky will remain incorruptible, given in trust to life everlasting; and yet sometimes the very present force of peril applies this goad of fear also from one part or another, that the earth may be suddenly withdrawn from under their feet, and fall into the bottomless pit, followed by the whole sum of things utterly giving way, and then may come the confused ruin of the world."

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[30] The earthquake a Sidon, mentioned also by Strabo and Seneca, probable occurred late in the fifth century BC. The towns of Helice and Buris, Near Aegium, were destroyed in 373-372 BC. (Smith's note).

Seneca *Natural Questions*

Life[31]. Lucius Anneas Seneca was a famous Roman public, literary and philosophical figure. As such, the details of his life are well attested by ancient authorities.

He was born in Spain about 4 BC and brought to Rome by his father while very young. There he received a good education and became familiar with the major philosophical movements of his day. He had some famous relatives, including his father who was a published author, a brother who was Proconsul of Achaea in the time that St. Paul was brought to trial, and a nephew who became the poet Lucan.

Seneca was extraordinarily popular as a speaker and writer. This notoriety won him friendship with many of the powerful political figures in Rome. Such high visibility carries a price and in 41 AD he was exiled to Corsica on a (probably false) charge of adultery. There he spent eight years, mostly writing and thereby keeping his reputation alive in Rome.

In 49 AD he was recalled from exile to act as tutor to Nero. When Nero became emperor in 54 AD Seneca remained as an intimate counsel, and thus was one of the most powerful men in Rome. For five years all went well with both Seneca and the Roman empire. Then, in 59 AD, Nero murdered his mother Agrippina, less than a year after having poisoned his half-brother Britannicus. Seneca's role in all of this, if any, is unknown.

Soon thereafter he lost favor with Nero and eventually, in 65 AD, was ordered by him to commit suicide.

Works. Seneca's extant works include *Moral Essays, Letters to Lucilius (Epistulae), the Natural Questions* , nine tragedies and a, possibly spurious, satire on Claudius called *Apocolocyntosis* . His lost works include books on India and Egypt. Also, from the following quotation[32] we know that he wrote a book on earthquakes, now lost: "...even though at one time as a young man I published a volume on earthquakes, none the less I would wish to test myself and find out whether age has added anything to me in the

[31] Based on biography in Corcoran (pp. vii-xxvii).
[32] Natural Questions 6.4.2.

way of knowledge or at any rate in the way of diligence." He is the only ancient author known to have a written a work exclusively concerned with earthquakes.

The Natural Questions was composed, in Latin, about 62 AD. In it Seneca attempts to give the reader an appreciation for the current state of knowledge in natural philosophy. It is also a vehicle for digressions into Seneca's moral philosophy.

Manuscripts. The earliest surviving manuscripts of the *Natural Questions* date from the twelfth century. There are four of these, one each in Paris, Geneva, Leiden (Germany), and Camercen (Italy).

Earthquake References. Seneca mentions or details the earthquake theories of fourteen of his predecessors. There is no other extant work as rich in earthquake theories. He also lists his theory on the subject. While not very original, it does need to be considered separately and will be found in Part II Chapter 21, below, along with his earthquake observations and precursors. All of this information can be found, albeit scattered, in the full quotations immediately below.

Quotations. The quotations are from the *Loeb Edition* of Corcoran. Listed here for convenience are the 18 separate quotations. The numbers represent book, section and sub-section in the *Natural Questions* ,

1. 2.1.2 - 3
2. 2.27.1
3. 3.11.1
4. 3.14.1
5. 4.2.28 - 30
6. 5.14.4
7. 6.1.1 - 3
8. 6.1.7
9. 6.1.11 - 15
10. 6.3.1 - 3
11. 6.4.1
12. 6.4.2 - 7.2
13. 6.9.1 - 16.1
14. 6.17.2 - 27.2
15. 6.30.1
16. 6.30.4
17. 6.30.5 - 31.3
18. 7.28.3.

The sub-section numbers have been included in this list and quotation headings for completeness, but I have not indicated these within the quotations.

Quotation 1: Book 2. Sect. 1., 2 - 3

"The second division[33] deals with phenomena occurring between the sky and the earth, such as clouds, rain, snow, wind, earthquakes[34], lightning, and

Thunder which will move
The mind of men;[35]

and whatever the atmosphere does or undergoes. Such phenomena we call *sublimia* because they are higher than the low phenomena on earth. The third division investigates water, land, trees, plants, and -- to use a legal term -- everything contained in the ground.

'Why,' you ask, 'have you put the study of earthquakes[36] in the section where you will talk about thunder and lightning?' Because, although an earthquake[37] is caused by a blast, a blast is none the less air in motion. Even if the air goes down into the earth it is not to be studied there. Let it be considered in the region where nature has placed it."

Quotation 2: Book 2. Sect. 27., 1

"27. Some authorities make a distinction between types of thunder. For example, they say that one kind has a deep rumble like the sound which precedes an earthquake[38] when the wind is obstructed and raging. I will explain how the types of thunder occur, as it seems to them."

Quotation 3: Book 3. Sect. 11., 1

"11. 'But,' someone says, 'if the causes from which rivers and streams arise are constant, why do they sometimes dry up, sometimes emerge in places where they did not exist before?' Their paths are often disturbed by an earthquake[39]; and landslides cut off channels for water which then searches for a new exit when it is blocked and in some directions does so violently; or rivers are shifted from one place to another by a vibration of the earth itself."

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[33] Of natural philosophy, i.e., meteorology. This passage occurs at the beginning of book2 on "Lightnings and Thunders". Seneca is discussing the three divisions of natural philosophy: cosmology, meteorology, and geography.

[34] earthquakes = "terrae motus".

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[36] earthquake = "terrae motu".

[37] earthquake = "motus" (Corcoran and MSS) or "motus terrae" (MSS A, B & V).

[38] earthquake = "terrarum motum".

[39] earthquake = "motu terrarum".

Quotation 4: Book 3. Sect. 14., 1

"14. The following theory of Thales is silly. For he says that this globe[40] of lands is sustained by water and is carried along like a boat, and on the occasions when the earth is said to quake it is fluctuating because of the movement of the water. It is no wonder, therefore, that there is abundant water for making the rivers flow since the entire round is in water. Reject this antiquated, unscholarly theory. There is also no reason that you should believe water enters this globe through cracks, and forms bilge."

Quotation 5: Book 4. Sect. 2., 28 - 30

"Diogenes of Apollonia says: 'The sun draws moisture to itself; the land, dried out, takes moisture from the sea; the sea itself draws moisture from other waters. But it cannot happen that some land is dry, other land flooded, for all lands are perforated with communicating passages and the dry sections draw from the moist. Otherwise, unless the land received some moisture it would have completely dried out. Accordingly, the sun draws up moisture, but only from those regions which the sun especially oppresses; that is, the southern regions. When the land is parched it draws in more moisture. Just as in a lamp the oil flows to where it is burned, so water inclines to where the force of the heat and of the burning land draws it. But where does the land draw it from? Surely from areas of eternal winter. The northern regions abound in water. (For this reason the swift current of the Pontus runs constantly towards the lower sea and does not ebb and flow in alternating tides the way other seas do, but always has a torrent descending in one direction). Unless this happened--that is, unless these passage-ways restored water to any land that lacked it and drained away surplus water--everything would already have been dried up or flooded.' "

Quotation 6: Book 5. Sect. 14., 4

"It is surely obvious that under the earth there is a great supply of sulphur and other substances which feed fire. When the air, searching for a way out, twists itself through these places, it necessarily kindles fire by its very friction. Then, as the flames spread more extensively, even any sluggish air that is present is rarefied and set in motion and seeks an outlet with great noise and violence. But I will take this matter up in more detail when I investigate earthquakes[41]".

Quotation 7: Book 6. Sect. 1., 1 - 3

"BOOK 6

EARTHQUAKES[42]

1. Lucilius, my good friend, I have just heard that Pompeii, the famous city in Campania, has been laid low by an earthquake[43] which also disturbed all the adjacent

[40] The Latin is "terrarum orbem" implying Thales thought the earth was spherical. This is not true, he thought it was a flat disc or squat cylinder. (Heath Aristarchus of Samos, p.18).

[41] earthquakes = "motibus terrae".

[42] earthquake = "de terrae motu".

districts. The city is in a pleasant bay, back a ways from the open sea, and bounded by the shores of Surrentum and Stabiae on the one side and the shores of Herculaneum on the other; the shores meet there. In fact, it occurred in days of winter, a season which our ancestors used to claim was free from such disaster. This earthquake[44] was on the Nones of February, in the consulship of Regulus and Verginius[45]. It caused great destruction in Campania, which had never been safe from this danger but had never been damaged and time and again had got off with a fright. Also, part of the town of Herculaneum[46] is in ruins and even the structures which are left standing are shaky. The colony of Nuceria escaped destruction but still has much to complain about. Naples also lost many private dwellings but no public buildings and was only mildly grazed by the great disaster; but some villas collapsed, others here and there shook without damage. To these calamities others were added: they say that a flock of hundreds of sheep was killed, statues were cracked, and some people were deranged and afterwards wandered about unable to help themselves. The thread of my proposed work, and the concurrence of this disaster at this time[47], requires that we discuss the causes of these earthquakes[48]."

Quotation 8: Book 6. Sect. 1., 7

""But the disaster of an earthquake[49] extends far and wide, is inevitable, insatiable, deadly for the entire state. It gulps down not only homes or families or individual cities; it inters entire nations and regions. Sometimes it covers them with ruins, sometimes buries them in a deep abyss, and does not even leave anything to indicate that what does not exist, at least once was. Soil extends over the noblest cities, without any trace of the way they used to look."

Quotation 9: Book 6. Sect. 1., 11 - 15

"All places have the same conditions and if they have not yet had an earthquake[50], they none the less can have quakes. Perhaps this night or, before tonight, this day will split open the spot where you stand securely. How do you know whether conditions are better in those places against which fortune has already exhausted her strength or in those places which are supported on their own ruins henceforth? We are mistaken if we believe any part of the world is exempt and safe from the danger of an earthquake. All regions lie under the same laws: nature has not created anything in such a way that it is immobile. Some things

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[43] earthquake = “terrae motu”.

[44] earthquake = “motus”.

[45] There is some confusion on the date of this earthquake between Seneca and Tacitus. (Ann. 15.22-23). It probably occurred 5 February 62 AD (from Corcoran’s note). Also see 6.1.13 and 7.28.3 below.

[46] This event should not be confused with the famous eruption of Vesuvius, in August of 79 AD, which completely buried Herculanium and Pompey.

[47] This is the statement that allows us to determine the composition date for the Natural Questions as about 62 AD.

[48] earthquake = “motus”.

[49] earthquake = [no explicit Latin phrase].

[50] earthquake = “mota”.

fall at one time, others at another, and just as in large cities one home here one home there is propped up, so on the globe of earth now this part now that has a flaw.

Tyre was once notorious for its ruinations. Asia lost twelve cities at one time. Last year the same disastrous force, whatever it is, that now has fallen upon Campania, struck Achaea and Macedonia. Fate travels in a circuit and returns to a place it has long passed by. Some regions it rarely troubles, others it disturbs frequently. But it permits nothing to be immune and unharmed. Not only we men, who are born short-lived and frail things, but cities also, and regions and coasts of earth, and even the sea, are slaves of fate. None the less we promise ourselves that benefits from fortune will be permanent, and we believe that happiness, whose fickleness is the most fleeting of all human affairs, will in some person have stability and duration. And since men promise themselves that all things are perpetual it does not enter the mind that the very land on which we stand is unstable. The flaw in Campania or Achaea exists not only there but in every ground. The earth stays together poorly and is disintegrated by many causes; it is permanent as a whole but its parts collapse."

Quotation 10: Book 6. Sect. 3., 1 - 3

"3. It will help also to keep in mind that gods cause none of these things and that neither heaven nor earth is overturned by the wrath of divinities. These phenomena have causes of their own; they do not rage on command but are disturbed by certain defects, just as our bodies are[51]. At the time they seem to inflict damage they actually receive damage. All these phenomena are terrible to us since we do not know the truth, and all the more terrible since the rarity of their occurrence increases our fear. Familiar things affect us lightly. The fear from unusual occurrences is greater. But why is anything unusual to us? Because we comprehend nature with our eyes, not our reason. We do not reflect upon what nature can do but only on what she has done. Accordingly, we pay the penalty for this negligence in being terrified by things as new when they are not new but merely unusual."

Quotation 11: Book 6. Sect. 4., 1

"4. Let us ask, then, what it is that moves the earth from the depths, what pushes such a great mass of weight; what is stronger than the earth that by its force it can shake so great a load. Let us investigate why the earth sometimes trembles, sometimes collapses and sinks, now is divided into sections and gapes open; why in one place it preserves for a long time the gap caused by its destruction, in other places it quickly compresses it again. Why at one time does it channel within itself rivers of noteworthy size, and at another time causes new rivers to appear. Why does it sometimes open veins of hot water, sometimes makes the water cold, and sometimes emits fire through a previously unknown opening of a mountain or a rock, but at other times suppresses fires that have been known and famous for ages. An earthquake[52] produces a thousand strange things and changes the appearance of

[51] Analogy between the earth and the human body is common in Seneca (Corcoran's note).
[52] earthquake = [no explicit Latin phrase].

places and carries away mountains, elevates plains, pushes valleys up, raises new islands in the sea. What causes these things to happen is a subject worth investigating."

Quotation 12: Book 6. Sect. 4., 2 - Sect. 7., 2

"Let us examine, then, why these phenomena occur. The investigation of them is so appealing to me that, even though at one time as a young man I published a volume[53] on earthquakes[54], none the less I would wish to test myself and find out whether age has added anything to me in the way of knowledge or at any rate in the way of diligence.

5. Some think the cause of earthquakes[55] exists in water, others in fire, or in the earth itself, or even in the air, or in several of these elements, or in all of them. Certain writers have said that it was clear to them that some cause of earthquakes[56] came from those elements; but it was not clear what the cause was.

I will now pursue each theory. Before anything else, I must say that the old theories are crude and inexact. Men were still in error about the truth. Everything was new for men who were making the first attempts. Later these same theories were refined. Yet, if anything has been discovered, it none the less ought to be acknowledged as having been received from them. It was the achievement of a great spirit to move aside the veil from hidden places and, not content with the exterior appearance of nature, to look within and to descend into the secrets of the gods. The man who had the hope that the truth could be found made the greatest contribution to its discovery. And so the ancients must be listened to, indulgently. Nothing is completed while it is beginning. This is true not only in this subject (which is the greatest and most complex of all), but in every other business as well. Even though much will have been done on the subject every age will none the less find something to do. As in every other subject, the first beginnings have always been far away from the completed knowledge.

6. The cause of earthquakes[57] is said to be in water by more than one authority but not in the same way. Thales of Miletus judges that the whole earth is buoyed up and floats upon liquid that lies underneath, whether you call it the ocean, the great sea, or consider it the as yet elementary water of a different character and call it merely a humid element. The disc is supported by this water, he says, just as some big heavy ship is supported by the water which it presses down upon.

It is pointless for me to give the reasons for his belief that the heaviest part of the universe cannot be carried by air, which is so tenuous and mobile; for the point now does not deal with location of the earth but with earthquakes[58]. By way of proof that waters exist as the cause of earthquakes[59] and that the earth is agitated by these waters, he proposes this: in every great earthquake[60] new springs generally break out, just as it also happens that if

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[53] This work is lost.
[54] earthquake = “motu terrarum”.
[55] earthquake = “terra concutitur”.
[56] earthquake = [no explicit Latin phrase].
[57] earthquake = [no explicit Latin phrase].
[58] earthquake = “motu agitur”.
[59] earthquakes = “orbis agitetur”.
[60] earthquake = “motu”.

ships tilt and lean to one side they take in water. In the case of all heavy objects which water carries, if they are submerged considerably, the water either flows over them or at least the water rises on the right or left more than usual.

It need not take long to deduce that Thales' theory is false. For, if the earth were supported by water and sometimes shaken by it, there would always be earthquakes[61] and we would not be amazed that the earth is shaken but that it remains at rest. Finally, the whole earth would be shaken, not just a part; for never is half a ship tossed about. As things are, a quake is not over the entire earth but on a part of it. Therefore, how can it happen that what is carried as a whole is not shaken as a whole if it is shaken by that which carries it? 'But why do waters break out?' First of all, there has often been an earthquake[62] and yet no new liquid flowed. Second, if water did burst forth for this reason it would pour around the sides of the earth, as we see happens in the case of rivers and the sea; just as when boats sink the increase of water appears mainly over the sides. Finally, no such scanty eruption of water as *you* say would ever occur, not would it seep in like bilge-water through a crack, but a huge deluge would be the result of liquid that is infinite and supports all that the earth consists of.

7. Some other writers also attribute earthquakes[63] to water but with different explanations. Throughout the entire earth, one of them says, run many different kinds of water. In some places there are perpetual rivers large enough to be navigable, even without the help of rains,. For example, there is the Nile, which carries great quantities of water all summer. Elsewhere, rivers flow midway between the pacified and the hostile; for example, the Danube or the Rhine, one checking the attacks of Sarmatians and marking a boundary between Europe and Asia, the other keeping back the Germans, a nation eager for war. Consider now the very wide lakes and inland waters surrounded by people unknown to each other, and swamps a boat cannot struggle through, impassable even for those who live on the edges. Then there are many springs, many sources of rivers disgorging sudden streams from hidden places, many rushing torrents that come together on an occasion, whose force is as brief as it is sudden."

Quotation 13: Book 6. Sect. 9., 1 - Sect. 16., 1

"9. Some authorities, and indeed men of high reputation, suppose that fire is the cause of earthquakes[64]. Anaxagoras especially estimates that both the atmosphere and the earth are shaken by just about the same cause. Moving air in the lower region inside the earth bursts the atmosphere, which is thick and compacted into clouds, with the same force that clouds in our part of the world are usually broken open. Fire flashes out from this collision of clouds and from the rush of air that is forced out. This fire, seeking an exit, runs against anything it meets and tears apart anything that resists it until either it finds a way out to the sky through narrow passages or makes a way out by force and destruction.

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[61] earthquakes = "moveretur".
[62] earthquake = "tremuit terra".
[63] earthquakes = "motum terrarum".
[64] earthquakes = "motus" (Corcoran and MSS), "motus terrarum" (MSS A, B & V).

Other authorities also conclude that the cause of earthquakes[65] is fire, but for a different reason: buried fire breaks out in many places and as it blazes away it burns everything near it. If ever the places fall when they have been eaten away, then there follows a movement of those parts of the earth which are deprived of the support which lies underneath, and they slip until they collapse since nothing rushes in to receive their weight. Then chasms, then vast gulfs are opened or, when they have hesitated a long time, they settle down over those things which are still standing under them. We see this happen also right in front of us when a section of a city suffers from fire. When beams are burned through or the members which gave support to the upper stories are destroyed, then the roofs, after trembling a long time, collapse, and waver for some time in their descent until they come to rest on something solid.

10. Anaximenes says that the earth itself is the cause of its earthquakes[66] and that the earth does not encounter from outside something that shakes it but something within itself and of itself. For, he says, certain parts of the earth fall in, which either moisture has dissolved or fire has eaten away or a blast of air has shattered; but even if these elements are not active, he says, there are other reasons that some part of the earth moves away or is torn away. In the first place, all things totter from length of time and nothing is safe from age; age wastes away even these very strong and solid objects. Accordingly, in old buildings when some sections have more weight than strength they fall even though they are not knocked off. The same thing happens in this whole body of the earth: its parts are loosened by age, and once loosened they fall and cause a tremor to the parts above them. The parts first do this when they give way, for nothing big is cut away without moving whatever it adhered to; then when they fall they meet something solid and rebound like a ball. When a ball falls it leaps up and bounces repeatedly, as many times as it is sent back from the ground into a new flight. Moreover, if parts of the earth have been carried down in stagnant waters, this fall by itself shakes the vicinity with a wave ejected by the sudden mass which has been shot down from above.

11. Some, indeed, attribute earthquakes[67] to fire but give different explanations. When heat grows intense in many places it necessarily rolls up an enormous cloud of vapor that has no way out and causes strain on the air by its force. If the vapor exerts excessive pressure it breaks through all that opposes it; but if it is fairly moderate it causes nothing more than a movement of the earth. We see water foam up when fire is put under it. What happens in the case of a small quantity of enclosed water we may believe happens much more when violent, extensive fire stirs up great quantities of water. Then by the vaporization of the billowing water the fire causes whatever it strikes to shake.

12. It is a favorite theory of most of the greatest authorities that it is moving air which causes earthquakes[68]. Archelaus, a scholar accurate in matters of ancient times[69], says as follows: winds are carried down into cavities of the earth; then, when all the spaces

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[65] earthquakes = [no explicit Latin phrase].
[66] earthquakes = “motus”.
[67] earthquakes = “tremorem”.
[68] earthquakes = [no explicit Latin phrase].
[69] But Archelaus (5th century BC) himself was ancient relative to Seneca (first century AD). The meaning and reading are doubtful (from Corcoran’s note).

are filled and the air is thickened as much as it can be, the moving air which comes in on top of it compresses the air that was there first and pushes it and with frequent blows first packs it together then forces it out. Then in seeking room the air unblocks all the narrow passageways and tries to break out of its enclosure. In this way it comes about that the earth is moved, when the moving air is struggling and searching for a way out. And so, a calm and quiet condition of the atmosphere precedes the period when there will be an earthquake[70], obviously because the force of air which usually stirs up the winds is retained in the interior of the earth. At this time too when the earthquake[71] occurred in Campania, even though it was the restless season of the winter, the air in the atmosphere remained still throughout the preceding days.

But what about this: has the earth never been shaken when the wind was blowing? Very rarely. Two winds may blow at the same time; indeed, not only can it happen but it is usual. If we accept this and it is agreed that two winds act at the same time, why can it not happen that one agitates the upper atmosphere, the other the lower regions?

13. In the same group you may place Aristotle and his student Theophrastus, a man not of divine eloquence, as he seemed to the Greeks, but nevertheless of a smooth and clear eloquence without effort. I will set forth the theory they both liked; from the earth there is always some sort of evaporation which is sometimes dry sometimes mixed with moisture. This emanates from the depths of the earth; when it has risen as far as possible and does not have a higher place to go, it is carried back and is rolled up on itself. The conflict of air moving back and forth hurls aside all obstacles and, whether it is blocked or struggles out through narrow openings, it causes a movement and a disturbance of the earth.

Strato is of the same school[72]. He especially cultivated this branch of philosophy and was an investigator of the nature of the universe. His decision is this: cold and heat always change into opposites. They cannot exist together. Cold flows into the place from which the force of heat has departed, and in turn heat exists in the place from which cold has been driven out. I will appear to you from the following that what I say is true and that both move contrary to each other.

In the wintertime, when there is cold on the surface of the earth, wells are warm, and caves, and all the recesses under the earth, because heat gathers there yielding to the cold which possesses the upper regions. When the heat penetrates to the lower regions and accumulates there, as much as it can, it becomes stronger as it becomes denser. Here it comes upon other air which necessarily yields to it, packed as that cold air is and compressed into a corner. The same thing happens in an opposite way when a great quantity of cold is carried down into the caverns. The heat that hides there gives way to the cold and withdraws to the narrow passages and is driven along with great impetus because the nature of the two does not allow harmony or delay in the same place. Therefore, the air in its flight and desire to escape in any way pushes back and tosses about all that is close to

[70] earthquake = “terrae motus”.
[71] earthquake = “motus”.
[72] The Peripatetic school founded by Aristotle. Strato succeeded Theophrastus as head of the Lyceum in 287 BC. Curiously, Lodge (London, 2nd ed., 1620, p.873) reads Strabo in place of Strato. Strabo (63? BC - 24? AD), a geographer and not a natural philosopher, was over two centuries later than Strato and there seems no reason to confuse them, other than similarity of spelling. Corcoran gives no variant MSS readings.

it. And so, before the earthquake[73] a roaring noise is usually heard from winds that are creating a disturbance underground. Otherwise it could not happen -- as our Virgil says:

> The ground bellows under our feet
> And the high ridges move--[74]

unless this were the work of winds.

Then this conflict of the winds goes through the same phases alternately. There is an accumulation of heat and again its eruption; then what is cold is restrained and gives way but subsequently it will become more powerful. Therefore, while the force runs back and forth and the air moves here and there, the earth is shaken.

14. There are those who think that earthquakes[75] are indeed caused by air, and by no other cause, but for a different reason from Aristotle's theory. Listen to what they say: our body is irrigated by blood; also by air, which runs along by its own routes. However, we have some rather narrow receptacles for breath through which air does nothing more than pass, others wider in which the air is collected and from there distributed to the parts of the body. In the same way this whole body of the entire earth is a passageway both for water, which takes the place of blood, and for winds, which you might call simply respiration[76]. These two elements run together in some places, are stationary in other places. But in our body the movement of the veins also preserves its rhythm undisturbed while there is good health but when there is something wrong the movement pulses more rapidly and inhaling and exhaling give signs of effort and exhaustion. In the same way the earth remains unshaken as long as its condition is normal. When something is wrong, then there is motion just like that of a sick body, because the air which was flowing through it in an even pattern is struck violently and causes its veins to shake. But not as they said a little above-- those who are fond of the theory that the earth is a living creature[77]. Otherwise, the earth would feel the agitation all over, the way an animal does. For, in us a fever does not attack certain parts more slowly than others but spreads through all parts with the same uniformity.

Consider, therefore, whether some of the air from the surrounding atmosphere enters into the earth. As long as it has a way out, it slips through without doing damage. If it stumbles against something or meets something which blocks its path, then at first it is loaded down with the atmosphere that flows upon it from behind, next it escapes with difficulty through some crack, and the narrower the crack the more violently the air spurts out. This cannot happen without a struggle, and a struggle cannot take place without causing movement. But if it does not find even a crack to flow out of, the air becomes massed there and rages and is driven around this way and that, hurling some obstacles aside, cutting through others. It is very extenuated yet at the same time very strong. It pushes through obstructions, however large, and whatever it enters it splits by its force and scatters. Then the earth is tossed about. For it either opens to give room to the air or when it has

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[73] earthquake = "terrae moveatur".
[74] Virgil Aeneid 6.256.
[75] earthquakes = "tremere terram".
[76] In book 3.15.1-2 Seneca treats more fully the concept that the earth has veins and arteries similar to those in the human body. Also, in book 5.4.2, he mentions the theory that winds are formed in a way analogous to flatulence in the human body (Corcoran's note).
[77] The Phythagorean theory that the earth is a living creature (Corcoran's note).

given room it is deprived of its foundation and collapses into the very cavern from which it released the air.

15. Some think along the following lines: the earth is perforated in many places, and has not only those places of admission which it first received at its beginning and which it had as though for breathing but many others which violent chance has formed. In some places water washed away areas from the earth's surface; the torrents cut through some parts, other places were laid open because they were broken apart by great tides. Air enters through these openings. If the sea encloses the air and drives it deeper down and the water does not permit it to come back out, then, when its way out and way back are at the same time blocked, the air is rolled about and, because it is not able to extend straight out, which is natural to it, it stretches itself upward and lashes apart the earth pressing down upon it.

16 And now I must state a theory which many authorities favour and which will perhaps be voted for without dissent. It is obvious that the earth is not without air. I speak not only of the air by which it holds itself together and joins the parts of itself, which exists also in rocks and dead bodies, but I also speak of that air which is vital and active, nourishing all things."

Quotation 14: Book 6. Sect. 17., 2 - Sect. 27., 2

"17. It follows, therefore, that air exercises its unique nature; whatever wants always to be in motion will at times put other things in motion. When does this happen? Whenever its path is forbidden to it. For, whenever air is not impeded it flows along calmly. When it is opposed and held back it rages and tears apart it barriers, like the River

Araxes raging at its bridge[78].

As long as a river has a smooth and open channel it unfolds it waters in steady succession. When, by man or chance, rocks are brought in to block its flow, then it seeks force from the obstruction and it finds more strength where more obstacles are opposed to it. For, when all the water that comes up from behind accumulates upon itself, and is not able to sustain its own weight, it acquires its force by destruction and escapes in a forward rush with those very obstacles which lay in its way. The same thing happens in the case of air: the stronger and more mobile it is the more rapidly it is swept away and the more violently it scatters every barrier. From this an earthquake[79] occurs, obviously on the part of the earth under which the struggle was going on.

What is said is also proved to be true by this: often when an earthquake[80] occurs, if only some part of the earth is broken open a wind blows from there for several days, as happened--according to reports--in the earthquake[81] which Chalcis suffered. You will find this in a work of Asclepiodotus, the pupil of Posidonius, where he deals with this very subject of phenomena in nature. Also, you will find in other writers that the earth has gaped open in some place and from there has puffed wind for a long time. Clearly the wind had made for itself the passageway through which it moved.

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[78] Virgil Aeneid 8.728.
[79] earthquake = "motus".
[80] earthquake = "terrae motus".
[81] earthquake = "terrae motu".

18. Accordingly, the principal cause of an earthquake[82] is air, swift by nature and changing from place to place. As long as it is not shoved and lurks in a vacant space, it lies harmless and is no trouble to surrounding areas. When a cause coming from outside stirs it up and pushes it together and drives it into a narrow space it merely gives way and shifts about if it is still permitted to do so. When the chance of getting away is cut off and it is beset on all sides then

> With a mighty rumbling of the mountain
> Around the barriers[83]

it rages, and after beating against these barriers a long time the air pulls them apart and hurls them aside, becoming more violent the stronger the obstacles with which it has struggled. Then when it has wandered around all that restrains it and is still unable to get out it rebounds from where it received the greatest impact and is either dissipated through hidden openings made here and there by the consequent movement itself of the earth or erupts through a new wound. Thus the great force of air cannot be checked, nor does any compact structure hold this wind. For it loosens any bond and carries every weight away with it and makes a space for itself, pouring through the smallest fissures. By the indomitable force of its nature air frees itself.

But moving air is an unconquerable thing; nothing will exist which

> Represses by authority
> Or restrains be chains and prison
> The winds when they struggle
> And the storms when they roar[84].

Undoubtedly the poets wanted this place where the winds lie shut in under the ground to be considered a prison. But they did not understand that what is shut in is no longer wind and that which is wind cannot be shut in. For whatever is in an enclosure is at rest and is stationary atmosphere; all wind is in flight.

And now to these arguments is added an analogy which makes it obvious that an earthquake[85] is brought about by moving air: our bodies also do not tremble except when some cause disturbs the air inside, when it is contracted by fear, grows weak in old age, becomes feeble with sluggish veins, is paralyzed by cold, or is thrown from its normal course under an attack of disease. For, as long as the air flows without damage and proceeds in its usual way, there is no tremor in the body; when something happens which inhibits its function, then it no longer is strong enough to support what it had maintained in its vigor. As it fails it causes to collapse whatever it had sustained when it was intact.

19. Let us listen, because we must, to Metrodorus of Chios stating what he prefers in giving his view. I do not permit myself to pass over even those opinions of which I disapprove, since it is better that there be an abundance of all views and to condemn the ones we disapprove of rather than omit them.

Well, what does he say? When someone sings into a large jar his voice vibrates and runs through the whole jar and resonates with a kind of quavering. Even though the voice is

[82] earthquake = "terra movetur".
[83] Virgil Aeneid 1.55-56.
[84] Virgil Aeneid 1.53-54.
[85] earthquake = "motum".

projected only slightly it none the less travels around impinging[86] on and causing a disturbance in the surrounding jar. In the same way the vast caves hanging down under the earth have air of their own, which other air, as soon as it falls from above, strikes and agitates, the way those empty spaces I just mentioned vibrate when a shout is sent into them.

20. Now we come to those writers who have stated as a cause of earthquakes[87] either all the elements I mentioned or several of them. Democritus thinks several. For he says that an earthquake[88] is produced sometimes by moving air, sometimes by water, sometimes by both. He follows through on his theory in this way: some parts of the earth are hollow. A large quantity of water flows into them. Some of this water is thin and accordingly more fluid than the rest. When it is driven back by the heavy mass coming upon it, it strikes against the earth and causes it to move, for water cannot fluctuate without causing what it shoves against to move.

And now we must speak about water also in the same way as we spoke about air. When it is accumulated in one place and ceases to restrain itself it inclines in one direction and opens a path, at first by its weight, then by its impetus. Having been enclosed for a long time, it cannot go out except down a slope, and is not able to fall straight down moderately or without a concussion of the things through which or into which it falls. But when it has already begun to be swept along, if it is halted at some place and the force of its current is rolled back upon itself, it is driven back against the earth containing it and attacks any part of the earth that is especially unstable. In addition, at times the earth becomes so saturated with moisture collected deep within it that it settles lower and its very foundations are weakened; then the earth is overwhelmed at the point against which the weight of converging waters leans most heavily.

In fact, air sometimes drives water and if it pushes strongly it obviously moves that part of the earth against which it carries the collected water. Sometimes the air is massed into subterranean passageways and in seeking an exit moves everything. Moreover, the earth is infiltrated by winds, and moving air is too subtle to be excluded, too violent to be resisted when it is aroused and swift-moving.

Epicurus says that all these things[89] can be causes and he tries several other causes. Also, he criticizes those who insist that some single one of them is the cause, since it is difficult to promise anything certain about theories which are based on conjecture[90]. Therefore, as he says, water can cause an earthquake[91] if it washes away and erodes some

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[86] The manuscripts read “tactu” meaning ‘contact with’ which is the sense and reading I have used here. Corcoran renders the phrase as ‘ travels around and causes a jolting and disturbance in the surrounding jar’. This reading is based on “tactu” being an error for “iactu”, but he says that the manuscript reading may well be right. The point is important because, as I have rendered it, Metrodorus is saying explicitly that sound incident on a solid object transfers vibration to that object. This is a first step in understanding that solid objects can transmit vibratory motion, the basis of modern seismology. Seneca is not too impressed by theory.

[87] earthquake = [no explicit Latin phrase].

[88] earthquake = “motum”.

[89] i.e., air, water and/or wind.

[90] This seems to imply that Epicurus made a distinction between ‘conjectural theories’ and some other kind of theory, probably a ‘theory based on observation’.

[91] earthquake = “terrarum movere”.

parts of the earth. When these parts are weakened they cease to be able to sustain what they supported when they were intact. The pressure of moving air can cause earthquakes[92]; for perhaps the air inside the earth is agitated by other air entering, perhaps the earth receives a shock when some part of it suddenly falls and from this the earth takes on movement. Perhaps some part of the earth is sustained by a sort of column, and by a kind of piling, and when they receive flaws or give way the weight imposed on them trembles. Perhaps a warm quantity of moving air is changed to fire and like lightning is carried along with great destruction to things that stand in its way. Perhaps some blast pushes the swampy and stagnant waters and consequently either the blow shakes the earth or the agitation of the air increases by its very motion and, stirring itself up, travels all the way from the depths to the surface of the earth. At any rate, Epicurus is satisfied that air is the main cause of earthquakes[93].

21. We also are satisfied that it is this moving air which can accomplish such things. Nothing in nature is more powerful than air, nothing more energetic. Without air not even the strongest elements have power. Air arouses fire. Waters are inert if you take away the wind; they acquire movement only when a blast of air drives them. Also, air is able to scatter vast expanses of the earth and to lift new mountains up from beneath and to place in the middle of the sea new islands never seen before. Does anyone doubt that air brought Thera and Therasia into the light of day, as well as that island which in our own time was born before our very eyes in the Agean Sea?

There are two ways in which the earth is moved, according to Posidonius. Each way has its distinctive term. One is a 'jolt underneath', when the earth is shaken by a jolt and moves up and down. The other is a 'tilt', when the earth leans to one side or the other like a ship. I am of the opinion that there is also a third way, which is designated in our vocabulary. Our elders for good reason spoke about the earth's 'tremor', which is unlike the other two, for at such a time things are neither jolted not tilted but vibrated. In an event of this sort the result is minimal damage. In the same way, a tilt s far more destructive than a jolt, for unless a movement which restores the tilt rushes in quickly from the other side a collapse necessarily follows.

22. Since these movements are dissimilar among themselves their causes are also different. First, therefore, let us talk about a jolting movement. If at any time heavy loads are drawn be a series of several vehicles, and their wheels, because of the greater strain, slip into ruts in the road, you will feel the ground quake.

Asclepiodotus reports: when rocks were torn from the side of a mountain and fell the buildings in the vicinity collapsed because of the resulting shock. The same thing can happen under the earth with the result that from overhanging cliffs something may be loosened and fall with a great crash and noise into the cavern lying below. The greater the weight or the height the more violently it comes down. And thus the whole roof of the underground valley is moved.

It is credible that rocks are not only split off by their own weight but also when liquid travels over them the continuous moisture weakens the joints in the stone and day by day carries away something of the mass to which the stone is attached and abrades the skin,

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[92] earthquakes = "motum".

[93] earthquake = "motus".

so to speak, by which the stone is held in place. Finally, the prolonged attrition through the ages weakens those parts which it wears into day by day to the extent that they cease to function in supporting a burden. Then rocks of vast weight fall down; then the crag falling headlong will not permit any movable object it strikes to continue at rest.

> It comes with a roar
> And everything is seen
> To collapse suddenly,[94]

as our Virgil says.

23. This must be the cause of the motion that makes the ground quake from beneath. Now I pass on to the second type[95]. The earth is naturally porous and has many voids. Air passes through these openings. When air in large quantities flows in and is not emitted it causes the earth to tilt.

This theory is accepted by others, as I mentioned a little above--if a crowd of authorities will impress you--but is also approved by Callisthenes, and he is a man not to be looked down upon. For he had outstanding intelligence and did not submit to the rage of his king. [...][96]

This Callisthenes, in books in which he describes how Helice and Buris were inundated--what disaster sent the cities into the sea or the sea into the cities--says what I said in an earlier section. Air enters the earth through hidden openings as it does everywhere and so also under the sea. Then, when the path through which it had descended is obstructed and the waters standing at the rear have cut off its return it is carried here and there and running into itself causes the earth to totter. So, the regions close by the sea are the most frequently harassed. Accordingly, this power the sea has for moving the earth is assigned to Neptune[97]. Anyone who has learned elementary literature knows that in Homer he is called the 'Earthshaker'.

24. And I myself agree that the cause of this disaster is air. But I will argue about how this air enters the earth, whether through thin openings undetectable to the eyes or through larger and more extended openings, and whether it comes only from the depths or also through the surface of the earth.

This last is unbelievable. For even in our bodies the skin keeps out the air, and air has no way in except by way of the parts through which it is breathed in, and even when it has been inhaled by us it cannot settle except in the relatively open part of the body. For it does not remain within the sinews or flesh but in the viscera and the wide cavity of the interior region. The same may be supposed about the earth from the fact also that an earthquake[98] is not in the earth's surface or around the surface but underneath, from the depths. An indication of this is that seas of great depth are tossed about obviously from the motion of the ground over which the seas spread. Accordingly, it is probable that the earth is moved from far below and that air is formed there in huge caverns.

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[94] Virgil Aeneid 8.525.
[95] Seneca never gets around to the third type, the tremor (Corcoran's note).
[96] A few lines are omitted which detail Seneca's disgust with Alexander the Great for having the philosopher Callisthenes imprisoned until his death for refusing to pay homage. This all occurred three hundred and fifty years earlier.
[97] Roman equivalent to the earlier Greek god Poseidon.
[98] earthquake = "motus".

'But no!' he says. 'When we shiver with cold, a trembling is the result. So also air coming from outside causes the earth to shake." This cannot happen to the earth at all. For the earth ought to feel cold so that the same thing happens to it as happens to us when an external cause produces a shuddering. I would agree that something similar to our condition occurs to the earth, but from a different cause. An interior injury has to afflict the earth deep inside. The greatest proof of my argument can be this: when the ground is opened by the enormous destruction of an earthquake[99], that gaping hole sometimes takes in and buries entire cities.

Thucydides says that around the time of the Peloponnesian War the island of Atalanta was either entirely submerged, or certainly most of it[100]. Believe Posidonius that the same thing happened at Sidon. Yet there is no need of authorities in regard to this, for within our own memory lands have been torn apart by internal movement and regions have been separated and plains have disappeared.

Now I will explain how I believe that this happens.

25. When moving air with great force completely fills an empty space under the earth and proceeds to struggle and think about a way out it repeatedly strikes the side-walls within which it lurks, over which cities are sometimes situated[101]. These 'walls' are sometimes so shaken that buildings placed above them fall down, sometimes to such an extent that the walls which support the whole covering of the cave fall into the immense depths.

If you are willing to believe it, they say that at one time Ossa was joined to Olympus; later they were separated by an earthquake[102] and the whole of a single large mountain was split into two parts. Then the Peneus River flowed away and dried up the swamps (from which Thessaly used to suffer) by carrying off in itself the waters that had once formed stagnant pools, since they had no way out. An earthquake[103] poured forth the Ladon River, which is midway between Elis and Megalopolis.

What do I prove by these things? That air accumulates under the earth in vast caverns (for what else should I call empty places?). Unless this were so, great expanses of the earth would by shaken and many regions would be disturbed at the same time. As it is now, only small areas suffer and an earthquake[104] does not extend two hundred miles. That recent earthquake[105], which has filled the world with stories, did not travel beyond Campania. How should I explain that when Chalcis trembled, Thebes stood firm; when Aegium suffered, Patrae, so near it, only heard about the earthquake[106]? The vast shock which smashed two cities, Helice and Buris, stopped around Aegium. Therefore, it appears

[99] earthquake = "motu".
[100] Thucydides (3.89.3) refers to a tidal wave but says that earthquakes are the causes of tidal waves.
[101] Lucan (3.459-461) describes the wind, seeking to break out, shaking the hollow caverns of the earth (Corcoran's note).
[102] earthquake = "terrarum motu".
[103] earthquake = "terrarum motus".
[104] earthquake = "motus".
[105] earthquake = [no explicit Latin phrase].
[106] earthquake = "motu".

that an earthquake[107] spreads over only as much area as the cavity of empty space extends under the earth.

26. In order to prove this I could have used, or misused, the authority of great men who report that Egypt has never had an earthquake. They give the following explanation of this phenomenon: the fact that Egypt has grown entirely from mud. For, if there is any reliability in Homer, Pharos was as far away from the continent as a ship travelling with full sails could measure in one day's journey[108]. But Pharos has been moved up to the continent[109]. The swollen Nile as it flows down carries with it a great quantity of mud and adds it from time to time to the existing land and by annual increment always carries Egypt farther out. Hence the land is a rich, muddy soil and does not have within itself any openings but grows into a solid as the mud dries. Its structure was compressed sediment when the parts were glued together; nor can any empty space intervene since liquid and soft substance is always added to the solid material.

But Egypt does have earthquakes[110], and so does Delos, which Virgil ordered to stand still:

> He arranged that it be tilled,
> A land without earthquake
> And scorning the winds.[111]

Philosophers, a credulous race, have also said, on Pindar's authority, that Delos did not have earthquakes[112]. Thucydides says that Delos was previously indeed stable but had an earthquake[113] around the time of the Peloponnesian War. Callisthenes says that this happened at another time, too. 'Among the many prodigies,' he says, 'by which the destruction of the two cities, Helice and Buris, was foretold, especially notable were both the immense columns of fire and the Delos earthquake[114].' He wishes Delos to be understood as stable because it is placed upon the sea and has hollow cliffs and porous rocks to give a way back for the air caught in them. And for this reason islands have firm ground and the closer cities come to the sea the safer they are.

Pompeii and Herculaneum know that this is not true. Now add that every seashore is subject to earthquakes[115]. For example, Paphos has collapsed more than once. The famous Nicopolis has already become familiar with this catastrophe also. Deep sea surrounds Cyprus, and Cyprus has earthquakes[116]. Tyre, too, is as much shaken by earthquakes[117] as it is washed away by the sea.

Such are the reasons generally given for why the earth trembles.

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[107] earthquake = "motum".
[108] Odyssey 4.354.
[109] In Caesar's time (first century BC) Pharos was connected with Alexandria by a narrow roadway like a bridge (Corcoran's note).
[110] earthquake = "movetur".
[111] Virgil Aeneid 3.77.
[112] earthquakes = "moveri".
[113] earthquake = "tremiusse".
[114] earthquake = "agitata".
[115] earthquakes = "motibus".
[116] earthquake = "agitatur".
[117] earthquake = "movetur".

27. Yet certain things are said to have happened peculiar to this Campanian earthquake[118], and they need to be explained. I have said that a flock of hundreds of sheep was killed in the Pompeian district. There is no reason you should think this happened to those sheep because of fear. For they say that a plague usually occurs after a great earthquake[119], and this is not surprising. For many death-carrying elements lie hidden in the depths. The very atmosphere there, which is stagnant either from some flaw in the earth or from inactivity and the eternal darkness, is harmful to those breathing it."

Quotation 15: Book 6. Sect. 30., 1

"30. I am not surprised that a statue was split apart in an earthquake[120] since I have described how mountains were separated from mountains and the ground itself was disrupted all the way from its depths."

Quotation 16: Book 6. Sect. 30., 4

"Enough has been said about what marvels these tremors of the earth do and how they produce amazing sights."

Quotation 17: Book 6. Sect. 30., 5 - Sect.31., 3

"But if an earthquake[121] cracks whole walls and entire homes and splits the sides of great towers, however solid they might be, and scatters pilings that support great structures, what reason is there that anyone should think it worth noting that a statue has been cut equally in two from top to bottom?"

31. Yet why has an earthquake[122] lasted for several days? For Campania did not cease its continuous trembling; the earthquake[123] became milder but still caused great damage because it shook things already shaken, and since they were scarcely standing, and were ready to fall, they did not need to be pushed but only to be shaken. Obviously all the air had not yet left but was still wandering around, even though the greater part of it had been emitted. Among the arguments that prove earthquakes[124] happen because of moving air this one you should not hesitate to propose also: when the greatest tremor to spend its rage against cities and countries has been produced, another equal to it cannot follow. After the largest shock there are only gentle quakes because the first tremor, acting with greater vehemence, has created an exit for the struggling air. The remains of the air that is left do not have the same force, nor do they have any need to struggle, since already they have found a path and follow the route by which the first and largest force of air escaped.

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[118] earthquake = “motu”.
[119] earthquake = “terrarum motus”.
[120] earthquake = [no explicit Latin phrase].
[121] earthquake = [no explicit Latin phrase].
[122] earthquake = “motus”.
[123] earthquake = “tremere”.
[124] earthquake = [no explicit Latin phrase].

I consider this also worth recording, since it was observed by a very wise and respected man. He happened to be taking a bath when this earthquake[125] occurred. He affirms that while in the bath he saw the tiles with which the floor was paved separate one from the other and come back together again, and that when the floor opened up water was taken into the joints and when it closed back together the water bubbled and was forced out. I have heard the same person telling that he saw earthen walls vibrating more gently and rhythmically than the nature of a hard substance permits[126]."

Quotation 18: Book 7. Sect. 28., 3

"The comet which appeared in the consulship of Paterculus and Vopiscus[127] did what was predicted by Aristotle and Theophrastus: for there were very violent and continuous storms everywhere, and in Achaea and Macedonia cities were destroyed by earthquake[128]".

[125] earthquake = [no explicit Latin phrase].
[126] An interesting empirical description of 'elastic' behavior; a concept not understood until modern times.
[127] 60 AD.
[128] earthquake = "terrarum motibus".

Pliny *Natural History*

Life[129]. Gaius Plinius Secundus, commonly called Pliny the Elder, was a Roman citizen born in northern Italy in 23 AD. At the age of twenty three he began a military career with the Roman Legions serving in Germany. Later in life he studied law, served as Procurator of Spain, and finally returned to Rome as an intimate advisor to the Emperor Vespasian. His public life is well documented.

Throughout this busy career he was constantly engaged in study. Ultimately, his scientific curiosity proved fatal as he was killed by poisonous gasses while investigating the famous eruption of Vesuvius in August of 79 AD which buried Herculaneum and Pompeii. His nephew, Pliny the Younger[130], gives us a first-hand account of the elder Pliny's devotion to study[131], as well as the circumstances surrounding his death[132].

Works. Pliny wrote several books which are lost. These include *Use of the Javelin*[133], *History of the German Wars*[5] , *Training of the Orator*[5] , *Dubious Sermo*[134] and *History of Rome*[5,135].

His surviving work is the massive *Natural History* composed in Latin in thirty-one books. In the preface of the work, Pliny dedicates it to Vespasian "six times counsel" --dating the completion of the work to 77 AD.

Pliny states[136] that "...by perusing about 2000 volumes, very few of which, owing to the obstruseness of their contents, are ever handled by students, we have collected in 36 volumes 20,000 noteworthy facts obtained from 100 authors that we have explored, with a great number of other facts in addition that were either ignored by our predecessors or have been discovered by subsequent experience." He is one of the few ancient writers to affix a table of contents to his work; it comprises all of book one. Also, rather than clutter up the

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129 Introductory information gathered from Rackam (pp. vii-xiii).
130 Gaius Plinius Caecilius Secundus.
131 Epist. 3.5.
132 Epist. 6.16.
133 Exact title unknown.
134 A treatise on grammar.
135 A continuation of the history of Aufidius Bassus.

body of the work with endless references, he lists the authorities used in each chapter along with its contents. This obviously leads to some confusion as to which information came from, or represents the opinion of, which authority. But it was his intent to give credit where due and "...not to do as most of the authors to whom I have referred did[137]". The work contains hoards of information that can found nowhere else, and therefore is of great importance. In its overall scope and character, it is something akin to a gigantic almanac.

Manuscripts. The earliest surviving copies of the Natural History date from the ninth, or possibly the eighth, century AD. There are a large number of later manuscripts.

Earthquake References. Pliny deals with earthquakes at length in book two, sections 81-97. He mentions only two men by name, and these[138] as having predicted earthquakes not formulated theories. He does not give a theory of his own[139]. In fact, he gives only a single earthquake theory[140], saying that "...their cause is to be attributed to the winds[141]". He does not name the author of this theory but it clearly is that of Aristotle, apparently stripped of the more elaborate 'exhalation concept'. Consistent with that, we find the authorities for book two, listed in his preface, include Aristotle.

Quotations. The following quotations are taken from the *Loeb Edition* of Rackam.

QUOTATION 1: BOOK 2.81.191 - 87.201

"81. The theory of the Babylonians deems that even earthquakes[142] and fissures in the ground are caused by the force of the stars that is the cause of all other phenomena, but only by that of those three stars[143] to which they assign thunderbolts; and that they occur when these are travelling with the sun or are in agreement with him, and particularly about the quadratures of the world. On this subject a remarkable and immortal inspiration is attributed (if we can believe it) to the natural philosopher Anaximander of Miletus, who is said to have warned the Spartans to be careful of their city and buildings, because an

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[136] Nat. Hist. pref.17
[137] pref.21-22.
[138] Anaximander (2.81.191) and Pherecydes (2.81.192).
[139] Accordingly he will not appear in Part II of the present work.
[140] Aside from the 'Babylonian Theory' (2.81.191).
[141] 2.81.192.
[142] earthquakes = "motus terrae".
[143] Saturn, Jupiter and Mars (Rackam's note).

earthquake[144] was impending; and subsequently the whole of their city collapsed, and also a large part of Mount Taygetus projecting in the shape of a ship's stern broke off and crashing down on it added to the catastrophe. Also another conjecture is attributed to Pherecydes the teacher of Pythagoras, this also inspired: he is said to have foretold to his fellow-citizens an earthquake[145], of which he had obtained a premonition in drawing water from a well. Assuming the truth of these stories, how far pray can such men even in their lifetime be thought to differ from a god? And though these matters may be left to the estimation of individual judgment; I think it indubitable that their cause is to be attributed to the winds. For tremors of the earth never occur except when the sea is calm and the sky so still that birds are unable to soar because all the breath that carries them has been withdrawn; and never except after wind, doubtless because then the blast has been shut up in the veins and hidden hollows of the sky. And a trembling in the earth is not different from a thunderclap in a cloud, and a fissure is no different from when an imprisoned current of air by struggling and striving to go forth to freedom causes a flash of lightning to burst out.

82. Consequently earthquakes[146] occur in a variety of ways, and cause remarkable consequences, in some places overthrowing walls, in others drawing them down into a gaping cleft, in others thrusting up masses of rock, in others sending out rivers and sometimes even fires or hot springs, in others diverting the course of rivers. They are however preceded or accompanied by a terrible sound, that sometimes resembles a rumble, sometimes the lowing of cattle or the shouts of human beings or the clash of weapons struck together, according to the nature of the material that receives the shock and the shape of the caverns or burrows through which it passes, proceeding with smaller volume in a narrow channel but with a harsh noise in channels that bend, echoing in hard channels, bubbling in damp ones, forming waves in stagnant ones, raging against solid ones. Accordingly even without any movement occurring a sound is sometimes emitted. And sometimes the earth is not shaken in a simple manner but trembles and vibrates. Also the gap sometimes remains open, showing the objects that it has sucked in, while sometimes it hides them by closing its mouth and drawing soil over it again in such a way as to leave no traces; it being usually cities that are engulfed, and a tract of farmland swallowed, although seaboard districts are most subject to earthquakes[147], and also mountainous regions are not free from disaster of the kind: I have ascertained that tremors have somewhat frequently occurred in the Alps and Appennines.

Earthquakes[148] are more frequent in autumn and spring, as is lightning. Consequently the Gallic provinces and Egypt suffer very little from them, as in the latter the summer is the cause that prevents them and in the former the winter. Similarly they are more frequent by night than in the daytime. The severest earthquakes[149] occur in the morning and the evening, but they are frequent near dawn and in the daytime about noon.

[144] earthquake = "motum terrae".
[145] earthquake = "terrae motum".
[146] earthquakes = [no explicit Latin phrase].
[147] earthquake = [no explicit Latin phrase].
[148] earthquakes = "terrae moventur".
[149] earthquakes = "motus".

They also occur at an eclipse of the sun or moon, since then storms are lulled, but particularly when heat follows rain or rain heat.

83. Sailors at sea can also anticipate an earthquake[150] and forecast it with certainty when a sudden wave swells up without there being a wind, or a shock shakes the vessel. Even in ships posts begin to tremble just as they do in buildings, and foretell an earthquake[151] by rattling; nay more, birds of timid kinds perch on the rigging. There is also a sign in the sky: when a earthquake[152] is impending, either in the daytime or a little after sunset, in fine weather, it is preceded by a thin streak of cloud stretching over a wide space.

84. Another sign is when the water in wells is muddier and has a somewhat foul smell, just as in wells there is also a remedy for earthquake[153] such as frequently caves too afford, as they supply an outlet for the confined breath. This is noticed in whole towns: buildings pierced by frequent conduits for drainage are less shaken, and also among these the ones erected over vaults are much safer--as is noticed in Italy at Naples, the solidly built portion of the city being specially liable to collapses of this nature. The safest parts of buildings are arches, also angles of walls, and posts, which swing back into position with each alternate thrust; and walls built of clay bricks suffer less damage from being shaken. There is also a great difference in the actual kind of movement, as the earth shakes in several ways; there is least danger when it quivers with a trembling rattle of the buildings, and when it rises in a swell and settles back again, with an alternating motion; also no harm is done when buildings collide and ram against each other, as the one motion counteracts the other. A waving bend and a sort of billowy fluctuation is dangerous, or when the whole movement drives in one direction. Earthquakes[154] stop when the wind has found an outlet, or else, if they go on, they do not stop before forty days, and usually even longer, some in fact having gone on for one or two years' time.

85. I find in the books of the lore of Tuscany that once a vast and portentous earthquake[155] occurred in the district of Modena; this was during the consulship[156] of Lucius Marcius and Sextus Julius. Two mountains ran together with a mighty crash, leaping forward and then retiring with flames and smoke rising between them to the sky; this took place in the daytime, and was watched from the Aemilian road by a large crowd of Knights of Rome with their retinues and passers by. The shock brought down all the country houses, and a great many animals in the buildings were killed. It was in the year before the Allies' War, which was perhaps more disastrous to the land of Italy than the civil wars. Our generation also experienced a not less marvellous manifestation in the last year[157] of the Emperor Nero, as we have set forth in our history[158] of his principate: meadows and olive trees with a public road running between them got over to the opposite

[150] earthquake = [no explicit Latin phrase].
[151] earthquake = [no explicit Latin phrase].
[152] earthquake = "motu".
[153] earthquake = [no explicit Latin phrase].
[154] earthquakes = "tremores".
[155] earthquake = [no explicit Latin phrase].
[156] 91 BC.
[157] 68 AD.
[158] A lost work by Seneca.

sides of the road; this took place in the Marrucinian territory, on the lands of Vettius Marcellus, Knight of Rome, Nero's estate-manager.

86. Earthquakes[159] are accompanied by inundations of the sea, which is presumably caused to flood the land by the same current of air, or drawn into the bosom of the earth as it subsides. The greatest earthquake[160] in human memory occurred when Tiberius Ceasar was emperor, twelve Asiatic cities being overthrown in one night; the most numerous series of shocks was during the Punic War, when reports reached Rome of fifty-seven in a single year; it was the year[161] when a violent earthquake[162] occurring during an action between the Carthaginian and Roman armies at Lake Trasimene was not noticed by the combatants on either side. Nor yet is the disaster a simple one, nor does the danger consist only in the earthquake[163] itself, but equally or more in the fact that it is a portent; the city of Rome was never shaken without this being a premonition of something about to happen.

87. The cause of the birth of new lands is the same, when the same breath although powerful enough to cause an upheaval of the soil has not been able to force an exit."

QUOTATION 2: BOOK 2.88.202 - 89.203

"88. New lands are also formed in another way, and suddenly emerge in a different sea, nature as it were balancing accounts with herself and restoring in another place what an earthquake[164] has engulfed.

89. The famous islands of Delos and Rhodes are recorded in history as having been born from the sea long ago, and subsequently small ones, Anaphe beyond Melos, Neae between Lemnos and the Dardanelles, Halone between Lebedos and Teos, Thera and Therasia among the Cyclades in the 4th year[165] of the 145th Olympiad; also in the same group Hiera, which is the same as Automate, 130 years later; and 2 stades from Hiera, Thia 110 years later, in our age, on July 8 in the year[166] of the consulship of Marcus Junius Silanus and Lucius Balbus.

Before our time also among the Aeolian Islands near Italy, as well as near Crete, there emerged from the sea one island 2500 paces long, with hot springs, and another in the 3rd year[167] of Olympiad 163 in the bay of Tuscany, this one burning with a violent blast of air; and it is recorded that a great quantity of fish were floating round it, and that people who ate of them immediately expired. So also the Monkey Islands are said to have risen in the bay of Campania, and later one among them, Mount Epopos, is said to have suddenly shot up a great flame and then to have been leveled with the surface of the plain. In the

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[159] earthquakes = "terrae motu".
[160] earthquake = "terrae....motus".
[161] 217 BC.
[162] earthquake = "motum".
[163] earthquake = "motu".
[164] earthquake = [no explicit Latin phrase].
[165] 197 BC.
[166] 19 AD.
[167] 126 BC.

same plain also a town was sucked down into the depths, and another earthquake[168] caused a swamp to emerge, and another overturned mountains and threw up the island of Procida."

QUOTATION 3: BOOK 2.96.209

"In some places, the earth trembles when trodden on--for instance in the Gabii district not far from the city of Rome about 200 acres shake when horsemen gallop over them, and similarly in the Reate district."

QUOTATION 4: BOOK 2.97.211

"It is recorded that at Locri and Croton there has never been a plague or earthquake[169], and that in Lycia an earthquake is always followed by forty days' fine weather."

Listing of precursors, etc. With so much earthquake information in these quotations, the following concise lists may be useful.

Precursors[170].

Earthquakes...

1. "...never occur except when the sea is calm and the sky still..."
2. "...never [occur] except after wind..."
3. "...are...preceded...by a terrible sound..."
4. "...also occur at an eclipse of the sun or the moon."
5. will occur when "...a sudden wave swells up without there being a wind..."
6. will occur when "...a shock shakes the vessel [sailing ship]."
7. will occur when "...birds of timid kinds perch on the rigging."
8. are "...preceded [in fine weather] by a thin streak of cloud stretching over a wide space."
9. are pending when "...water in wells is muddier and has a somewhat foul smell..."

Observations and Associations[171].

1. walls are drawn "...down into a gaping cleft..."
2. "...thrusting up masses of rock..."
3. "...sending out rivers and even fires or hot springs..."
4. "...accompanied by a terrible sound..."

[168] earthquake = "motu terrae".
[169] earthquake = "terrae motu".
[170] Precursor quote refs: 1&2 = 2.81.192; 3 = 2.82.193; 4 = 2.82.195; 5-9 = 2.83.196.
[171] Observ. and Assoc. quote references: 1-4 = 2.82.193; 5-8 = 2.82.194; 9-10 = 2.82.195.

5. "...the gap [in the earth] sometimes remains open..."
6. "...sometimes [the gap in the earth] hides...by closing its mouth and drawing soil over it again...[leaving] no traces..."
7. "...seaboard districts are most subject to earthquakes..."
8. "...mountainous regions are not free from [earthquakes]..."
9. "...more frequent in autumn and spring..."
10[172]. "...more frequent by night than in the day time."
11. "...frequent near dawn and in the daytime about noon."
12. "They also occur at an eclipse of the sun or the moon."
13. "...buildings pierced by frequent conduits for drainage are less shaken..."
14. Kinds of movement:
    a. the earth "...quivers with a trembling rattle of the buildings..."
    b. the earth "...rises in a swell and settles back again, with an alternating motion..."
    c. "a waving bend and a sort of billowy fluctuation..."
    d. "...the whole movement drives in one direction."
    e. "...sometimes the earth is not shaken in a simple manner but trembles and vibrates."
15. "...if they go on, they do not stop before forty days, and usually...longer, some...having gone on for one or two years time."
16. Two mountains ran together them separated "...with flames and smoke rising between them to the sky..."
17. "...meadows and olive trees with a public road running between them got over to the opposite sides of the road..."
18. "Earthquakes are accompanied by innundations of the sea."
19. Earthquakes are "The cause of the birth of lands..."
20. "Mount Epopos, is said to have suddenly shot up a great flame and then to have been leveled with the surface of the plain."
21. "...a town was sucked down into the depths..."
22. "...another earthquake caused a swamp to emerge..."
23. "...in Lycia an earthquake is always followed by forty days' fine weather."

Supernatural Influences. Only once does Pliny hint that earthquakes have a supernatural aspect. The quotation is:

"...nor does the danger consist only in the earthquake itself, but equally or more in the fact that it is a portent; the city of Rome was never shaken without this being a premonition of something about to happen[173]".

[172] Observ. and Assoc. quote references cont.: 10-12 = 2.82.195 ; 13 = 2.84.197; 14a-d = 2.84.198; 14e = 2.82.194; 15 = 2.84.198; 16-17 = 2.85.199; 18 = 2.86.200; 19 = 2.87.201; 20-22 = 2.89.203; 23 = 2.107.211.

[173] 2.86.200.

Pseudo-Plutarch *Placita Philosophorum*

Life and work[174]. The *Placita Philosophorum[175]* is our most obscure source for earthquake theories. It is a fascinating collection of brief philosophical opinions on subjects ranging from the nature of the universe and man's soul, to the gestation period of different creatures and whether or not plants are alive in the same sense that animals are.

The author is unknown, but at an early date it became associated with and included in the *Moral Essays* collection by Plutarch[176], hence the work is attributed to 'Pseudo-Plutarch'. Heath attributes the Placita to "...an insignificant writer of about the middle of the second century AD, who palmed them off as Plutarch".[177]

Earthquake references. Earthquake theories in the Placita are contained in Book 3 Chapter 15[178]. This information is thought to be ultimately based on the lost *Physical Opinions* by Theophrastus. The quality of the information in the *Placita* is often unreliable because of its reliance on intermediate sources and its apparently uncritical compiler.

Quotations. The Greek text of the *Placita* can be found in scholarly works on the history of Greek natural philosophy such as Diels[179]. However, a modern English translation does not exist[180].

The quotations given here are from the first English edition of Plutarch's *Moralia[181]*. Some of the seventeenth century idioms and sentence constructions have been modernized, otherwise the translation is as given by Holland.

Quotation 1: Book 3, Chap.15

"CHAPTER 15

Of Earthquakes

Thales and Democritus believe that water is the cause of earthquakes.

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174 From Heath Aristarchus, pp.3-4.
175 Literally, "Opinions of the Philosophers".
176 Greek historian and biographer (46?-120? AD).
177 Aristarchus ,p.3.
178 Erroneously given as Chapter 16 in Holland's (1603) index to the Placita (p.803), but correctly given as Chapter 15 in the body of the translation (p.831 [misprinted as p.825]).
179 Doxographi Greaci , ed. H. Diels. (G. Reimer).Berlin, 1879 (Heath Aristarchus , p.4).
180 Personal communication Prof. David Furley, Classics Dept., Princeton Univ.

The Stoics say that moisture in the earth is rarefied and transformed into air, which forcibly escapes causing an earthquake.

Anaximenes says that earthquakes are caused by gluts of rain falling in regions where the earth is exceedingly dry, and non-dense, due to excessive drought.

Anaxagoras holds that when air is trapped in the earth and, moving up, reaches near to the surface, which it finds impenetrable, it shakes the surface of the earth with a sort of trembling.

Aristotle alleges that there exists an all-encompassing cold around the earth, both above and below; for heat attempts to move upward, being light by nature. Therefore a dry exhalation which finds itself trapped in the earth tries to break out through the body of the earth. In so doing, it moves about shaking the earth.

Metrodorus believes that no body being in its own proper and natural place can stir or move, unless something actually pushes or pulls it. The earth therefore (he says) being situated in its own place, naturally does not move, but parts of the earth are capable of movements.

Parmenides and Democritus reason this way: since the earth stretches away equally in all directions all parts of the earth are counterbalanced, and there is no force or cause why some part of it should incline more to one side than another. Therefore it is possible for part of it to shake, but it cannot stir and move as a whole.

Anaximenes says that the earth is carried up and down in the air because it is broad and flat.

Others say that the earth floats on water like a wooden plank, and it is this flotation which causes earthquakes.

Plato affirms that there are six sorts of motions; up and down, right and left, forward and back. Also, that the earth cannot possibly move in any of these directions, for on every side it is the lowest of all things in the world and therefore rests unmovable, having no cause why it should incline more to one part than another. But some parts of the earth, because of their lack of density, do jog and shake.

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[181] Philemon Holland. <u>Plutarch's Moral Essays</u> . London, 1603 (my copy).

Epicurus keeps to his old tune; he says that it may be that the earth is shaken, and therefore moves and quakes, because it is rocked and beaten by the air underneath which is dense and of the nature of water. Also, it may be (he says) that, the earth being porous and hollow below, it is forced to tremble and shake by air that is trapped in these voids."

Diogenes Laertius *Lives Of Emminent Philosophers*

Life[182]. Aside from what can be inferred from his own writings, nothing is known about the life or date of Diogenes Laertius. Concerning his date, in his major work, the *Lives of Emminent Philosophers* , he refers to three philosophers of the third century AD[183], so he wrote in that century or later. Further, he wrote before 500 AD since he is quoted by Sopater[184] who was active in the fifth century AD. He is considered by modern scholars to have been active in the period c.225-250 AD.

There has historically been much confusion over the form of his name and whether it holds a clue to his birthplace. In antiquity, he was variously called Laertius Diogenes (manuscripts of his own book, Suidas[185] and Sopater), Diogenes Laertius (Stephanus of Byzantium[186]), Laertius (Eustathius[187]), simply Diogenes (Stephanus of Byzantium), and Diogenes of Laertius[188] (Stephanus of Byzantium). The modern view is that Laertius was a surname implying that he was learned.

Work. Diogenes composed his writings in Greek. Aside from *the Lives of Emminent Philosophers* we know only of a lost book of poems that he claims to have published.

The full title of his extant work, as given in the manuscripts, goes something like this: *Laertius Diogenes' Lives and Opinions of Those Who Were Distinguished in Philosophy and Succinct Collection of the Doctrines Acceptable to Each School*. In ancient time it was shortened to *Philosopher's Lives* in citations by other authors.

It is a massive, piecemeal collection in ten books concerning the lives and opinions of the Greek philosophers. The work as we have it is very nearly complete, lacking only the end of book seven.

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182 These introductory notes are largely gathered from the preface of Hicks (pp. xv-xxvi).
183 These are Theodosius the Sceptic, Sextus Empiricus and Saturnius.
184 Sopater of Apamea or Alexandria, a rhetorician and teacher.
185 A Byzantine (?) writer (fl.c.970 AD).
186 A Byzantine writer and geographer (fl.500 AD).
187 Archbishop of Thessalonica and commentator of Homer (latter half of 12th century AD).

From the point of view of modern criticism, Diogenes is a hopelessly *uncritical* compiler of sensational stories and erroneous information. His sources[189] are often second- or third-hand accounts, themselves often quite unreliable. However, buried within this heap of historically suspect material we sometimes find valuable and accurate information. As an example, and an important one, he actually quotes the earthquake theory of Epicurus. This is our best independent account of Epicurus' theory for comparison with that given by Lucretius. Diogenes should be appreciated for preserving such material, albeit infrequently, and not too harshly judged for his popular style; a style which is as enjoyable to the modern general reader as it was to his Roman audience.

Quotations. The quotations are taken from the *Loeb Edition* of Hicks. Names in parentheses in quotation headings are chapter headings in Diogenes.

Quotation 1: Book 1 (Pherecydes), Section 116

"And as he[190] was drinking water which had been drawn up from a well he predicted that on the third day there would be an earthquake; which came to pass."

Quotation 2: Book 2 (Anaxagoras), Section 9

"He [Anaxagoras] held that winds arise when the air is rarefied by the sun's heat; that thunder is clashing together of the clouds, lightning their violent friction; and earthquake a subsidence of air into the earth."

Quotation 3: Book 7 [Zeno of Cittium], Section 154

"Earthquakes, say they[191], happen when the wind finds its way into, or is imprisoned in, the hollow parts of the earth: so Posidonius in his eighth book; and some of them are tremblings, others openings of the earth, others again lateral displacements, and yet others vertical displacements."

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[188] This form implies that he is a native of a town called Laerte(s). Two obscure towns by that name are known but the connection seems unfounded. (see Hicks, p. xv).

[189] These suspect sources include Antigonus of Carystus, Antisthenes of Rhodes, Apollodorus the chronologist, Demetrius and Diocles of Magnesia, Heraclides Lembus, Hermippus, Hieronymus of Rhodes, Hippobotus, Neanthes of Cyzincus, Pamphila, and Favorinus. The work includes "...1,186 explicit references to 365 books by about 250 authors, as well as more than 350 anonymous references..." (Hicks, p. xix).

[190] i.e., Pherecydes.

[191] 'They' are the Stoics, a philosophical sect founded by Zeno of Cittium in about 310 BC. The opinions of the sect given here are almost certainly those of Zeno himself.

Quotation 4: Book 10 [Epicurus], Sections 105-106

" 'Earthquakes may be due to the imprisonment of wind underground, and to its being interspersed with small masses of earth and then set in continuous motion, thus causing the earth to tremble. And the earth either takes in this wind from without or from the falling in of foundations, when undermined, into subterranean caverns, thus raising a wind in the imprisoned air. Or they may be due to the propagation of movement arising from the fall of many foundations and to its being again checked when it encounters the more solid resistance of earth. And there are many other causes to which these oscillations of the earth may be due[192]' ".

[192] Diogenes says that this is a direct quotation from an epistle Epicurus wrote to one Pythocles concerning celestial phenomena.

Ammianus Marcellinus *The Roman History*

Life[193]. Ammianus Marcellinus was born a Roman citizen in Syrian Antioch in about the year 330 AD. Virtually nothing is known of his family or education. At an early age he joined the Roman military service where he fought in the Eastern Empire against the Alemanni and Persians. He was active during the reigns of Constantius II, Julian, Jovian, Valentinian and Valens. He was in the military from c.350 to at least 378 and perhaps later. This experience shows up as eyewitness testimony throughout his written work. He was still living in 391, and probably in 393, but how much longer he lived is not known.

Work. At the end of his military career he retired to Rome and wrote his only extant work The *Roman History*. He is not known to have produced any other literary works.

The Roman History chronicles Roman affairs over a period of nearly 300 years. It began with the ascension of Nerva to emperor in 96 AD, thus forming a continuation of the *Annals* of Tacitus. This was a very deliberate starting point, Tacitus being Ammianus' model as a historian. The *History* ends with the death and crushing defeat of the emperor Valens by the Goths at Adrianople in 378. The period 353-378 is in large part a valuable eye-witness account by Ammianus.

The *History* was composed, probably in Rome, between c.378 and Ammianus' death in 391 or a little later. It was written in Latin for the Roman audience although Greek was his native language. Originally it consisted of thirty-one books, but only books fourteen through thirty-one have survived. The first thirteen may have been published separately and were apparently lost at an early date. Priscian, a Latin grammarian of the 6th century is the only ancient authority to quote Ammianus, and he did not have access to the complete work.

Manuscripts. The earliest extant copies of Ammianus are two manuscripts dating from the ninth century. One is in Rome and contains all of books fourteen through thirty-

[193] These introductory remarks are gathered out of Rolfe (pp. ix-xlvii) and Nettleship, et. al (p.26).

one. The other, in Germany, is fragmentary containing only six sheets forming part of books thirteen, twenty-eight and thirty. Beyond these there are thirteen 15th century manuscripts, all of which are direct or indirect copies of the Rome manuscripts.

Earthquake references in Ammianus. Ammianus refers to three men as speculating about, or predicting, earthquakes. These are Anaximander (17.7.12), Anaxagoras (17.7.11; 22.16.22) and Aristotle (17.7.11). In addition he gives several interesting and graphic descriptions of earthquakes and earthquake-related phenomena. For completeness these have been included in the following quotations. Ammianus does not put forward a theory of his own and thus will not be included in part II of this work.

Quotations. The quotations are taken from the *Loeb Classical Library* edition of Rolfe.

Quotation 1: Book 17. Chap.7. 1 - 14

"17. Nicomedia is destroyed by an earthquake[194]; the different ways in which the earth is shaken[195].

1. At that same time fearful earthquakes[196] throughout Asia, Macedonia and Pontus with the repeated shocks[197] shattered numerous cities and mountains. Now among these instances of manifold disaster was pre-eminent the collapse of Nicomedia, the metropolis of Bithynia; and of the misfortune of its destruction I shall give a true and concise account.

2. On the twenty-fourth of August[198], at the first break of day, thick masses of darkling clouds overcast the face of the sky, which had just before been brilliant; the sun's splendor was dimmed, and not even objects near at hand or close by could be discerned, so restricted was the range of vision, as a foul, dense mist rolled up and settled over the ground. 3. Then, as if the supreme deity were hurling his fateful bolts and raising the winds from every quarter, a mighty tempest of raging gales burst forth; and at its onslaught were heard the groans of the smitten mountains and the crash of the wave-lashed shore; these were followed by whirlwinds and waterspouts, which, together with a terrific earthquake[199], completely overturned the city and its suburbs. 4. And since most of the houses were carried down the slopes of the hills, they fell one upon another, while everything resounded with the vast roar of their destruction. Meanwhile the highest points re-echoed all manner of outcries, of those seeking their wives, their children, and whatever near kinsfolk belonged

[194] earthquake = "terrae motu".
[195] The summaries which appear at the chapter heads are not due to Ammianus.
[196] earthquakes = "terrae motus".
[197] shocks = "pulsibus".
[198] 24 August 358 AD.
[199] earthquake = "tremore terrarum".

to them. 5. Finally, after the second hour[200], but well before the third, the air, which was now bright and clear, revealed the fatal ravages that lay concealed. For some who had been crushed by the huge bulk of the debris falling upon them perished under its very weight; some were buried up to their necks in the heaps of rubbish, and might have survived had anyone helped them, but died for want of assistance; others hung impaled upon the sharp points of projecting timbers. 6. The greater number were killed at one blow, and where there were just now human beings, were then seen confused piles of corpses. Some were imprisoned unhurt within slanting houseroofs, to be consumed by the agony of starvation. Among these was Aristaenetus, vice-governor of the recently created diocese which Constantius, in honor of wife, Eusebia, had named Pietas; by this kind of mishap he slowly panted out his life amid torments. 7. Others, who were overwhelmed by the sudden magnitude of the disaster, are still hidden under the same ruins; some who with fractured skulls or amputated arms or legs hovered between life and death, imploring the aid of others in the same case, were abandoned, despite their pleas and protestations[201]. 8. And, the greater part of the temples and private houses might have been saved, and of the population as well, had not a sudden onrush of flames, sweeping over them for five days and nights, burned up whatever could be consumed.

9. I think the time has come to say a few words about the conjectures[202] which the men of old have brought together about earthquakes[203]; for the hidden depths of the truth itself have neither been sounded by this general ignorance of ours, nor even by the everlasting controversies of the natural philosophers, which are not yet ended after long study[204]. 10. Hence in the books of ritual[205] and in those which are in conformity with the pontifical priesthood[206], nothing is said about the god that causes earthquakes[207], and this with due caution, for fear that by naming one deity instead of another, since it is not clear which of them thus shakes the earth[208], impieties may be perpetrated. 11. Now earthquakes[209] take place (as the theories state, and among them Aristotle is perplexed and troubled) either in the tiny recesses of the earth, which in Greek we call *suriggai*[210], under the excessive pressure of surging waters; or at any rate (as Anaxagoras asserts) through the force of the winds, which penetrate the innermost parts of the earth; for when these strike

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[200] i.e., the second hour of daylight.

[201] There is some ambiguity in the MSS concerning this passage, but it is irrelevant to the present study (see Rolf, vol.1,p.345,note 1).

[202] conjectures = "conjectura" This word was translated as 'theories' by Rolfe, but that may be a bit misleading and conjecture seems closer to the sense that Ammianus intended. From the passages immediately following, Ammianus clearly holds that earthquakes were incompletely understood in his and earlier times. This fits nicely with a definition of conjecture such as: 'supposition; inference from defective or presumptive evidence'. (Harris, et. al., p.474) The use of 'theory' as translation of the Latin "opinions" is ubiquitous and proper (17.7.11 below, and elsewhere).

[203] earthquakes = "terrae pulsibus".

[204] i.e., natural phenomena, including earthquakes, are not well understood.

[205] See Cicero, de Div.1.33.72; Festus, p.285 M (Rolfe's note).

[206] The 'pontificales libri' of Seneca, Epist.108.31 (Rolfe's note).

[207] earthquakes = "motus terrae".

[208] shakes the earth = "terram concutiat".

[209] No explicit Latin phrase for earthquake.

[210] subterranean passages or pores.

the solidly cemented walls and find no outlet, they violently shake[211] those stretches of land under which they crept when swollen. Hence it is generally observed that during an earthquake[212] not a breath of wind if felt where we are[213], because the winds are busied in the remotest recesses of the earth. 12. Anaximander says that when the earth dries up after excessive summer drought, or after soaking rainstorms, great clefts open, through which the upper air enters with excessive violence; and the earth, shaken by the mighty draft of air through these, is stirred from its very foundations. Accordingly such terrible disasters happen either in seasons of stifling heat or after excessive precipitation of water from heaven. And that is why the ancient poets and theologians call Neptune (the power of the watery element) Ennosigaeos[214] and Sisichthon[215].

13. Now earthquakes[216] take place in four ways; for they are either *brasmatiae*[217], or upheavings, which lift up the ground from far within, like a tide and force upward huge masses, as in Asia Delos came to the surface, and Hiera, Anaphe, and Rhodes, called in former ages Ophiusa and Pelagia, and once drenched with a shower of gold; also Eleusis in Boeotia[218], Vulcanus in the Tyrrhenian Sea, and many more islands. Or they are *climatiae*[219] which rush along to one side and obliquely, leveling cities, buildings, and mountains. Or they are *chasmatiae*, or gaping, which with their intensive movement suddenly open abysses and swallow up parts of the earth; as in the Atlantic Ocean an island more extensive than all Europe[220], and in the Crisaean Gulf[221], Helice and Bura; and in the Ciminian district of Italy the town of Saccumum[222]. These were all sunk into the deep abysses of Erebus[223], and lie hidden in eternal darkness. 14. Among these three sorts of earthquakes[224] the *mycematiae*[225] are heard with a threatening roar, when the elements break up into their component parts and clash of their own accord, or slide back when the ground settles. For then of necessity the crashing and rumbling of the earth must resound like the bellowing of a bull."

Quotation 2: Book 22. Chap.9. 5

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[211] shake = "convibrant".
[212] earthquake = "terrae tremente".
[213] But compare Ammianus 17.7.3 above where strong winds are said to have accompanied the Nicomedian earthquake of 24 August 358 AD.
[214] 'earthshaker' Juv.10.182 (Rolfe's note).
[215] 'earthquaker' Gell.2.28.1 (Rolfe's note).
[216] earthquakes = "terrarum motus".
[217] From 'brazein' a Greek word meaning 'boil up'. (Rolfe's note) ...Arist. de Mundo....earthquakes which shake the earth up and down (Holland's note). De Mundo is now recognized as a spurious work by "Pseudo-Aristotle". For further information, see Appendix of the present work.
[218] Destroyed by inundation not earthquake. Strabo 9.12.18; Paus. 9.24.2 (Rolfe's note).
[219] Literally 'moving sideways' (Rolfe's note).
[220] Atlantis. See Plato Timaeus (Rolfe's note).
[221] Salona Bay, a part of the Corinthian Gulf; see Diod.14.48,49 (Rolfe's note).
[222] Exact location unknown. Near Lago di Vico (Rolfe's note).
[223] The primal darkness; the underworld.
[224] earthquakes = "terrae motuum".
[225] Literally, 'bellowing'.

"5. Having here also in a similar way generously furnished many things that were necessary for repairing the damage done by the earthquake[226], he went on past Nicaea to the borders of Gallograecia."

Quotation 3: Book 22. Chap.16. 22

"22. From here[227] Anaxagoras foretold a rain of stones, and by handling mud from a well predicted[228] and earthquake[229]."

Quotation 4: Book 23. Chap.1. 7

"7. Besides these, other lesser signs also indicated from time to time what came to pass. For amid the very beginning of the preparations for the Parthian campaign[230] word came that Constantinople had been shaken by an earthquake[231], which those skilled in such matters said was not a favorable omen for a ruler who was planning to invade another's territory."

Quotation 5: Book 26. Chap.10. 15 - 19

"15. While that usurper[232] of whose many deeds and his death we have told, still survived, on the twenty-first of July in the first consulship of Valentinian with his brother[233], horrible phenomena suddenly spread through the entire extent of the world, such as are related to us neither in fable nor in truthful history. 16. For a little after daybreak, preceded by heavy and repeated thunder and lightning, the whole of the firm and solid earth was shaken and trembled, the sea with its rolling waves was driven back and withdrew from the land, so that in the abyss of the deep thus revealed men saw many kinds of sea-creatures stuck fast in the slime; and vast mountains and deep valleys, which Nature, the creator, had hidden in the unplumbed depths, then, as one might well believe, first saw the beams of the sun. 17. Hence, many ships were stranded as if on dry land, and since many men roamed about without fear in the little that remained of the waters, to gather fish and similar things with their hands, the roaring sea, resenting, as it were, this forced retreat, rose in its return; and over the boiling shoals it dashed mightily upon islands and broad stretches of the mainland, and leveled innumerable buildings in the cities and wherever else they were found; so that amid the mad discord of the elements the altered face of the earth revealed marvelous sights. 18. For the great mass of waters, returning when it was least expected, killed many thousands of men by drowning; and by the swift recoil of the eddying tides a

[226] earthquake = "terrae subverterat tremor". The earthquake referred to occurred 24 August 358 AD (Ammianus 22.7.2-8).
[227] Egypt.
[228] predicted = "futuros praedixerat".
[229] earthquake = "tremores...terrae".
[230] Spring(?) of 363 AD.
[231] earthquake = "terrae pulsu vibratum".
[232] Procopius, a Roman envoy to the Persians.
[233] i.e., 21 July 365 AD.

number of ships, after the swelling of the wet element subsided, were seen to have foundered, and the lifeless bodies of shipwrecked persons lay floating on their backs or on their faces. 19. Other great ships, driven by the mad blasts, landed on the tops of buildings (as happened at Alexandria), and some were driven almost two miles inland[234], like a Laconian ship which I myself in passing that way saw near the town of Mothone[235], yawning apart through long decay."

[234] Compare the following accounts from Geology Principles and Processes (Emmons, et. al, 1939, pp.336-7): "On August 13, 1868, the west coast of South America was shaken from Quayaquil, Ecuador, to Valdivia, in Chile, the most violently shaken region being in the neighborhood of Arica, a city on the west coast, where many buildings were destroyed. A few minutes after the destructive shock the sea slowly receded from the shore, and ships anchored in 42 feet of water were left dry. Later the water returned as a great wall, caught up the ships and swept them inland as if they had been chips of wood. The United states steamer Wateree was carried inland 1/4 mile with little damage and left ashore." (p.336); "On November 1, 1755, a great earthquake and sea waves destroyed Lisbon, Portugal. The waves were 30 to 60 feet higher than the highest tide and came about one hour after the town had been shattered by the earthquake. At first the sea withdrew, the withdrawal of the water being followed soon after by the greatest wave." (p.337).

[235] Called Methone by Thucydides,2.25. It was in the southern part of Messinia. There was another Methone in Magnesia (Rolfe's note).

"The history of seismology has been traced back to the earliest times. It would be interesting to know whether the ancients possessed any accurate knowledge of the subject, as they did in the case of astronomy."

G. W. Walker *Modern Seismology* (London, 1913, pp. viii-ix)

Part II: Catalogue of Earthquake Theories

Thales

Thales of Miletus: lived c.640(625?)-547 BC; philosopher, astronomer, mathematician, statesman, mechanician, one of the seven sages; earliest Greek philosopher, first of the Ionian philosophers.

Extant Works: none

Lost Works: *Nautical Astronomy* (?) [also attributed to Phocus of Samos]
On the Solstice (?)
On the Equinox (?)
First Causes (?)

Earthquake Notices/Fragments:

Seneca Natural Questions [Book 3. Sect. 14.1]

"14. The following theory of Thales is silly. For he says that this globe of lands is sustained by water and is carried along like a boat, and on the occasions when the earth is said to quake it is fluctuating because of the movement of the water. It is no wonder, therefore, that there is abundant water for making the rivers flow since the entire round is in water. Reject this antiquated, unscholarly theory. There is also no reason that you should believe water enters this globe through cracks, and forms bilge."

***Ibid*. [Book 6. Sect. 6.1 - 4]**

"6. The cause of earthquakes is said to be in water by more than one authority but not in the same way. Thales of Miletus judges that the whole earth is buoyed up and floats upon liquid that lies underneath, whether you call it the ocean, the great sea, or consider it the as yet elementary water of a different character and call it merely a humid element. The disc is supported by this water, he says, just as some big heavy ship is supported by the water which it presses down upon[236]."

Pseudo-Plutarch *Placita Philosophorum* [Book 3. chap.15.1]

"Thales and Democritus believe that water is the cause of earthquakes.".

[236] Seneca's refutation (6.6.2-4): "It is pointless for me to give the reasons for his belief that the heaviest part of the universe cannot be carried by air, which is so tenuous and mobile; for the point now does not deal with location of the earth but with earthquakes. By way of proof that waters exist as the cause of earthquakes and that the earth is agitated by these waters, he proposes this: in every great earthquake new springs generally break out, just as it also happens that if ships tilt and lean to one side they take in water. In the case of all heavy objects which water carries, if they are submerged considerably, the water either flows over them or at least the water rises on the right or left more than usual.

It need not take long to deduce that Thales' theory is false. For, if the earth were supported by water and sometimes shaken by it, there would always be earthquakes and we would not be amazed that the earth is shaken but that it remains at rest. Finally, the whole earth would be shaken, not just a part; for never is half a ship tossed about. As things are, a quake is not over the entire earth but on a part of it. Therefore, how can it happen that what is carried as a whole is not shaken as a whole if it is shaken by that which carries it? 'But why do waters break out?' First of all, there has often been an earthquake and yet no new liquid flowed. Second, if water did burst forth for this reason it would pour around the sides of the earth, as we see happens in the case of rivers and the sea; just as when boats sink the increase of water appears mainly over the sides. Finally, no such scanty eruption of water as you say would ever occur, not would it seep in like bilge-water through a crack, but a huge deluge would be the result of liquid that is infinite and supports all that the earth consists of."

Anaximander

Anaximander of Miletus: lived c.610-546 BC; philosopher, astronomer, pupil or associate of Thales; second of the Ionian philosophers.

Extant Works: none

Lost Works: "*On Nature*" [actual title unknown]

Earthquake Notices/Fragments:

Pliny *Natural History* [Book 2.81.191]

"On this subject a remarkable and immortal inspiration is attributed (if we can believe it) to the natural philosopher Anaximander of Miletus, who is said to have warned the Spartans to be careful of their city and buildings, because an earthquake was impending; and subsequently the whole of their city collapsed, and also a large part of Mount Taygetus projecting in the shape of a ship's stern broke off and crashing down on it added to the catastrophe."

Ammianus Marcellinus *The Roman History* [Book 17. Chap.7.12]

"12. Anaximander says that when the earth dries up after excessive summer drought, or after soaking rainstorms, great clefts open, through which the upper air enters with excessive violence; and the earth, shaken by the mighty draft of air through these, is stirred from its very foundations. Accordingly such terrible disasters happen either in seasons of stifling heat or after excessive precipitation of water from heaven."

Pherecydes

Pherecydes of Syros: lived c.600?-550? BC; mystic and theologian; possibly teacher of Pythagoras (doubtful).

Extant Works: none

Lost Works: The Seven Chambered Cosmos
[known in antiquity by several other titles]

Earthquake Notices/Fragments[237]:

Pliny Natural History [Book 2.81.192]

"Also another conjecture is attributed to Pherecydes the teacher of Pythagoras, this also inspired: he is said to have foretold to his fellow-citizens an earthquake, of which he had obtained a premonition in drawing water from a well."

Diogenes Laertius Lives of Emminent Philosophers [Book 1.Sect. 116]

"And as he [Pherecydes] was drinking water which had been drawn up from a well he predicted that on the third day there would be an earthquake; which came to pass."

[237] "[Pherecydes] was credited with having prophesied a shipwreck, an earthquake, the capture of a city; but Andron said that these prophecies were the work of Pythagoras, and were falsely attributed to Pherecydes by Theopompus." (Freeman, Companion , p.38) Theopompus flourished in the 4th century BC; Andron's date is uncertain.

Anaximenes

Anaximenes of Miletus: lived 585?-524? BC; philosopher, astronomer; third of the Ionian philosophers.

Extant Works: none

Lost Works: [one book of unknown title]

Earthquake Notices/Fragments:

Aristotle *Meteorologica* [Book 2. ch. 7.365a17]

"Up to the present three theories have been put forward by three separate men. For Anaxagoras of Clazomenae and before him Anaximenes of Miletus both published views on the subject, and after them Democritus of Abdera."

Ibid. [Book 2. ch. 7.365b7 - 20]

"Anaximenes says that when the earth is in process of becoming wet or dry it breaks, and is shaken by the high ground breaking and falling. Which is why earthquakes occur in droughts and again in heavy rains: for in droughts the earth is dried and so, as just explained, breaks, and when the rains make it excessively wet it falls apart."

Seneca *Natural Questions* [Book. 6 Sect. 10.1 - 2]

"10. Anaximenes says that the earth itself is the cause of its earthquakes and that the earth does not encounter from outside something that shakes it but something within itself and of itself. For, he says, certain parts of the earth fall in, which either moisture has dissolved or fire has eaten away or a blast of air has shattered; but even if these elements are not active, he says, there are other reasons that some part of the earth moves away or is torn away. In the first place, all things totter from length of time and nothing is safe from age; age wastes away even these very strong and solid objects. Accordingly, in old buildings when some sections have more weight than strength they fall even though they ate not knocked off. The same thing happens in this whole body of the earth: its parts are loosened by age, and once loosened they fall and cause a tremor to the parts above them. The parts first do this when they give way, for nothing big is cut away without moving whatever it adhered to; then when they fall they meet something solid and rebound like a ball. When a ball falls it leaps up and bounces repeatedly, as many times as it is sent back from the ground into a new flight. Moreover, if parts of the earth have been carried down in stagnant waters, this fall by itself shakes the vicinity with a wave ejected by the sudden mass which has been shot down from above."

Pseudo-Plutarch *Placita Philosophorum* [Book 3.chap.15.3]

"Anaximenes says that earthquakes are caused by gluts of rain falling in regions where the earth is exceedingly dry, and non-dense, due to excessive drought."

Ibid. [Book 3.chap.15.7]

"Anaximenes says that the earth is carried up and down in the air because it is broad and flat."

Anaxagoras

Anaxagoras of Clazomanae: lived 500?-428; philosopher, astronomer, mathematician.

Extant Works: none

Lost Works: "*On Nature*" [exact title unknown]

Earthquake Notices/Fragments:

Aristotle *Meteorologica* [Book 2.chap 8.365a16 - 25]

"Up to the present three theories have been put forward by three separate men. For Anaxagoras of Clazomenae and before him Anaximenes of Miletus both published views on the subject, and after them Democritus of Abdera.

Anaxagoras says that the air, whose natural motion is upwards, causes earthquakes when it is trapped in hollows beneath the earth, which happens when the upper parts of the earth get clogged by rain, all earth being naturally porous. For he regards the globe as having an upper and a lower part, the part on which we live being the upper part, the other the lower[238]."

Seneca *Natural Questions* [Book6.sect. 9.1]

"9. Some authorities, and indeed men of high reputation, suppose that fire is the cause of earthquakes. Anaxagoras especially estimates that both the atmosphere and the earth are shaken by just about the same cause. Moving air in the lower region inside the earth bursts the atmosphere, which is thick and compacted into clouds, with the same force that clouds in our part of the world are usually broken open. Fire flashes out from this collision of clouds and from the rush of air that is forced out. This fire, seeking an exit,

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238 Aristotle's refutation of this theory (2.8.365a26 - 36): "It is perhaps hardly necessary to say anything to refute this very elementary account. For it is very silly to think of up and down as if heavy bodies did not fall down to the earth from all directions and light ones (e.g. fire) rise up from it, especially when we see that throughout the known world the horizon always changes as we move, which indicates that we live on the convex surface of a sphere. It is silly, too, to think that the earth rests on the air because of its size, and that it is jarred right through by a shock from below. Besides, he fails to account for any of the peculiar features of earthquakes, which do not occur in any district or at any time indiscriminately."

runs against anything it meets and tears apart anything that resists it until either it finds a way out to the sky through narrow passages or makes a way out by force and destruction. "

Pseudo-Plutarch ***Placita Philosophorum*** [Book 3.chap.15.4]

"Anaxagoras holds that when air is trapped in the earth and, moving up, reaches near to the surface, which it finds impenetrable, it shakes the surface of the earth with a sort of trembling."

Diogenes Laertius ***Lives of Emminent Philosophers*** [Book 2.sect. 9]

"He [Anaxagoras] held that winds arise when the air is rarefied by the sun's heat; that thunder is clashing together of the clouds, lightning their violent friction; and earthquake a subsidence of air into the earth."

Ammianus Marcellinus ***The Roman History*** [Book 17.chap 7.11]

"11. Now earthquakes take place...(as Anaxagoras asserts) through the force of the winds, which penetrate the innermost parts of the earth; for when these strike the solidly cemented walls and find no outlet, they violently shake those stretches of land under which they crept when swollen[239]."

Ibid**.** [Book 22.chap 16. 22]

"22. From here Anaxagoras foretold a rain of stones, and by handling mud from a well predicted and earthquake."

[239] The next sentence is: "Hence it is generally observed that during an earthquake not a breath of wind is felt where we are, because the winds are busied in the remotest recesses of the earth." Whether this observation is due to Anaxagoras or Ammianus (or someone else) seems uncertain.

Parmenides

Parmenides of Elea: flourished about 475 BC; philosopher.

Extant Works: none

Lost Works: "*On Nature*" [exact title unknown]

Earthquake Notices/Fragments:

Pseudo-Plutarch *Placita Philosophorum* [Book 3.chap.15.7]

"Parmenides and Democritus reason this way: since the earth stretches away equally in all directions all parts of the earth are counterbalanced, and there is no force or cause why some part of it should incline more to one side than another. Therefore it is possible for part of it to shake, but it cannot stir and move as a whole."

Diogenes Of Apollonia

Diogenes of Apollonia: flourished 460? BC; philosopher

Extant Works: none

Lost Works: *On Natural Science*
Meteorology
Nature of Man
Against the Natural Scientists (or Sophists)

Earthquake Notices/Fragments[240]:

Seneca *Natural Questions* [Book 4.sect. 2.28 - 30]

"Diogenes of Apollonia says: 'The sun draws moisture to itself; the land, dried out, takes moisture from the sea; the sea itself draws moisture from other waters. But it cannot happen that some land is dry, other land flooded, for all lands are perforated with communicating passages and the dry sections draw from the moist. Otherwise, unless the land received some moisture it would have completely dried out. Accordingly, the sun draws up moisture, but only from those regions which the sun especially oppresses; that is, the southern regions. When the land is parched it draws in more moisture. Just as in a lamp the oil flows to where it is burned, so water inclines to where the force of the heat and of the burning land draws it. But where does the land draw it from? Surely from areas of eternal winter. The northern regions abound in water. (For this reason the swift current of the Pontus runs constantly towards the lower sea and does not ebb and flow in alternating tides the way other seas do, but always has a torrent descending in one direction). Unless this happened--that is, unless these passage-ways restored water to any land that lacked it and drained away surplus water--everything would already have been dried up or flooded.' "

Ibid. [Book 6.sect. 15.1]

"15. Some think [Diogenes of Apollonia?][241] along the following lines: the earth is perforated in many places, and has not only those places of admission which it first received at its beginning and which it had as though for breathing but many others which violent

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[240] "[Diogenes said the earth] rests on air, and can be moved by it, the result being an earthquake." (Freeman, Companion , p.281).
[241] The association of this theory with Diogenes of Apollonia is made by Corcoran (p.173, note 2) who then references Book 4.2.28 - 30.

chance has formed. In some places water washed away areas from the earth's surface; the torrents cut through some parts, other places were laid open because they were broken apart by great tides. Air enters through these openings. If the sea encloses the air and drives it deeper down and the water does not permit it to come back out, then, when its way out and way back are at the same time blocked, the air is rolled about and, because it is not able to extend straight out, which is natural to it, it stretches itself upward and lashes apart the earth pressing down upon it."

Archelaus

Archelaus of Miletus or Athens: flourished c.450 BC; philosopher; pupil of Anaxagoras

Extant Works: none

Lost Works: *On Physical Science (or Physiologia)*

[and a poem of unknown title]

Earthquake Notices/Fragments:

Seneca *Natural Questions* [Book 6.sect. 12.1 - 2]

"12. It is a favourite theory of most of the greatest authorities that it is moving air which causes earthquakes. Archelaus, a scholar accurate in matters of ancient times, says as follows: winds are carried down into cavities of the earth; then, when all the spaces are filled and the air is thickened as much as it can be, the moving air which comes in on top of it compresses the air that was there first and pushes it and with frequent blows first packs it together then forces it out. Then in seeking room the air unblocks all the narrow passageways and tries to break out of its enclosure. In this way it comes about that the earth is moved, when the moving air is struggling and searching for a way out. And so, a calm and quiet condition of the atmosphere precedes the period when there will be an earthquake[242], obviously because the force of air which usually stirs up the winds is retained in the interior of the earth.[243] "

[242] The precursor given in this line may be due to Archelaus; the text is not clear.

[243] The last sentence may be Seneca's comment rather than a point due to Archelaus. Seneca continues (6.12.3): "At this time too when the earthquake occurred in Campania, even though it was the restless season of the winter, the air in the atmosphere remained still throughout the preceding days.

"But what about this: has the earth never been shaken when the wind was blowing? Very rarely. Two winds may blow at the same time; indeed, not only can it happen but it is usual. If we accept this and it is agreed that two winds act at the same time, why can it not happen that one agitates the upper atmosphere, the other the lower regions?"

Antiphon The Sophist

Antiphon the Sophist: believed to be of Athens; lived during the late fifth century BC; rhetorician, seer, interpreter of Dreams.

Extant Works: none

Lost Works: *Truth*
On Concord
The Statesman or Discourse on the State
On the Interpretation of Dreams
Arts of Rhetoric
The Art of Freedom from Pain

Earthquake Notices/Fragments:

The only information that I have is the following statement by Freeman[244],

"[Antiphon says] Earthquakes are caused by (internal) fires, which burn and melt the earth, causing it to wrinkle and quiver: an observation derived from volcanic eruptions".

I do not know the ancient source from which this information is drawn.

[244] Companion , p.396.

Democritus

Democritus of Abdera: lived 460?-362? BC; philosopher, astronomer, mathematician.

Extant Works: none

Lost Works: [A mass of written work was produced at Abdera during and shortly after Democritus' lifetime. It is not known which of these lost works were actually by Democritus; the earthquake references probably come from a genuine treatise on meteorology.]

Earthquake Notices/Fragments:

Aristotle *Meteorologica* [Book 2.chap 7.365a17 - 19]

"Up to the present three theories have been put forward by three separate men. For Anaxagoras of Clazomenae and before him Anaximenes of Miletus both published views on the subject, and after them Democritus of Abdera."

Ibid. [Book 2.chap 7.365b1 - 6]

"Democritus says the earth is full of water and that earthquakes are caused when a large amount of rain water falls besides this; for when there is too much for the existing cavities in the earth to contain, it causes an earthquake by forcing its way out. Similarly, when the earth gets dried up water is drawn to the empty places from the fuller and causes earthquakes by the impact of its passage."

Seneca *Natural Questions* [Book 6.sect. 20.1]

"20. Now we come to those writers who have stated as a cause of earthquakes either all the elements I mentioned or several of them. Democritus thinks several. For he says that an earthquake is produced sometimes by moving air, sometimes by water, sometimes by both. He follows through on his theory in this way: some parts of the earth are hollow. A large quantity of water flows into them. Some of this water is thin and accordingly more fluid than the rest. When it is driven back by the heavy mass coming upon it, it strikes against the earth and causes it to move, for water cannot fluctuate without causing what it shoves against to move."

Pseudo-Plutarch *Placita Philosophorum* [Book 3.chap 15.1]

"Thales and Democritus believe that water is the cause of earthquakes."

Ibid. [Book 3.chap 15.1]

"Parmenides and Democritus reason this way: since the earth stretches away equally in all directions all parts of the earth are counterbalanced, and there is no force or cause why some part of it should incline more to one side than another. Therefore it is possible for part of it to shake, but it cannot stir and move as a whole."

Plato

Plato of Athens: lived 427?-347; one of the greatest Greek philosophers, mathematician, mechanician; pupil of Socrates, teacher of Aristotle.

Extant Works: [all thirty-six of his philosophical works survive]

Lost Works: none

Earthquake Notices/Fragments:

Pseudo-Plutarch *Placita Philosophorum* [Book 3.chap 15.10]

"Plato affirms[245] that there are six sorts of motions; up and down, right and left, forward and back. Also, that the earth cannot possibly move in any of these directions, for on every side it is the lowest of all things in the world and therefore rests unmovable, having no cause why it should incline more to one part than another. But some parts of the earth, because of their lack of density, do jog and shake."

[245] Aristotle lists all theories known to him and does not include one by Plato, therefore this reference is almost surely incorrect.

Aristotle

Aristotle of Stagiera: lived 384-322

Life and works: see Chapter 1 of Part I

Aristotle's Theory of Exhalations. Aristotle begins his discussion on the causes of earthquakes with the following sentence[246]:

"Now it is clear, as we have already said, that there must be exhalation[247] both from moist and dry, and earthquakes are a necessary result of these exhalations."

Thus our understanding of Aristotle's earthquake theory is entirely dependent on our understanding of his theory of exhalations. The following notes may prove helpful to the reader.

This theory is somewhat confusing and judging from quotations in Seneca and elsewhere[248] it was not well-understood in ancient times. It is not a conceptually difficult theory, but Aristotle's terminology is inconsistent and often imprecise. In his defense, this may be due in part to the fact that the meteorologica, like all of his extant work, was not a published book but a collection of lecture notes. The confusion we see may well have been edited out of the published version (if it were indeed published), which is lost.

An account of the theory begins with a look at Aristotle's concept of the universe (Fig.1).

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[246] Book 2.8.365b21.

[247] The word 'exhalation' unfortunately does not mean much to the modern reader. Transliteration of the Greek word is *anathumiasis*, literally 'a rising-up of vapour or smoke'. "Exhalation, though not accurate, is used in default of a single term that would be exact." (Freeman Companion, p.109, n.d1).

[248] Seneca Nat. Quest. 6.13.1; Ammianus 17.7.11.

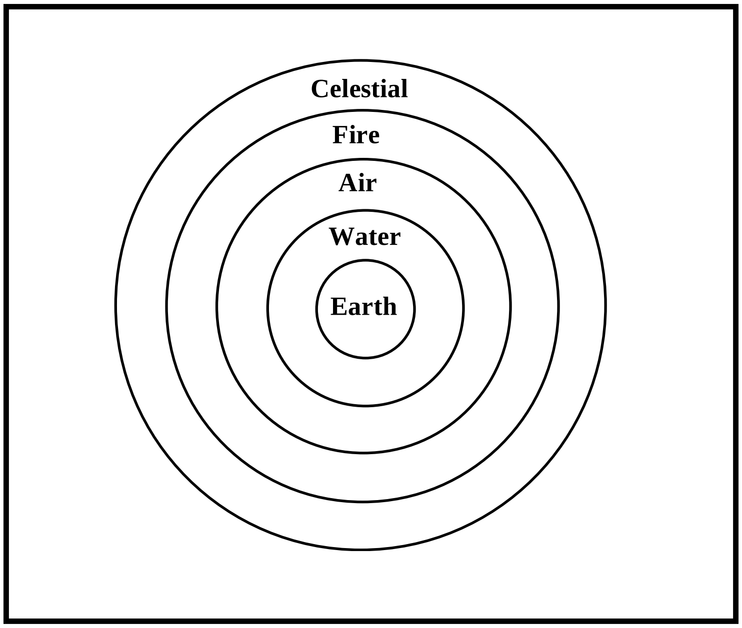

Figure 1. Aristotle's view of the universe

It is composed of five concentric spheres. Reckoning from the innermost, these spheres are the elements Earth, Water, Air, Fire and the Celestial Element. Thus he recognizes five elements, not four. The four 'lower' elements are termed sublunar since the celestial sphere includes the moon and everything beyond. The spherical scheme is not exact; he explains, for example, that the earth-water interface is irregular with the land rising out of the sea in direct contact with air. The earth he sees as porous and saturated, or nearly saturated with water.

In the sublunar region, Aristotle is faced with the enormous problem of accounting for all observed objects and phenomena using just four elements. These elements themselves can interact and combine in only a limited number of ways. Somehow he needed to introduce the complexity and variability which characterized the real world into this theory.

To solve this problem he develops the concept of "qualities". An element is said to posses certain of these qualities -- it is characterized by them in much the same way that we think of a substance as defined by its chemical formula.

Aristotle implies that there are four types of qualities which I have called motion, moisture, heat and state. These qualities are apparently not continuously variable; motion does not go from still to slowly moving to quickly moving. To Aristotle something is either moving or it is not, and thus the four qualities can assume only certain values,

motion = moving or still or either(E)
moisture = moist or dry
heat = hot or cold
state = gaseous or non-gaseous.

Aristotle describes the primary elements earth and water in terms of these qualities -- the order of the qualities is arbitrary, I have used motion/moisture/heat/state -- specifically,

earth = E/dry/cold/non-gas
water = E/moist/cold/non-gas.

(To ward off confusion at this point, it may be helpful to note that we often use a similar sort of classification system, for example when we describe a certain day as sunny, windy and warm.)

The next major concept involves what happens when the primary elements are heated. A new non-elemental substance is formed by a process akin to evaporation; this is an exhalation. Since there are two primary elements there are two "kinds" of exhalation each with its own combination of qualities,

earth-exhalation = still/dry/hot/gas
water-exhalation = E/moist/cold/gas.

As a good example of Aristotle's confusion in terminology consider the following equivalent terms which occur in the *Meteorologica* :

1. earth-exhal. = exhalation = dry and hot exhalation
   = dry and hot = windy = windy exhalation
   = smokey = smoke = like smoke
   = fire (ignited) = potential fire
2. water-exhal. = watery exhal. = moist exhalation
   = moist and cold = vapour
   = moist and cold exhalation
   = potential water = water vapour.

The exhalations given off by earth and water rise and mix to form the element air. Although thoroughly mixed as air they are yet distinct and the lighter earth-exhalation rises until it finally enters the region above the air where it is ignited to form the element fire. These secondary elements also have combinations of qualities,

air = E/moist/hot/gas
fire = still/dry/hot/gas.

So how are earthquakes related to all this? Aristotle says that earthquakes are caused by wind moving through or trapped within the earth. But he is adamant that wind is not simply 'moving air' (which would be moving/moist/hot/gas). He defines wind as moving earth-exhalation (moving/dry/hot/gas). Once this distinction is understood, many of his statements become somewhat comprehensible. Otherwise, something like "wind sets air in motion" is meaningless.

For clarity, the entire scheme of Aristotle's exhalation theory is shown in Fig. 2.

Earthquake Quotations/Notices:

Theory.

Aristotle *Meteorologica* [Book 2.chap 8.365b21 - 366a5]

"Chapter 8. Now it is clear, as we have already said, that there must be exhalation both from moist and dry, and earthquakes are a necessary result of the existence of these exhalations. For the earth is in itself dry but contains much moisture because of the rain that falls on it; with the result that when it is heated by the sun and its own internal fire, a considerable amount of wind is generated both outside it and inside, and this sometimes all flows out, sometimes all flows in, while sometimes it is split up.

This process is inevitable. Our next step should therefore be to consider what substance has the greatest motive power. This must necessarily be the substance whose natural motion is most prolonged and whose action is most violent. The substance most violent in action must be that which has the greatest velocity, as its velocity makes its impact most forcible. The farthest mover must be the most penetrating, that is, the finest. If, therefore, the natural constitution of wind is of this kind, it must be the substance whose motive power is the greatest. For even fire when conjoined with wind is blown to flame and moves quickly. So the cause of earth tremors is neither water not earth but wind, which causes them when the external exhalation flows inwards."

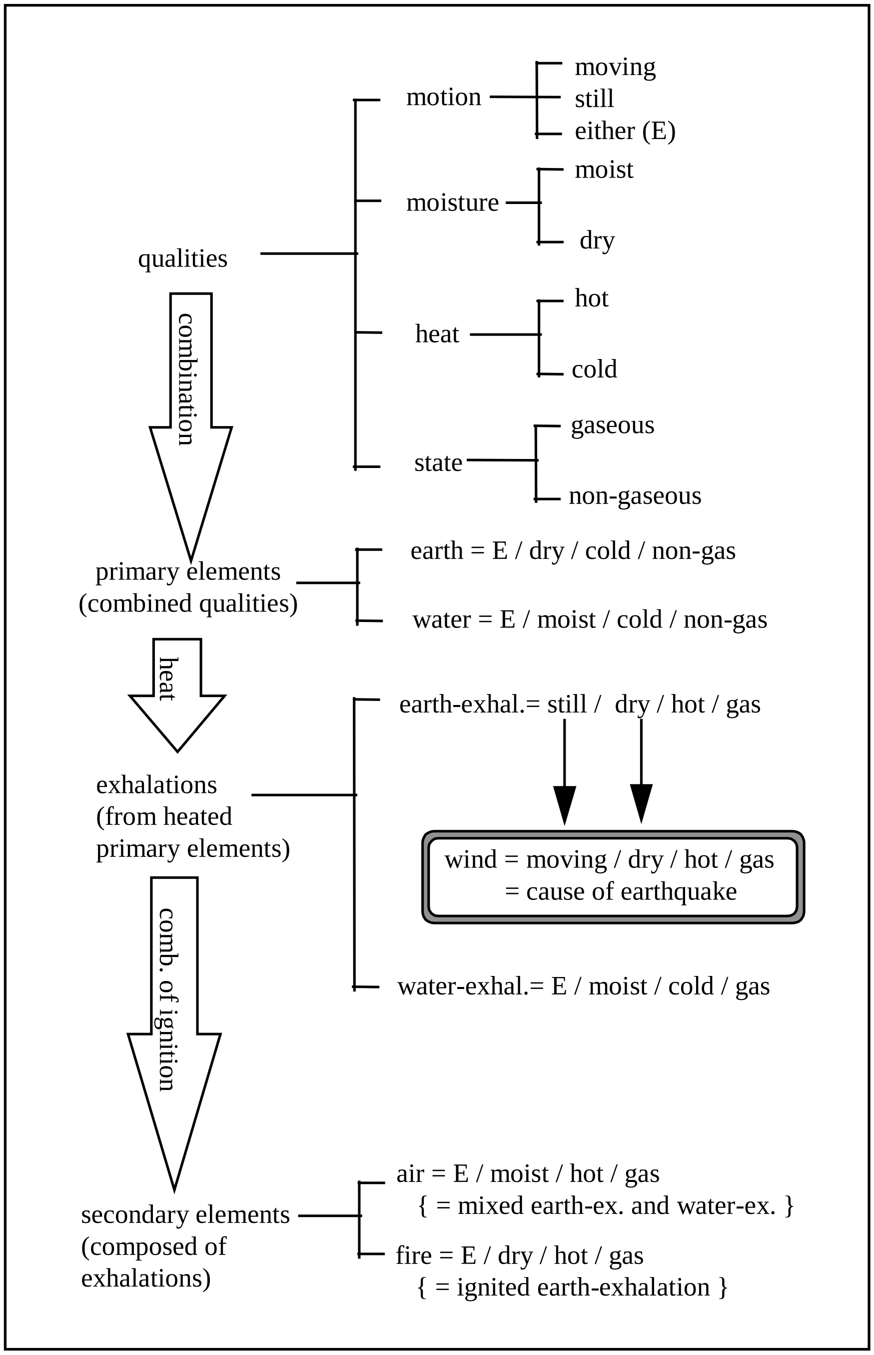

Figure 2 Aristotle's exhalation theory

Ibid. [Book 2.chap 8.366a6 - 9]

"...the exhalation being continuous in general follows its initial impulse and tends either all to flow inwards at once or all outwards."

Ibid. [Book 2.chap 8.366a10 - 24]

"...we sometimes see several winds blowing at the same time, and when one of these plunges into the earth the resultant earthquake is accompanied by wind. But these earthquakes are less violent, because the energy of their original cause is divided. Most major earthquakes occur at night, and those that occur in daytime at midday, this being as a rule the calmest time of day, because when the sun is at its strongest it confines the exhalation within the earth, and it is at its strongest about midday; and the night again is calmer than the day because of the sun's absence. So at these times the flow turns inwards again, like an ebb as opposed to the outward flood. This happens especially towards dawn, for it is then that winds normally begin to blow. If, then, the original impulse of the exhalation changes direction, like the Euripus, and turns inwards, it causes a more violent earthquake because of its quantity."

Ibid. [Book 2.chap 8.366a25 - 366b30]

"...where the sea is full of currents or the earth is porous and hollow... earthquakes occur mostly because of the constricted space. For when a violent wind arises the volume of the inflowing sea drives it back into the earth, when it would naturally be exhaled from it. And places whose subsoil is porous are shaken more because of the large amount of wind they absorb.

For the same reason earthquakes occur most often in spring and autumn and during rains and droughts, since these periods produce most wind. For summer and winter both bring calm weather, the one because of its frosts, the other because of its warmth, the one thus being too cold, the other being too dry to produce winds. But in times of drought the air is full of wind, drought simply being an excess of dry over moist exhalation. In times of rain the exhalation is produced within the earth in greater quantity, and when what has been so produced is caught in a constricted space and forcibly compressed as the hollows within the earth fill with water, the impact of the stream of the wind on the earth causes a severe shock, once the compression of a large quantity of it into a small space begins to have its effect. For we must suppose that the wind in the earth has effects similar to those of the wind in out bodies whose force when it is pent up inside us can cause tremors and throbbings, some earthquakes being like a tremor, some like a throbbing. We must suppose, again, that the earth is affected as we often are after making water, when a sort of tremor runs through the body as a body of wind turns inwards again from without. For the force that wind has can be seen not only by studying its effects in the air, when one would expect it to be able to produce them because of its volume, but also in the bodies of living things. Tetanus and spasms are movements caused by wind, and are so strong that the combined strength and efforts of a number of men is unable to master the movements of their victims. And if we may compare great things with small, we must suppose that the same sort of thing happens to the earth."

Ibid. [Book 2.chap 8.366b31 - 367a11]

"For in some places there has been an earthquake which has not ceased until the wind which was its motive force has broken out like a hurricane and risen into the upper region...in Hiera, one of the so-called Aeolian Islands...part of the earth swelled up and rose with a noise in crest-shaped lump; this finally exploded and a large quantity of wind broke out, blowing up cinders and ash...This too must be regarded as the cause of the fire that there is in the earth; for when the air is broken up into small particles, percussion then causes it to catch fire."

Ibid. [Book 2.chap 8.367a18 - 20]

"This causes a noise but no earthquake because there is plenty of room for the wind, of which there is only a small quantity and which can overflow into the void outside."

Ibid. [Book 2.chap 8.367a26 - 367b8]

"Calm must usually fall, as we have explained, because the wind drains back as it were into the earth, and the greater the earthquake the more this happens; for the earthquake is bound to be more severe if the wind is not dispersed, some outside and some in, but moves in a mass. The reason for the cold is that the exhalation, which is by nature essentially warm, is directed inwards. Winds are not usually supposed to be warm because they set the air in motion and the air contains large quantities of cold vapor... So the warm element disappears into the earth, and wherever this happens, the vaporous exhalation being moist condenses and causes cold."

Ibid. [Book 2.chap 8.367b19 - 31]

"...an earthquake sometimes occurs at an eclipse of the moon. For when the interposition is approaching but the light and warmth from the sun, though already fading, have not entirely disappeared from the air, a calm falls when the wind runs back into the earth. And this causes the earthquake before the eclipse. ...when the cause which held it quiet ceases to operate the air is set in motion again and a wind rises..."

Ibid. [Book 2.chap 8.367b34 - 368b17]

"When an earthquake is severe the shocks do not cease immediately... The cause of the severity is the amount of the wind and the shape of the passages through which it has to flow. When it meets with resistance and cannot easily get through, the shocks are severest and air is bound to be left in the narrow places, like water that cannot get out of a vessel. ...the originating cause of the exhalation and the source of the wind clearly do not expend all at once the material which produces the wind which we call an earthquake. Until, therefore, the rest of it is expended shocks must continue, their force decreasing until there is too little exhalation to cause a shock that is noticeable.

Wind is also the cause of noises beneath the earth, among them the noises that precede earthquakes, though they have also been known to occur without an earthquake following. For as the air when struck gives out all sorts of noises, so also it does when it is itself the striker; the effect is the same in either case, since every striker is itself also struck. The sound precedes the shock because the sound is of finer texture and so more penetrating than the wind itself. When the wind is too fine to communicate any impulse to the earth, being unable to do so because of the ease with which it filters through it, nevertheless when it strikes hard or hollow masses of all shapes it gives out all sorts of noises, so that sometimes the earth seems to bellow as they say it does in fairy stories.

Water has sometimes burst out of the earth when there has been an earthquake. But this does not mean that the water was the cause of the shock. It is the wind which is the cause, whether it exerts its force on the surface or from beneath--just as the winds are the cause of waves and not the waves of winds. Indeed one might as well suppose that the earth is the cause of the shock as that the water is; for in an earthquake it is overturned like water, and upsetting water is a form of overturning. But in fact both earth and water are material causes, being passive not active, but wind the motive cause.

When a tidal wave coincides with an earthquake the cause is an opposition of winds. This happens when the wind which is causing the earthquake is unable quite to drive out the sea which is being driven in by another wind, but pushes it back and piles it together till a large mass has collected. Then if the first wind gives way the whole mass is driven in by the opposing wind and breaks on the land and causes a flood.

Earthquakes are confined to one locality, often quite a small one, but winds are not. They are localized when the exhalations of a particular locality and its neighbor combine, which was what we said happens in local droughts and rainy seasons."

Ibid. [Book 2.chap 8.368b18 - 30]

"...earthquakes originate in the earth, and so their constituent exhalations tend to move all in one direction; the sun has less power over them than it has with the exhalations in the air which therefore flow on in one direction when the sun's movement gives them an impulse, differing according to the difference of its position.

So then, when the quantity of wind is large it causes an earthquake shock which runs horizontally, like a shudder: occasionally in some places the shock runs up from below, like a throb. The latter type of shock is therefore the rarer, for sufficient force to cause it does not easily collect since a shock from below requires many times the amount of exhalation as that required for a shock running horizontally. But whenever this type of earthquake does occur, large quantities of stones come to the surface, like the chaff in a winnowing sieve."

Ibid. [Book 2.chap 8.368b34 - 369a4]

"Earthquakes are rarer in islands that are far out at sea than in those close to the mainland. For the quantity of the sea cools the exhalations and its weight crushes them and prevents their forming; and the force of the winds causes waves and not shocks in the sea. Again, its extent is so great that the exhalations do not run into it but are produced from it and joined by those from the land."

Ibid. [Book 2.chap 9.370a26 - 31]

"Our own view is that the same natural substance causes wind on the earth's surface, earthquakes beneath it, and thunder in the clouds; for all these have the same substance, the dry exhalation. If it flows one way it is wind, in another it causes earthquakes..."

Seneca *Natural Questions* [Book 6.sect. 13.1]

"13. In the same group you may place Aristotle and his student Theophrastus, a man not of divine eloquence, as he seemed to the Greeks, but nevertheless of a smooth and clear eloquence without effort. I will set forth the theory they both liked; from the earth there is always some sort of evaporation which is sometimes dry sometimes mixed with moisture. This emanates from the depths of the earth; when it has risen as far as possible and does not have a higher place to go, it is carried back and is rolled up on itself. The conflict of air moving back and forth hurls aside all obstacles and, whether it is blocked or struggles out through narrow openings, it causes a moment and a disturbance of the earth."

Pseudo-Plutarch *Placita Philosophorum* [Book 3.chap 15.5]

"Aristotle alleges that there exists an all-encompassing cold around the earth, both above and below; for heat attempts to move upward, being light by nature. Therefore a dry exhalation which finds itself trapped in the earth tries to break out through the body of the earth. In so doing, it moves about shaking the earth."

Ammianus Marcellinus *The Roman History* [Book 17.chap 7.11]

"11. Now earthquakes take place (as the theories state, and among them Aristotle is perplexed and troubled) either in the tiny recesses of the earth, which in Greek we call suriggai, under the excessive pressure of surging waters; or at any rate (as Anaxagoras asserts) through the force of the winds, which penetrate the innermost parts of the earth; for when these strike the solidly cemented walls and find no outlet, they violently shake those stretches of land under which they crept when swollen. Hence it is generally observed that during an earthquake not a breath of wind if felt where we are, because the winds are busied in the remotest recesses of the earth."

Observations/Associations

Aristotle *Meteorologica* [Book 2.chap 8.366a6]

"...the majority of earthquakes and the greatest occur in calm weather."

Ibid. [Book 2.chap 8.366a9 - 13]

"...some earthquakes occur when a wind is blowing ... but these earthquakes are less violent."

Ibid. [Book 2.chap 8.366a14 - 15]

"Most major earthquakes occur at night, and those that occur in daytime at midday..."

Ibid. [Book 2.chap 8.366a24 - 27]

"...the severest earthquakes occur in places where the sea is full of currents or the earth is porous and hollow. So they occur in the Hellespont and Achaea and Sicily, and in the districts in Euboea where the sea is supposed to run in channels beneath the earth."

Ibid. Book 2.chap 8.366a35 - 366b1]

"...places whose subsoil is porous are shaken more because of the large amount of wind they absorb."

Ibid. [Book 2.chap 8.366b2]

"...earthquakes occur most often in spring and autumn and during rains and droughts..."

Ibid. [Book 2.chap 8.366b17]

"...some earthquakes being like a tremor, some like a throbbing."

Ibid. [Book 2.chap 8.366b32 - 367a8]

"...in some places there has been an earthquake which has not ceased until the wind which was its motive force has broken out like a hurricane and risen into the upper region...in Hiera, one of the so-called Aeolian Islands...part of the earth swelled up and rose with a noise in a crest-shaped lump; this finally exploded and a large quantity of wind broke out, blowing up cinders and ash..."

Ibid. [Book 2.chap 8.367b20 - 23]

"...an earthquake sometimes occurs at an eclipse of the moon. ...the earthquake before the eclipse."

Ibid. [Book 2.chap 8.367b34 - 368a1]

"When an earthquake is severe the shocks do not cease immediately or at once, but frequently go on for forty days or so in the first instance, and symptoms appear subsequently for one or two years in the same district."

Ibid. [Book 2.chap 8.368a26 - 27]

"Water has sometimes burst out of the earth when there has been an earthquake."

Ibid. [Book 2.chap 8.368b8 - 10]

"...there was a tidal wave at the same time as the earthquake -- an earthquake which was all the more violent because..."

Ibid. [Book 2.chap 8.368b14]

"Earthquakes are confined to one locality, often quite a small one..."

Ibid. [Book 2.chap 8.368b23 - 34]

"...when the quantity of wind is large it causes an earthquake shock which runs horizontally, like a shudder: occasionally in some places the shock runs up from below, like a throb. The latter type of shock is therefore the rarer... But whenever this type of earthquake does occur, large quantities of stones come to the surface, like the chaff in a winnowing sieve. This kind of earthquake it was that devastated the country round Sipylos, the so-called Phlegraean plain and the districts of Liguria.

Earthquakes are rarer in islands that are far out at sea than in those close to the mainland."

Seneca *Natural Questions* [Book 7.sect. 28.3]

"The comet which appeared in the consulship of Paterculus and Vopiscus did what was predicted by Aristotle and Theophrastus: for there were very violent and continuous storms everywhere, and in Achaia and Macedonia cities were destroyed by earthquake."

Precursors.

Aristotle *Meteorologica* [Book 2.chap 8.367a22 - 24]

"...before them the sun becomes misty and dimmer though there is no cloud, and that before earthquakes that occur at dawn there is often a calm and a hard frost."

Ibid. [Book 2.chap 8.367a26]

"Calm and cold towards sunrise and dawn are also necessary..."

Ibid. [Book 2.chap 8.367b9 - 10]

"In clear weather, either by day or a little after sunset, a fine long streak of cloud appears, like a long straight line carefully drawn..."

Ibid. [Book 2.chap 8.367b20]

"...an earthquake sometimes occurs at an eclipse of the moon."

Ibid. [Book 2.chap 8.368a14 - 15]

"Wind is also the cause of noises beneath the earth, among them the noises that precede earthquakes, though they have also been known to occur without an earthquake following."

Ibid. [Book 2.chap 8.368a19]

"The sound precedes the shock..."

Ibid. [Book 2.chap 8.368a24 - 25]

"...sometimes the earth seems to bellow as they say it does in fairy stories."

Seneca *Natural Questions* [Book 7.sect. 28.3]

"The comet which appeared in the consulship of Paterculus and Vopiscus did what was predicted by Aristotle and Theophrastus: for there were very violent and continuous storms everywhere, and in Achaia and Macedonia cities were destroyed by earthquake."

Influence on early modern thought.

1. Thomas Digges (London, 1576) -- cause of earthquakes is trapped wind.

Precursors:

a. "...fiery cloud, appearing in the [atmosphere] like a pillar..."
b. "...obscurity or darkness of the Sunne, without clouds, and strangely coloured..."
c. "...well water and others are troubled or salte, or infected by favour..."
d. "...great quietness of ayre, by land and sea, ...long absence of wyndes..."
e. "strange noises ... clamorous of men ... mornings, lamentations ... signify earthquakes at hand."

2. R. B. (London, 1694)

(p.2) "An earthquake is a shaking of the earth, occasioned by wind and exhalations inclosed within the caves and bowels of the earth, which can find no passage, or at least none long enough to discharge themselves, and therefore breaking forth with force and violence, it sometimes shaketh the earth, another while rendeth and openeth the flame, sometimes casting up earth at a great height into the air, otherwhile causing the ground to sink down a great depth, swallowing cities, town, palaces, castles, yea prodigious high mountains, leaving in the place nothing but deep holes or long and unfathomable lakes of water."

(pp.3-4) Four types of earthquakes:

1. "...the earth is shaken laterally..."
2. "...the earth is lifted up with great violence..."
3. "...the opening rending or gaping of the earth..."
4. "..., when great mountains arise ... or ... some part of the land sinketh down, ..."

(pp.4-6) precursors:

1. "...raging of the sea when there are no teptestuous winds to move it..."
2. "...water in the bottom of deep wells is troubled and infected with a sulpherous smell..."
3. "...the calmness and coldness of the air..."
4. "...a long thin strake of cloud seen when the sky is clear after sunset..."
5. "...the sun appeareth dim certain days before..."
6. "...the birds... sit trembling on the ground."
7. "...there are heard before, at, and after an earthquake great noises and sounds under the earth...terrible groanings and thunderings..."

3. Nathan Bailey (London, 1730)

(leaf ttt2, no pagination) "Earthquake, a violent shock or concussion of the earth, or some parts of it, caused by fire or hot vapours pent up in the bowels or hollow parts of it, which force a passage, and frequently produce dreadful effects, as the destruction of whole cities..."

Theophrastus

Theophrastus of Eresus: lived 372-287 BC; philosopher; pupil of Plato and Aristotle.

Extant Works: *Characters*
The History of Plants
On the Origin of Plants *[6 of 8 books survive]*
Mineralogy
Scientific Works" *[various titles]*

Lost Works: *Metaphysics*
On Marriage
Physical Opinions

Earthquake Notices/Fragments:

Seneca *Natural Questions* [Book 6. Sect. 13.1]

"13. In the same group you may place Aristotle and his student Theophrastus, a man not of divine eloquence, as he seemed to the Greeks, but nevertheless of a smooth and clear eloquence without effort. I will set forth the theory they both liked; from the earth there is always some sort of evaporation which is sometimes dry sometimes mixed with moisture. This emanates from the depths of the earth; when it has risen as far as possible and does not have a higher place to go, it is carried back and is rolled up on itself. The conflict of air moving back and forth hurls aside all obstacles and, whether it is blocked or struggles out through narrow openings, it causes a movement and a disturbance of the earth."

Ibid. [Book 7.sect. 28.3]

"The comet which appeared in the consulship of Paterculus and Vopiscus did what was predicted by Aristotle and Theophrastus: for there were very violent and continuous storms everywhere, and in Achaia and Macedonia cities were destroyed by earthquake."

Callisthenes

Callisthenes of Olynthus: lived 360?-327 BC; historian, probably not a natural philosopher.

Extant Works: *Hellenica [fragmentary]*
History of Alexander [fragmentary]
History of the Sacred War [fragmentary]

Lost Works: none known

Earthquake Notices/Fragments:

Seneca *Natural Questions* [Book 6.sect. 23.2]

"This theory[249] is accepted by others, as I mentioned a little above--if a crowd of authorities will impress you--but is also approved by Callisthenes, and he is a man not to be looked down upon. For he had outstanding intelligence and did not submit to the rage of his king."

Ibid. [Book 6.sect. 23.4]

"This Callisthenes, in books in which he describes how Helice and Buris were inundated--what disaster sent the cities into the sea or the sea into the cities--says what I said in an earlier section. Air enters the earth through hidden openings as it does everywhere and so also under the sea. Then, when the path through which it had descended is obstructed and the waters standing at the rear have cut off its return it is carried here and there and running into itself causes the earth to totter."[250]

Ibid. [Book 6.sect. 26.2 - 3]

"Philosophers, a credulous race, have also said, on Pindar's authority, that Delos did not have earthquakes. Thucydides says that Delos was previously indeed stable but had an

[249] 6.23.1: "The earth is naturally porous and has many voids. Air passes through these openings. When air in large quantities flows in and is not emitted it causes the earth to tilt."

[250] Seneca continues (6.23.4): "So, the regions close by the sea are the most frequently harassed. Accordingly, this power the sea has for moving the earth is assigned to Neptune. Anyone who has learned elementary literature knows that in Homer he is called the 'Earthshaker'." These thoughts are probably Seneca's own and not due to Callisthenes.

earthquake around the time of the Peloponnesian War. Callisthenes says that this happened at another time, too. 'Among the many prodigies,' he says, 'by which the destruction of the two cities, Helice and Buris, was foretold, especially notable were both the immense columns of fire and the Delos earthquake.' He wishes Delos to be understood as stable because it is placed upon the sea sand has hollow cliffs and porous rocks to give a way back for the air caught in them. And for this reason islands have firm ground and the closer cities come to the sea the safer they are."

Metrodorus

Metrodorus of Chios: lived in the fourth century BC; philosopher.

Extant Works: none

Lost Works: *On Nature*
"Origins and Customs of Ionia" [exact title unknown]
On Trojan Matters

Earthquake Notices/Fragments:

Seneca *Natural Questions* [Book 6.sect. 19.1 - 2]

"19. Let us listen, because we must, to Metrodorus of Chios stating what he prefers in giving his view. I do not permit myself to pass over even those opinions of which I disapprove, since it is better that there be an abundance of all views and to condemn the ones we disapprove of rather than omit them.

Well, what does he say? When someone sings into a large jar his voice vibrates and runs through the whole jar and resonates with a kind of quavering. Even though the voice is projected only slightly it none the less travels around impinging on and causing a disturbance in the surrounding jar. In the same way the vast caves hanging down under the earth have air of their own, which other air, as soon as it falls from above, strikes and agitates, the way those empty spaces I just mentioned vibrate when a shout is sent into them."

Pseudo-Plutarch *Placita Philosophorum* [Book 3. chap. 15.6]

"Metrodorus believes that no body being in its own proper and natural place can stir or move, unless something actually pushes or pulls it. The earth therefore (he says) being situated in its own place, naturally does not move, but parts of the earth are capable of movements."

Epicurus

Epicurus: lived 342?-270 BC; philosopher.

Extant Works: "Doctrine" [exact title unknown]
[also three letters and a will]

Lost Works: *On Nature*
[Diogenes Laertius lists 39 other titles]

Earthquake Notices/Fragments:

Lucretius[251] *De Rerum Natura* [Book 6.535 - 607]

"Now attend and learn what is the reason for earthquakes. And in the first place, be sure to consider the earth below as above to be everywhere full of windy caverns, nearing many lakes and many pools in her bosom with rocks and steep cliffs; and we must suppose that many a hidden stream beneath the earth's back violently rolls its waves and submerged boulders; for the facts themselves demand that she be everywhere like herself.

Since therefore she has these things attached beneath her and ranged beneath, the upper earth trembles under the shock of some great collapse when time undermines those huge caverns beneath; for whole mountains fall, and with the great shock the tremblings in an instant creep abroad from the place far and wide -- and with good reason, since when wagons of no great weight pass, whole buildings hard by the road tremble with the shock, nor less do [the wagons themselves][1] jump [when a stone in the road][252] jolts up the iron tires of the wheels on this side and that.

Sometimes also, when from lapse of time a huge mass is rolled forwards from the earth into some great and wide pool of water, the earth also is moved and shaken by the wave of water: just as a vessel sometimes cannot remain still, unless the water within it ceases to be moved about in waves to and fro.

Besides, when a wind gathering together through the hollow places beneath the earth throws itself forward from one quarter, and bears hard, thrusting with great force into the lofty caverns, the earth leans over in the direction of the wind's headlong force. Then those buildings which are built up above the earth, and each all the more, the more they tower up towards heaven, lean suspended, pushing forward in the same direction, and the beams

[251] Lucretius being an Epicurean, his views are considered to be those of Epicurus himself.
[252] The manuscripts (line 550) are corrupted in this passage and thus the reading is uncertain. The general sense is not in doubt.

dragged forward hang over ready to go. And yet people fear to believe that this great world has waiting for it some period of destruction and ruin, although they see the earth's mighty mass leaning over! Yet if the winds should never abate, no force could curb the world back or hold it back in its rush to perdition. As it is, because in turns they abate and gather force, and rally as it were and come back and then are driven back in retreat, for this reason the earth more often threatens to fall than it does fall; for it inclines forward and then again springs back, and after tumbling forward recovers its proper place in equilibrium. This then is how all buildings totter, the top more than the middle, the middle than the foundation, the foundation the merest trifle.

There is also another cause of the same great trembling, when wind or a very great force of air, either from without or arising within the earth itself, has thrown itself suddenly into the hollow places of the earth, and there in the great caverns first growls tumultuously and is carried whirling about, afterwards the force thus excited and driven outwards bursts forth, and at the same time cleaving the earth asunder makes a great chasm. This befell at Syrian Sidon, and came to pass at Aegium in the Peloponnese, when such an issue of air overthrew those cities with the earthquake that followed. Many another city wall has fallen by great quakings in the earth, many cities have sunk down to the bottom of the sea along with their inhabitants.

But if there is no breaking forth, yet the impetuous air itself and the furious force of wind is distributed abroad through the many interstices of the earth like an ague, and thus transmits the trembling; just as, when cold penetrates deep into our limbs, it shakes them, making them tremble and quake against our will. Therefore men shiver in their cities with a twofold terror: they fear the houses above, they dread the caverns below, lest the earth's nature loosen all asunder in a moment, or torn asunder open abroad her own gaping jaws, and in confusion seek to gorge it with her own ruins.

Therefore let them believe as they please that earth and sky will remain incorruptible, given in trust to life everlasting; and yet sometimes the very present force of peril applies this goad of fear also from one part or another, that the earth may be suddenly withdrawn from under their feet, and fall into the bottomless pit, followed by the whole sum of things utterly giving way, and then may come the confused ruin of the world."

Seneca *Natural Questions* [Book 6.sect. 20.5 - 7]

"Epicurus says that all these things can be causes and he tries several other causes. Also, he criticizes those who insist that some single one of them is the cause, since it is difficult to promise anything certain about theories which are based on conjecture. Therefore, as he says, water can cause an earthquake if it washes away and erodes some parts of the earth. When these parts are weakened they cease to be able to sustain what they supported when they were intact. The pressure of moving air can cause earthquakes; for perhaps the air inside the earth is agitated by other air entering, perhaps the earth receives a shock when some part of it suddenly falls and from this the earth takes on movement. Perhaps some part of the earth is sustained by a sort of column, and by a kind of piling, and when they receive flaws or give way the weight imposed on them trembles. Perhaps a warm quantity of moving air is changed to fire and like lightning is carried along with great destruction to things that stand in its way. Perhaps some blast pushes the swampy and stagnant waters and consequently either the blow shakes the earth or the agitation of the air increases by its very motion and, stirring itself up, travels all the way from the depths to the surface of the earth. At any rate, Epicurus is satisfied that air is the main cause of earthquakes."

Pseudo-Plutarch ***Placita Philosophorum*** [Book 3. chap 15.11]

"Epicurus keeps to his old tune; he says that it may be that the earth is shaken, and therefore moves and quakes, because it is rocked and beaten by the air underneath which is dense and of the nature of water. Also, it may be (he says) that, the earth being porous and hollow below, it is forced to tremble and shake by air that is trapped in these voids."

Diogenes Laertius ***Lives of Emminent Philosophers*** [Book 10.sect. 105 - 106]

" 'Earthquakes may be due to the imprisonment of wind underground, and to its being interspersed with small masses of earth and then set in continuous motion, thus causing the earth to tremble. And the earth either takes in this wind from without or from the falling in of foundations, when undermined, into subterranean caverns, thus raising a wind in the imprisoned air. Or they may be due to the propagation of movement arising from the fall of many foundations and to its being again checked when it encounters the more solid resistance of earth. And there are many other causes to which these oscillations of the earth may be due.' "

Zeno

Zeno of Cittium: lived 333-261 BC; philosopher.

Extant Works: none

Lost Works: *Republic*
Of Life according to Nature
Of Impulse, or Human Nature
Of Duty
Of Law
Of Greek Education
Of Vision
Of the Whole World
Of Signs
Pythagorean Questions
Universals
Of Varieties of Style
Homeric Problems
Of the Reading of Poetry
Handbook of Rhetoric
Solutions
Refutations
Recollections of Crates
Ethics

Earthquake Notices/Fragments:

Pseudo-Plutarch *Placita Philosophorum* [Book 3. chap 15.2]

"The Stoics say that moisture in the earth is rarefied and transformed into air, which forcibly escapes causing an earthquake."

Diogenes Laertius *Lives of Emminent Philosophers* [Book 7.sect. 154]

"Earthquakes, say they[253], happen when the wind finds its way into, or is imprisoned in, the hollow parts of the earth: so Posidonius in his eighth book; and some of them are tremblings, others openings of the earth, others again lateral displacements, and yet others vertical displacements."

[253] 'They' are the Stoics, a philosophical sect founded by Zeno of Cittium in about 310 BC. The opinions of the sect given here are almost certainly those of Zeno himself.

Strato

Strato of Lampsacus: flourished about 288 BC; philosopher, astronomer.

Extant Works: none

Lost Works: none known

Earthquake Notices/Fragments:

Seneca *Natural Questions* [Book 6.sect. 13.12]

"Strato is of the same school[254]. He especially cultivated this branch of philosophy and was an investigator of the nature of the universe. His decision is this: cold and heat always change into opposites. They cannot exist together. Cold flows into the place from which the force of heat has departed, and in turn heat exists in the place from which cold has been driven out.[255] "

[254] i.e., he agrees with the theory Seneca ascribes to Aristotle and Theophrastus (6.13.1): "...from the earth there is always some sort of evaporation which is sometimes dry sometimes mixed with moisture. This emanates from the depths of the earth; when it has risen as far as possible and does not have a higher place to go, it is carried back and is rolled up on itself. The conflict of air moving back and forth hurls aside all obstacles and, whether it is blocked or struggles out through narrow openings, it causes a moment and a disturbance of the earth."

[255] Seneca continues with the following supporting evidence (6.13.2 - 6): "It will appear to you from the following that what I say is true and that both move contrary to each other. "In the wintertime, when there is cold on the surface of the earth, wells are warm, and caves, and all the recesses under the earth, because heat gathers there yielding to the cold which possesses the upper regions. When the heat penetrates to the lower regions and accumulates there, as much as it can, it becomes stronger as it becomes denser. Here it comes upon other air which necessarily yields to it, packed as that cold air is and compressed into a corner. The same thing happens in an opposite way when a great quantity of cold is carried down into the caverns. The heat that hides there gives way to the cold and withdraws to the narrow passages and is driven along with great impetus because the nature of the two does not allow harmony or delay in the same place. Therefore, the air in its flight and desire to escape in any way pushes back and tosses about all that is close to it. And so, before the earthquake a roaring noise is usually heard from winds that are creating a disturbance underground. Otherwise it could not happen -- as our Virgil says:

> The ground bellows under our feet
> And the high ridges move--

unless this were the work of winds.

Then this conflict of the winds goes through the same phases alternately. There is an accumulation of heat and again its eruption; then what is cold is restrained and gives way but subsequently it will become more powerful. Therefore, while the force runs back and forth and the air moves here and there, the earth is shaken."

Posidonius

Posidonius of Apamea: lived 135-51 BC; philosopher, astronomer, mathematician, geographer; teacher of Asclepiodotus and Cicero.

Extant Works: none

Lost Works: *Against Zeno of Sidon*
Meteorologica
On the Ocean
On the Size of the Sun

Earthquake Notices/Fragments:

Seneca *Natural Questions* [Book 6.sect. 21.2]

"There are two ways in which the earth is moved, according to Posidonius. Each way has its distinctive term. One is a 'jolt underneath', when the earth is shaken by a jolt and moves up and down. The other is a 'tilt', when the earth leans to one side or the other like a ship.[256] "

Ibid. [Book 6.sect. 24.6]

"Thucydides says that around the time of the Peloponnesian War the island of Atalanta was either entirely submerged, or certainly most of it. Believe Posidonius that the same thing happened at Sidon. Yet there is no need of authorities in regard to this, for within our own memory lands have been torn apart by internal movement and regions have been separated and plains have disappeared."

Diogenes Laertius *Lives of Emminent Philosophers* [Book 7.sect. 154]

"Earthquakes, say they, happen when the wind finds its way into, or is imprisoned in, the hollow parts of the earth: so Posidonius in his eighth book; and some of them are

[256] Seneca continues by describing a third kind of motion (6.21.2): "I am of the opinion that there is also a third way, which is designated in our vocabulary. Our elders for good reason spoke about the earth's 'tremor', which is unlike the other two, for at such a time things are neither jolted not tilted but vibrated. In an event of this sort the result is minimal damage. In the same way, a tilt s far more destructive than a jolt, for unless a movement which restores the tilt rushes in quickly from the other side a collapse necessarily follows."

tremblings, others openings of the earth, others again lateral displacements, and yet others vertical displacements."

Asclepiodotus

Asclepiodouts: lived in the first century BC; Greek writer.

Extant Works: *Macedonian Military System*

Lost Works: "*Causes of Natural Phenomena*" [exact title unknown]

Earthquake Notices/Fragments:

Seneca *Natural Questions* [Book 6.sect. 17.3]

"What is said is also proved to be true by this: often when an earthquake occurs, if only some part of the earth is broken open a wind blows from there for several days, as happened--according to reports--in the earthquake which Chalcis suffered. You will find this in a work of Asclepiodotus, the pupil of Posidonius, where he deals with this very subject of phenomena in nature."

Ibid. [Book 6.sect. 22.2]

"Asclepiodotus reports: when rocks were torn from the side of a mountain and fell the buildings in the vicinity collapsed because of the resulting shock."

Seneca

Seneca: lived 4 BC to 65 AD. Seneca is the only ancient author known to have written a book dealing exclusively with earthquakes[257]. This work is lost. See Chapter 3 of Part I for life and works.

Earthquake Theory Quotations:

Seneca *Natural Questions* [Book 2.sect. 1.3]

"...an earthquake is caused by a blast, a blast is none the less air in motion."

Ibid. [Book 2.sect. 27.1]

"...an earthquake when the wind is obstructed and raging."

Ibid. [Book 5.sect. 14.4]

"When the air, searching for a way out, twists itself through these places, it necessarily kindles fire by its very friction. Then, as the flames spread more extensively, even any sluggish air that is present is rarefied and set in motion and seeks an outlet with great noise and violence."

Ibid. [Book 6.sect. 1.15]

" The earth stays together poorly and is disintegrated by many causes; it is permanent as a whole but its parts collapse."

Ibid. [Book 6.sect. 18.1 - 5]

"...the principal cause of an earthquake is air, swift by nature and changing from place to place. As long as it is not shoved and lurks in a vacant space, it lies harmless and is no trouble to surrounding areas. When a cause coming from outside stirs it up and pushes it together and drives it into a narrow space it merely gives way and shifts about if it is still permitted to do so. When the chance of getting away is cut off and it is beset on all sides

[257] see p.28-29 above.

then ... it rages, and after beating against these barriers a long time the air pulls them apart and hurls them aside, becoming more violent the stronger the obstacles with which it has struggled. Then when it has wandered around all that restrains it and is still unable to get out it rebounds from where it received the greatest impact and is either dissipated through hidden openings made here and there by the consequent movement itself of the earth or erupts through a new wound. Thus the great force of air cannot be checked, nor does any compact structure hold this wind. For it loosens any bond and carries every weight away with it and makes a space for itself, pouring through the smallest fissures. By the indomitable force of its nature air frees itself.

...what is shut in is no longer wind and that which is wind cannot be shut in. For whatever is in an enclosure is at rest and is stationary atmosphere; all wind is in flight."

Ibid. [Book 6.sect. 24.1]

" And I myself agree that the cause of this disaster is air. But I will argue about how this air enters the earth, whether through thin openings undetectable to the eyes or through larger and more extended openings, and whether it comes only from the depths or also through the surface of the earth."

Ibid. [Book 6.sect. 25.1]

" When moving air with great force completely fills an empty space under the earth and proceeds to struggle and think about a way out it repeatedly strikes the side-walls within which it lurks, over which cities are sometimes situated. These 'walls' are sometimes so shaken that buildings placed above them fall down, sometimes to such an extent that the walls which support the whole covering of the cave fall into the immense depths."

Ibid. [Book 6.sect. 25.3]

"... air accumulates under the earth in vast caverns..."

Ibid. [Book 6.sect. 25.4]

"... it appears that an earthquake spreads over only as much area as the cavity of empty space extends under the earth."

Ibid. [Book 6.sect. 27.2]

"... many death-carrying elements lie hidden in the depths. The very atmosphere there, which is stagnant either from some flaw in the earth or from inactivity and the eternal darkness, is harmful to those breathing it."

Ibid. [Book 6.sect. 31.2]

"...when the greatest tremor to spend its rage against cities and countries has been produced, another equal to it cannot follow."

Precursors.

Seneca *Natural Questions* [Book 2.sect. 27.1]

"... a deep rumble like the sound which precedes an earthquake..."

Ibid. [Book 6.sect. 13.5]

"... before the earthquake a roaring noise is usually heard from winds that are creating a disturbance underground."

Observations/Associations.

Seneca *Natural Questions* [Book 3.sect. 11.1]

"... rivers and streams... Their paths are often disturbed by an earthquake..."

Ibid. [Book 3.sect. 11.1]

"... rivers are [sometimes] shifted from one place to another by a vibration of the earth itself."

Ibid. [Book 6.sect. 1.1]

"... an earthquake...occurred in days of winter, a season which our ancestors used to claim was free from such disaster."

Ibid. [Book 6.sect. 1.3]

"... they say that a flock of hundreds of sheep was killed, statues were cracked, and some people were deranged and afterwards wandered about unable to help themselves."

Ibid. [Book 6.sect. 1.11]

" All places have the same conditions and if they have not yet had an earthquake, they none the less can have quakes."

Ibid. [Book 6.sect. 4.1]

"Let us ask, then, what it is that moves the earth from the depths, what pushes such a great mass of weight; what is stronger than the earth that by its force it can shake so great a load. Let us investigate why the earth sometimes trembles, sometimes collapses and sinks, now is divided into sections and gapes open; why in one place it preserves for a long time the gap caused by its destruction, in other places it quickly compresses it again. Why at one time does it channel within itself rivers of noteworthy size, and at another time causes new rivers to appear. Why does it sometimes open veins of hot water, sometimes makes the water cold, and sometimes emits fire through a previously unknown opening of a mountain or a rock, but at other times suppresses fires that have been known and famous for ages. An earthquake produces a thousand strange things and changes the appearance of places and carries away mountains, elevates plains, pushes valleys up, raises new islands in the sea."

Ibid. [Book 6.sect. 12.2]

"... when the earthquake occurred in Campania, even though it was the restless season of the winter, the air in the atmosphere remained still throughout the preceding days."

Ibid. [Book 6.sect. 17.3]

"...often when an earthquake occurs, if only some part of the earth is broken open a wind blows from there for several days..."

Ibid. [Book 6.sect. 21.2]

" There are two ways in which the earth is moved, according to Posidonius. Each way has its distinctive term. One is a 'jolt underneath', when the earth is shaken by a jolt and moves up and down. The other is a 'tilt', when the earth leans to one side or the other like a ship. I am of the opinion that there is also a third way, which is designated in our vocabulary. Our elders for good reason spoke about the earth's 'tremor', which is unlike the other two, for at such a time things are neither jolted not tilted but vibrated. In an event of this sort the result is minimal damage. In the same way, a tilt is far more destructive than a jolt, for unless a movement which restores the tilt rushes in quickly from the other side a collapse necessarily follows."

Ibid. [Book 6.sect. 24.3]

"... an earthquake is not in the earth's surface or around the surface but underneath, from the depths. ...it is probable that the earth is moved from far below and that air is formed there in huge caverns."

Ibid. [Book 6.sect. 24.5]

"... when the ground is opened by the enormous destruction of an earthquake, that gaping hole sometimes takes in and buries entire cities."

Ibid. [Book 6.sect. 24.6]

"...within our own memory lands have been torn apart by internal movement and regions have been separated and plains have disappeared."

Ibid. [Book 6.sect. 25.3]

"...an earthquake does not extend two hundred miles."

Ibid. [Book 6.sect. 26.1 - 2]

"I could have used, or misused, the authority of great men who report that Egypt has never had an earthquake. ...But Egypt does have earthquakes..."

Ibid. [Book 6.sect. 31.3]

" I consider this also worth recording, since it was observed by a very wise and respected man. He happened to be taking a bath when this earthquake occurred. He affirms that while in the bath he saw the tiles with which the floor was paved separate one from the other and come back together again, and that when the floor opened up water was taken into the joints and when it closed back together the water bubbled and was forced out. I have heard the same person telling that he saw earthen walls vibrating more gently and rhythmically than the nature of a hard substance permits."

Appendix A: Pseudo-Aristotle On The Cosmos

Introduction: As we have seen earlier, Aristotle's earthquake work is to be found in his *Meteorologica*. This is the only Aristotelian work concerning earthquakes which modern scholars consider genuine. However, there is another work which deals with earthquakes and is associated with the name of Aristotle. This is titled *On the Cosmos*[258] and is attributed to "Pseudo-Aristotle."

The date of the work is quite uncertain. It was probably composed between c.50 BC and c.140 AD.

It was not dealt with as a source, in Part I above, because there are no earthquake theories actually discussed in the work. One theory is briefly given, but this is intended to be only an overview of the theory of Aristotle. Rather, the value of this work for our study lies in an earthquake classification scheme which is given. The classification is qualitative, but it is also the most detailed such scheme which has come down to us from antiquity.

It still appears to be a common misconception that Aristotle classified earthquakes according to type of ground motion. The only such language to be found in the *Meteorologica*[259] is:

> "...when the quantity of wind is large it causes an earthquake shock which runs horizontally, like a shudder: occasionally in some places the shock runs up from below, like a throb. The latter type of shock is therefore the rarer..."

In no sense is this comparable, in concept or detail, to the classification scheme occurring in Pseudo-Aristotle.

Earthquake Quotations: The quotations are taken from the *Loeb* edition of Furley.

Quotation 1: Chap. 4, 395b33-396a17

"Often when a large quantity[260] from outside is confined within the hollows of the earth and cut off from exit, it shakes the earth violently, seeking an exit for itself, and

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[258] More commonly known by the Latin title De Mundo.
[259] Book 2.chap 8.368b23 - 34.

produces the effect that we call an earthquake. Earthquakes which shake the earth obliquely at a very acute angle we call *horizontal*; those which blast upwards and downwards perpendicularly are called *heaving earthquakes*; those which cause a settlement of the earth into hollows are called *sinking* earthquakes; and those which open up chasms and split the earth are called *splitting* earthquakes. Some, called *thrusting* earthquakes, overturn things with a single heave. Others cause recoil this way and that, and in the process of lurching to one side and rebounding again the things that are shaken are held and their effect is a sort of trembling. There are also *roaring* earthquakes, which shake the earth with a great din. There is often, also, a roaring of the earth without an earthquake, when the wind is not sufficient to shake the earth but lashes about enveloped in the earth with tumultuous force. The blasts of wind that enter the earth are recondensed also by the moisture that is hidden in the earth."

Quotation 2: Chap. 5, 397b24-397b30

"The earth, too, that is crowned with plants of every kind and bubbles with springs and teems with living creatures everywhere, that brings forth everything in season and nurtures it and received it back again, that produces a myriad shapes and conditions--this earth still keeps its never-aging nature unchanged, though it is racked by earthquakes, swamped by floods, and burnt in part by fires. All these things, it seems, happen for the good of the earth and give it preservation from age to age: for when it is shaken by an earthquake, there is an upsurge of the winds transfused within it, which find vent-holes through the chasms, as I have already said; when it is washed by rain it is cleansed of all noxious things; and when the breezes blow round about it the things below and above it are purified."

Quotation 3: Chap. 6, 400a24-400b1

"...the transient things on earth admit many alterations and conditions. For violent earthquakes before now have torn up many parts of the earth, monstrous storms of rain have burst out and overwhelmed it, incursions and withdrawals of the waves have often made seas of dry land and dry land of seas; sometimes whole cities have been overturned by the violence of gales and typhoons; flaming fires from the heavens once burnt up the Eastern parts, they say, in the time of Phaeton, and others gushed and spouted from the earth, in the West, as when the craters of Etna erupted and spread over the earth like a mountain-torrent."

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[260] of wind.

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