

THE SHAPE OF THE EARTH IN ARCHELAUS, DEMOCRITUS AND LEUCIPPUS*

1

Archelaus is an enigmatic figure among the Presocratics. Theophrastus considered him worthy of a special book; Aristotle was careful never to mention him. We are told repeatedly that he was Socrates' teacher, but nothing in the Platonic dialogues would imply such an affinity. One may guess that precisely this affinity has something to do with Plato's attitude, respectfully inherited by Aristotle. There were scandalous rumours, but we are hardly in a position to comment on them.¹

The evidence for Archelaus' teaching is scanty and sometimes puzzling. Only one fragment has been handed down to us. No direct quotation from Theophrastus has been preserved. Diogenes Laertius' account is brief and not without corruption. A note in Seneca is admittedly valuable; but it deals with a particular question of what causes earthquakes. The only exposition which presents Archelaus' teaching at some length is that in Hippolytus. And here we find a very strange report about Archelaus' doctrine of the shape of the earth. *Hip. Ref.* 1. 9. 4; 60 A 4 DK:

ἐπικλιθῆναι δὲ τὸν οὐρανὸν φησι καὶ οὕτως τὸν ἥλιον ἐπὶ τῆς γῆς ποιῆσαι φῶς καὶ τὸν τε ἀέρα ποιῆσαι διαφανῆ καὶ τὴν γῆν ξηράν. λίμνην γὰρ εἶναι τὸ πρῶτον, ἅτε κύκλῳ μὲν οὖσαν ὑψηλὴν, μέσον δὲ κοίλῃν. σημειῶν δὲ φέρει τῆς κοιλότητος, ὅτι ὁ ἥλιος οὐχ ἅμα ἀνατέλλει τε καὶ δύεται πᾶσιν, ὅπερ ἔδει συμβαίνειν, εἴπερ ἡ ὁμαλή.

A standard English translation runs as follows:

He says that the heavens are inclined, with the result that the sun gave light on the earth, made the air transparent, and the earth dry. For it was originally a marsh, being lofty around the edge and hollow in the middle. He adduces

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¹ Theophrastus' book: D. L. 5. 42; the teacher of Socrates: 60 A 1–3 DK, some affinity between Archelaus and Socrates is attested already by Ion of Chios, their contemporary; rumours: Aristox. fr. 52 b Wehrli; 60 A 3 DK.

as a proof of this hollowness the fact that the sun does not rise and set at the same time for all men, as would inevitably happen if the earth were flat.²

“Lofty around the edge and hollow in the middle” is a natural interpretation of the Greek text. But then what we hear about Archelaus’ demonstration of the shape of the earth is really strange. It was pointed out long ago that the testimony makes Archelaus “draw from the observed facts with regard to the rising and setting of the sun a conclusion the very opposite to the truth”.³ In Archelaus, “the sun would rise later, instead of earlier, as one approached the eastern rim of the cup, and set earlier, rather than later, near the western rim”⁴ and there would hardly be any difference for the inhabitants of the intermediate regions. In other words, Archelaus’ argument requires an earth which is shaped not like a cup, but like an inverted cup.

How was it possible “to draw conclusions precisely opposite to those which should have been drawn?”, asked Paul Tannery, without giving any answer.⁵ Thomas Heath cited Tannery’s question, again without any answer. William Heidel did not ask the question, though he recognised the difficulty. The problem was not tackled in Zeller,⁶ Berger,⁷ Gilbert,⁸ Gisinger,⁹ Frank¹⁰ or Burnet.¹¹ Nor does it make any appearance in Guthrie’s presentation.¹² Archelaus’ argument did not escape attention of D. R. Dicks; he did not recognise, however, the difficulty this argument involves.¹³

² G. S. Kirk, J. E. Raven, M. Schofield, *The Presocratic Philosophers* (Cambridge²1983) 387.

³ Sir Thomas Heath, *Aristarchus of Samos, the Ancient Copernicus* (Oxford 1913) 124.

⁴ W. A. Heidel, *The Frame of the Ancient Greek Maps: With a Discussion of the Discovery of the Sphericity of the Earth* (New York 1937) 78. In the words of Ptolemy, “if the earth were concave, the stars would be seen rising first by those more towards the west” (*Synt.* 1.4; G. J. Toomer’s transl.). Also Cleomedes (p. 29 Todd; 80 Ziegler) explains all this at length. Cf. *Mart. Cap.* 6. 591.

⁵ Paul Tannery, *Pour l’histoire de la science hellène* (Paris²1930) 288.

⁶ Eduard Zeller, *Die Philosophie der Griechen in ihrer geschichtlichen Entwicklung*, hrsg. von Wilhelm Nestle (Darmstadt⁷1963) 1, 1274.

⁷ Hugo Berger, *Geschichte der wissenschaftlichen Erdkunde der Griechen* (Leipzig²1903).

⁸ Otto Gilbert, *Die meteorologischen Theorien des griechischen Altertums* (Leipzig 1907) 285, n. 1.

⁹ F. Gisinger, “Geographie”, *RE* Suppl. IV, 521–685, esp. 545.

¹⁰ Erich Frank, *Plato und die sogenannten Pythagoreer* (Halle 1923) 187–89.

¹¹ John Burnet, *Early Greek Philosophy* (London⁴1930) 358 ff.

¹² W. K. C. Guthrie, *A History of Greek Philosophy* (Cambridge 1965) 2, 342 f.

¹³ D. R. Dicks, *Early Greek Astronomy to Aristotle* (Ithaca 1970) 77: “Archelaus apparently considered the earth not as a flat disc, but as a disc with a raised edge and a hollow middle part. This, he thought, explained why the sun does not rise and set at the same time in all regions, as it ought to be if the earth were level. Presumably the idea was that the sun would appear to rise and set at different times behind the raised outer rim according to the position of the

There is, I believe, a simple answer to Tannery's question: it is unlikely that Archelaus drew conclusions opposite to those he should have drawn. Archelaus could not cite as an *argument* a suggestion which implied that the sun rises earlier for the Greeks than for the Indians. Something is wrong, therefore, either with Hippolytus' text or with our understanding the information this text conveys.

As a matter of fact Archelaus' argument became a traditional – one might even say a textbook – argument for the convexity of the surface we live on and thus, in combination with other considerations, for the sphericity of the earth.

Ptol. *Synt.* 1. 4: “That the earth taken as a whole, is sensibly spherical can best be grasped from the following considerations. We can see that the sun, moon and other stars do not rise and set simultaneously for everyone on earth, but do so earlier for those more toward the east, later for those toward the west ... If the earth were plane, they would rise and set simultaneously for everyone” (after G. J. Toomer's transl.). A similar passage is found in Theon of Smyrna (p. 121. 1–5 Hiller): the risings and settings of the stars make manifest the sphericity of the earth, for they happen earlier in the eastern regions (κλίμασι) and later in the western ones. Again it is said in an introduction to the *Scholia in Aratum* (p. 26 Martin): “if the earth were flat, there would be no earlier risings and settings”. Cleomedes says (p. 28 Todd, p. 76 Ziegler) that if the earth were flat, there would be one and the same horizon for all people on the earth, and thus “the risings and settings would happen in the same way for all”. Manilius also employs this argument, though only with reference to the moon: “if the earth were flat, you would rise for the whole world only once and the failure of your light would be lamented by every land at the same time” (l. 228 f.; G. P. Goold's transl.), and it appears in Martianus Capella as well, though in somewhat inaccurate formulation (6. 591).

Thus the ancients used the argument properly, which strongly adds to the implausibility of supposing that Archelaus, its apparent originator, used it in a wrong way. A confirmation can be deduced from Hippolytus' own account. The continuation of the above quoted text from Hippolytus runs as follows:

On the subject of animals, he holds that when the earth was originally getting warm in the lower region (θερμαινομένης τῆς γῆς τὸ πρῶτον ἐν τῷ κάτω μέρει), where the hot and the cold were mingled, many animals began to appear, including men (Raven's transl.).

inhabitants on the slopes of the hollow part; again this is a recognizable attempt to accommodate theory to the facts of observation”.

There is no lower region on a spherical earth. On the other hand, if Archelaus' earth was a hollow cup, then life originated on the bottom of it, that is in the region, now occupied by the Mediterranean sea, most remote from the sun. This does not go well with common ancient notion of the role of heat in generating life. A report on Democritus' earth makes *southern* part of the earth, which is at the same time the *lower* part of it, especially proper for generating life (Ps.-Plut. *Plac.* 3. 12; quoted below, n. 22). Diodorus cites a well established view according to which the Ethiopians were the first of all men: indeed,

that those who dwell beneath the noon-day sun were, in all likelihood, the first to be generated by the earth is clear for all; since, inasmuch as it was the warmth of the sun, which, at the generation of the universe, dried up the earth when it was still wet and impregnated with life, it is reasonable to suppose that the region which was nearest the sun was the first to bring forth living creatures (3. 2. 1; cf. 1. 7. 4; C. H. Oldfather's transl.).

One can be certain that reasoning of that kind was already current in the fifth century since a symmetrical view is found in Herodotus (4. 5), who tells us that the Scythians are the youngest nation in all the world.¹⁴ It follows that Hippolytus' passage on the origin of life fits better with an earth conceived like an *inverted* cup or a tortoise's shell.

An earth shaped like an inverted cup can still be κοίλη, that is hollow. The body of such an earth might have been thought of as filled with air, which should prevent its sinking down. The idea was explained, or rather referred to, by Aristotle, its critic: "while the air, not having room enough to change its place because it is underneath the earth, stays there in mass, like the water in the case of the water-clock; and they adduce an amount of evidence to prove that air, when cut off and at rest, can bear a considerable weight" (*De Cael.* 294 b 18; J. L. Stocks' transl.). The theory of earthquakes attested for Archelaus (60 A 16 a DK) agrees well with the assumption that his earth was κοίλη in the specified sense (that is, hollow and filled with air), which points to a likely origin of Hippolytus' confusion of Archelaus' views.

One can see that Hippolytus' account in its standard, admittedly most natural, understanding is not only illogical, but also equivocal in its language.¹⁵ The crucial point, however, is that the considerations presented above can be supported by a direct testimony, hitherto overlooked, concerning the

¹⁴ Herodotus maintains that such was the opinion of the Scythians themselves, but this deserves no more credit than "the Medes' own account of themselves" in 7. 62.

¹⁵ κύκλω οὖσαν ὑψηλήν should not be connected with λίμνην γὰρ εἶναι τὸ πρῶτον, which refers to the original conditions. ἄτε is apparently due to a compiler's tendency to

shape of the earth in Archelaus. It comes from the *Turba Philosophorum*, a Latin alchemical treatise, based on an Arabic original (c. 900 A. D.) from which only fragments are known.¹⁶ The *Turba Philosophorum* depicts an assembly of Greek philosophers under the presidency of Pythagoras. Each philosopher delivers a shorter or longer speech. Despite fictitious character of the assembly and many anachronistic and arbitrary statements, the content of a number of speeches is based on ancient doxographic tradition.¹⁷ Thus the evidence of the *Turba Philosophorum* is not entirely to be dismissed. The evidence, in which Archelaus appears under the name of Arisleus, runs as follows: *Turba Philosophorum*, p. 57 Plessner:

Ait Arisleus: Scitote, quod terra est collis et non est plana, unde non ascendit sol super climata terrae una hora. Nam si plana esset, uno ascenderet momento super totam terram.

You should know that the earth is a hill and it is not level, hence the sun does not rise at the same time for the regions of the earth. If the earth were level, the sun would rise simultaneously above the whole earth.

Here everything seems to be in right place. The assumed shape of the earth and the argument to demonstrate it are in agreement and not in contradiction. The only unexpected detail is the *climata*. This term refers usually to different latitudes, to the variation of place along the north-south axis, whereas Archelaus' argument involves first of all the difference in time along the east-west axis. However, Theon (quoted above) speaks about earlier risings and settings "in the eastern κλίμασι", and the "four *klimata*", as referring to the four directions, was a formula in antiquity.¹⁸

connect various statements into a coherent text. λίμνην γὰρ picks up ξηράν and no further connection is necessary.

¹⁶ Text and German translation: Julius Ruska, *Turba Philosophorum: Ein Beitrag zur Geschichte der Alchemie* (Berlin 1931); text of the initial part with a running commentary: Martin Plessner, *Vorsokratische Philosophie und griechische Alchemie: Studien zu Text und Inhalt der Turba Philosophorum* (Wiesbaden 1975); see further: U. Rudolph, "Christliche Theologie und Vorsokratische Lehren in der *Turba Philosophorum*", *Oriens* 32 (1990) 111 ff.; Peter Kingsley, "From Pythagoras to the *Turba Philosophorum*: Egypt and Pythagorean Tradition", *Journal of the Warburg and Courtauld Institutes* 57 (1994) 1–13, esp. 9 ff.

¹⁷ Cf. the speeches of Anaximander, Anaximenes and Anaxagoras: pp. 36–52 Plessner.

¹⁸ Isid. *Etym.* 13. 1. 3 explains *quattuor climata mundi* as "east and west, north and south". Strab. 10. 2. 12 speaks about τὰ τέτταρα κλίματα in a similar way; cf. Iren. 3. 11. 8: τέσσαρα κλίματα τοῦ κόσμου; Georon. 1. 11. 1: ἀπὸ τῶν τεσσάρων κλιμάτων τέσσαρες ἀθθεντικοὶ πνέουσι ἄνεμοι. I cannot share the view of Ernst Honigmann, *Die sieben Klimata und die ΠΟΛΕΙΣ ΕΠΙΣΗΜΟΙ* (Heidelberg 1929) 4 according to which the notion of *klima* implies necessarily a spherical earth; hemisphere or a body like tortoise's shell is enough and even preferable since a

To sum up, there is admittedly little doubt about how Hippolytus understood what he said. But he read the original work of Archelaus no more than we do, and we are not obliged to perpetuate his mistake.

2

Our discussion of Archelaus' earth is still incomplete, for it should be not isolated from taking into consideration the testimonies about the shape of the earth in Democritus: *κοίλη* appears here once more.

Eus. *Praep. ev.* 15. 56 (Περὶ σχήματος γῆς); 68 A 94 DK; fr. 405 Luria: Λεύκιππος τυμπανοειδῆ. Δημόκριτος δισκοειδῆ τῷ πλάτει, κοίλην δὲ τῷ μέσῳ.

Ps.-Plut., *Plac.* 3. 10:

Λεύκιππος τυμπανοειδῆ. Δημόκριτος δισκοειδῆ τῷ πλάτει, κοίλην δὲ τὸ μέσον.

Ps.-Galen. 82; Dox. 633:

Λεύκιππος τυμπανοειδῆ τῷ πλάτει, κοίλην δὲ τῷ μεγέθει.

Exc. astron. cod. Vatic., p. 143 Maass, *Aratea*; 59 A 87 DK; fr. 405 Luria: ὅτι οὔτε κοίλη ἢ γῆς, ὡς Δημόκριτος, οὔτε πλατεῖα, ὡς Ἀναξαγόρας. *Aetius Arabus*, p. 181 Daiber:

Demokritus glaubte: sie ist schalenförmig in ihrer Breite, aber ihre Mitte ist concav.

The evidence does not cause much discrepancy among scholars. Common opinion about the shape of the earth in Democritus can be presented in the words of Guthrie: "He also said, like Archelaus, that it was concave".¹⁹ As far as I know, only Louis Löwenheim suggested that Democritus' earth was convex, but his only argument was that such a shape better agrees with the

spherical body has no "inclinations". It is worth noting that κλίματα of the earth appears in a testimony on Xenophanes' views (21 A 41 a DK) and that a book περὶ τῶν κλιμάτων is ascribed to Democritus (B 306 DK). Note also a formulation in Achilles (*Isag.* 1. 19, p. 47 Maass): κλίματα δὲ εἴρηται διὰ τὸ τὴν γῆν μὴ εἶναι ὁμαλήν, ἀλλ' ἔχειν ὅσον ἐγκλίματά τινα ὑψηλοτέρων ὄντων καὶ ταπεινοτέρων τῶν μερῶν αὐτῆς καὶ τὰς οἰκίσεις τῶν ἔθνων ἄλλας ἀλλαχοῦ εἶναι. As we remember, Archelaus' argument was aimed at proving that the earth μὴ εἶναι ὁμαλή.

¹⁹ W. K. C. Guthrie, *A History of Greek Philosophy*, 2, 422. Guthrie, following the path of Cyril Bailey, *The Greek Atomists and Epicurus* (New York 1964, first published in 1928) 151 f., contrasts the round earth of Leucippus with the elongated one of Democritus. But a δισκοειδῆ earth can hardly be elongated. We must assume that terms "earth" and "oikumene" have been confused in Agathemerus; if not, then Hipparchus' earth was not spherical, but trapezium-shaped! See *Geographi Graeci Minores*, ed. C. Müller, 2, 471: Πρῶτος δὲ Δημόκριτος, πολὺπειρος ἀνὴρ, συνείδεν, ὅτι προμήκης ἐστὶν ἡ γῆ, ἡμίολιον τὸ μήκος τοῦ πλάτους ἔχουσα: συνήνεσε τούτῳ καὶ Δικαίαρχος ὁ Περιπατητικός: Εὐδοξος δὲ τὸ μήκος διπλοῦν τοῦ πλάτους, ὁ δὲ Ἐρατοσθένης πλείον τοῦ διπλοῦ: Κράτης δὲ ὡς ἡμικύκλιον: Ἰππάρχος δὲ

phenomena, plus his assumption (again, simply taken for granted) that Leucippus' earth was hemispherical.²⁰

Let us now set the standard interpretation against other testimonies about the earth in Democritus. There are three additional ones in our sources. Namely, that the earth, according to Democritus, is supported by air, having a shape proper for such a support; that the earth occupies the centre of the cosmos and in the virtue of the equidistance remains in equipoise; that the earth is tilted (to use, provisionally, the standard rendering) towards the south.

(1) Aristot. *De Cael.* 294 b 14:

Anaximenes and Anaxagoras and Democritus give the flatness²¹ of the earth as the cause of its staying still. Thus, they say, it does not cut, but covers like a lid, the air beneath it. This seems to be the way of flat-shaped bodies: for even the wind can scarcely move them because of their power of resistance. The same immobility, they say, is produced by the flatness of the surface which the earth presents to the air which underlies it; while the air, not having room enough to change its place because it is underneath the earth, stays there in mass, like the water in the case of the water-clock. And they adduce an amount of evidence to prove that air, when cut off and at rest, can bear a considerable weight (J. L. Stocks' transl.).

(2) Ps.-Plut. *Plac.* 3. 15; 68 A 98 DK; fr. 403 Luria; cf. *Aet. Arab.*, p. 185 Daiber: According to Parmenides and Democritus, the earth stands fast in equilibrium because of the equal distance from all sides, having no reason for inclining in this rather than in that direction; thus it is only subject to trembles and not movement.

(3) Ps.-Plut. *Plac.* 3. 12; 68 A 96 DK; fr. 419 Luria; cf. *Aet. Arab.*, p. 181 Daiber: According to Leucippus, the earth slopes towards the southern parts because of the looseness of material in these parts, for because of the cold the northern parts became stuck fast, while the opposite ones were heated up. According to Democritus, because the southerly part of the surrounding [atmosphere] is weaker, the earth as it grew tilted in that direction; for the northerly parts are intemperate, the southern temperate, hence it grew heavier in the latter quarter where it is abundant in fruits and produce.²²

τραπεζοειδή, κτλ. The passage is correctly understood in Luria and in D. R. Dicks, *The Geographical Fragments of Hipparchus* (London 1960) 148; erroneously by Diels: see his translation of 68 B 15 DK. A parallel testimony of Eustathius (68 A 94 DK; fr. 407 Luria), who speaks about Democritus' elongated *oikumene*, leaves no room for doubt. In general, the question of an elongated earth in the Presocratics deserves a special treatment.

²⁰ Louis Löwenheim, *Die Wissenschaft Demokrits und ihr Einfluß auf die moderne Naturwissenschaft* (Berlin 1914) 99.

²¹ Literally "breadth", τὸ πλάτος.

²² Λεύκιππος παρεκπεσεῖν τὴν γῆν εἰς τὰ μεσημβρινὰ μέρη διὰ τὴν ἐν τοῖς μεσημβρινοῖς ἀραιότητα, ἅτε δὴ πεπηγότων τῶν βορείων διὰ τὸ κατεψύχθαι τοῖς

Contrary to the first impression, (1) and (2) are not incompatible.²³ (2) does not contradict the assumption that Democritus' earth was a disk with concave middle part. But (3) makes the whole picture odd, not to say absurd. If the earth is tilted, how would it not cleave the air, how would it make the air cut off? If the earth is tilted, the argument of the equidistance loses its elegance. In general, the picture of a tilted earth hanging in the middle of the spherical cosmos is bizarre, to say the least.

On the other hand, everything is in order if one assumes that the middle part of the earth is in fact convex and not concave. The earth is not tilted at all, but it is high north of us and slopes gently in all directions from its uppermost point (which is probably right below the northern celestial pole). The contrast of the cold and warm regions, which is invoked to account for the inclination of the earth in both Leucippus and Democritus, is perfectly compatible with a conical earth: the whole lower band of such an earth would be closer to the sun's orbit.

Why, then, there is particular reference to the inclination towards the *south*? First of all, it is by no means necessary that the related doxographic entry (Περὶ ἐγκλίσεως γῆς) reflects just an aspect of general question of the shape of the earth and not an independent problem. For such a problem is very easy to indicate. There was a wide-spread belief that the known part of the earth was sloping from the north towards the south, which was a logical conclusion from the established facts: a number of great rivers flow southwards through the plain and empty into the Pontus Euxinus, while a strong current from the Pontus itself moves water further south through the Propontis and the Hellespont.²⁴ Therefore particular preoccupation with the southwards inclination should not surprise us.²⁵

κρυμοῖς, τῶν δὲ ἀντιθέτων πεπυρωμένων. Δημόκριτος διὰ τὸ ἀσθενέστερον εἶναι τὸ μεσημβρινὸν τοῦ περιέχοντος ἀξιομένην τὴν γῆν κατὰ τοῦτο ἐγκλιθῆναι· τὰ γὰρ βόρεια ἄκρατα, τὰ δὲ μεσημβρινὰ κέκραται· ὅθεν κατὰ τοῦτο βεβάρηται, ὅπου περισσὴ ἐστὶ τοῖς καρποῖς καὶ τῇ αὔξει. The part on Democritus is given in Guthrie's translation. Also Kirk, *The Presocratic Philosophers*, 419 and David Furley, *The Greek Cosmologists* (Cambridge 1987) I, 141; 145 employ the tilt for the rendering of the idea. The reason why the earth happened to be inclined towards the south should not us concern here.

²³ See my "Ὁμοιος and ὁμοιότης in Anaximander and Thales", *Hyperboreus* 1 (1994) 1: 28–55, esp. 51 f.

²⁴ Aristot., *Meteor.* 354 a 14–32 (with a reference to a well-established view); Strab. 1. 3. 4.

²⁵ How is it possible, on such a theory of the earth's shape, that the Nile flows northwards? It was assumed that the Nile flows from the west (Hdt. 2. 33), and for its flow within the region of Egypt some local peculiarities could be invoked. In any case, the Nile presents no lesser difficulty for the standard interpretation of Democritus' earth. Note also that all geographical views denied by Herodotus are the views incompatible with the notion of a hill-like earth.

To provide modern readers with a clear illustration to the shape of such an earth, I would refer to a hat. The ancients would refer to a shield, with its convex middle and flattened outer part.

One would search in vain for comparison of the earth to a shield in Diels-Kranz. Nevertheless this comparison was preserved in mediaeval remains, both Arabic and Latin, of Greek doxographic tradition.

It is said in Yāqūt's *Mu'jam Al-Buldān*:

The ancients have disagreed as to the shape and form of the earth. Some of them have stated that it is flat-surfaced and spread out in four directions – in the east and in the west, in the north and in the south. There are among them those who have held that it is shaped like a shield, those who have held that it is shaped like a table, and those who have held that it is shaped like a drum. Some of them have alleged that it is shaped like a dome, similar to a hemisphere, and that the heaven is mounted upon its edges. Others have maintained that it is elongated like a stone cylinder or pillar.

One group has said that the earth stretches downward to infinity and that the heaven stretches upward to infinity. Another group has asserted that what is seen of the movement of the planets is but the movement of the earth and not of the celestial spheres. Others have maintained that the various parts of the earth hold each other. Some have stated that the earth is located in a void, and there is no end to that void. Aristotle has said that beyond the world there is vacuum great enough for the heaven to breathe in. Many of the ancients have alleged that the rotation of the celestial spheres over the earth holds it in the center from all sides.

As for the Mutakallimun, they too are in disagreement ...²⁶

I quoted the passage at length in order to make clear its context. This is the context of Greek doxographic tradition. Diverging opinions about the earth are divided into two groups, those of Islamic theologians, Mutakallimun, and those of the ancients. Almost all items among the opinions of the ancients are easy to identify. “Flat-surfaced” earth points to Anaxagoras, “like a table” to Anaximenes, “like a drum” to Leucippus, “like a stone cylinder” to Anaximander. That the earth “stretches downward to infinity” is a view attributed to Xenophanes. Infinite void reflects the view of either the Atomists

The northern ocean is impossible on such an earth. Hence Europe cannot be surrounded by the sea in the north, the Caspian Sea cannot be a gulf of the northern ocean, and the river Eridanus issuing into the northern sea as well as the Tin islands located there are also impossible – see Hdt. 4. 45; 1. 203; 3. 115.

²⁶ *The Introductory Chapters of Yaqut's Mu'jam Al-Buldān*, transl. and annotated by Wadie Jwaideh (Leiden 1959) 19–21.

or the Stoics. The opinion ascribed to Aristotle is not of course his own, but what he says about the cosmology of the Pythagoreans.

As to the particular point we are interested in, the comparison of the shape of the earth to a shield appears elsewhere in Arabic literature, again without any particular attribution.²⁷ An attribution, although hardly correct, is given in Pseudo-Bede's treatise *De Mundi Celestis Terrestrisque Constitutione*:

Nunc de forma terre disseramus, quam Anaxagoras rotundam et planam esse in modum ancilis volebat.

Now let us speak of the form of the earth, which Anaxagoras imagined to be round and flat in the manner of a shield.²⁸

The identification of the shield-like earth as that of Anaxagoras is problematic. Anaxagoras consciously rejected the idea of the earth's sphericity and advanced quite a sophisticated argument that the surface we live on must be essentially flat,²⁹ whereas the shield is not normally flat throughout, but convex in the middle. Furthermore, the theory of the Milky Way as attested for Anaxagoras requires an elongated earth. The confusion is easy to explain. The above quoted passage from a *codex Vaticanus* (p. 27) contrasts, and thus juxtaposes as well, Anaxagoras' and Democritus' notions of the shape of the earth. It is likely that some words have fallen out in the text of Pseudo-Bede or his source, with an effect similar to that in above quoted passage from Pseudo-Galen (p. 27), where Democritus' view is attached to Leucippus. The attribution to Anaxagoras being dismissed, the identification of the shield-like earth as that of Democritus is otherwise self-suggesting.³⁰

Now the comparison with a shield is ambiguous. The middle part of it is certainly hollow (κοίλη), but is it convex or concave? When a shield is put on the ground, its hollow part probably faces down and thus has concave shape. When one holds a shield to defend oneself, then it looks convex. A doxographer who epitomised Theophrastus and did not read the original work

²⁷ See Jwaideh's note *ad loc.* and Hans Daiber, *Aetius Arabus*, 429.

²⁸ Text and translation are from Pseudo-Bede, *De Mundi Celestis Terrestrisque Constitutione*, ed. and transl. by Charles Burnett (London 1985) 20 f.

²⁹ Aristot. *De Cael.* 293 b 24; cf. Mart. Cap. 6. 590–92 and further my "Anaxagoras' Argument Against the Sphericity of the Earth", *Hyperboreus* 3 (1997) 1: 175–78.

³⁰ Actually already suggested by Jwaideh who follows, however, Zeller's view that Democritus' earth was concave. Aristot. *Meteor.* 345 a 26 ascribes a common theory of the Milky Way to οἱ περὶ Ἀναξαγόραν καὶ Δημόκριτον. Such indiscriminate formulations in Aristotle repeatedly lack precision, and the doxographic tradition refers specifically Democritus' explanation of the phenomenon (A 91 DK; fr. 418 Luria).

of Democritus could easily commit a mistake.³¹ Another fact to be pointed out is that κοῖλος was used in Greek literature to emphasise *non-flatness* of a shield and thus to refer to its convex part. “The Egyptians carried ἀσπίδας κοίλας with broad rims”, says Herodotus (7. 89).³² In an Alcaeus’ poem κοίλαι ἀσπίδες lie on the floor (fr. 140. 12 Campbell). Aeschylus makes one of the Seven assaulting the Thebes cause rumour by the decoration of the hollow-bellied orb (κύκλος κοιλογάστωρ) of his shield (496). The Lusitanians, Strabo says (3. 3. 6), “have a small shield two feet in diameter, concave in front” (κοῖλον εἰς τὸ πρόσθεν). One may suggest that κοίλην δὲ τῷ μέσῳ of the doxographic tradition is a deceptive echo of Democritus’ comparison of the earth to a shield. And there is nothing to prevent us from the conclusion, argued above, that this shield was thought of to face by its hollow part up and not down.

3

It should be not concluded from our discussion that the notion of a concave earth was simply due to later confusions. Cleomedes knows a reason for the earth’s concavity. He says that such a shape was adopted by those who thought that water would not remain on the earth if the latter did not have the shape of a deep and hollow body (Cleomed., p. 27 Todd; 74 Ziegler; cf. Mart. Cap. 6. 590). It can be said, and should be said, that the authors like Cleomedes were not really interested in clearly antiquated ideas and therefore their presentation of out-of-date views must be taken with caution,³³ but the idea of a concave earth seems to appear in Plato. He makes fun in the *Phaed.* 99 b of a thinker (or thinkers) who “puts the air underneath the earth as a support, as if for a broad kneading-trough” (ὁ δὲ ὡσπερ καρδόπῳ πλατεία βάθρον τὸν ἀέρα ὑπερείδει). καρδόπος, be it here a kneading-trough or something else, is in any case a container and thus is “lofty around the edge

³¹ Note that the entry *On the shape of the earth* provides four metaphorical expressions attributed to four different persons without giving any explanation of the actual meaning of the metaphors, which are far from self-explanatory. Ἀναξιμανδρος λίθῳ κίονι τὴν γῆν προσφερῆ. Does it refer to a drum of a column or to a base? What is precisely the shape of the surface we live on? Ἀναξιμένης τραπεζοειδῆ. Even if one assumes that this means “table-like” and not “trapezium-shaped”, it remains unclear what kind of table, round or rectangular, is meant. Λεύκιππος τυμπανοειδῆ: see below.

³² Cf. George Rawlinson’s comments *ad loc.* J. E. Powell’s rendering “concave” in his *Lexicon to Herodotus* is not appropriate.

³³ Did anybody really maintain that the earth was cubical or pyramidal, as Cleomedes wants us to believe?

and hollow in the middle” (to use the language of Hippolytus’ account of Archelaus’ earth).³⁴

The idea of a high rim surrounding a concave earth is not surprising. There was widely accepted view that the earth is surrounded by the Ocean. Until the sphericity of the earth and its watery surface was not recognised or accepted, it was natural to look for a device to keep the Ocean within a frame, for water needs a container. The doxographic tradition regrettably has no word to clarify the issue. However, Plato’s Atlantis story mentions a “real continent” round the Ocean (*Tim.* 24 e – 25 a). The idea must be older than the *Timaeus*, for it makes no sense as applied to a spherical earth (accepted in the main part of the *Timaeus*). The notion of cosmic whirl (δίνη) provided an additional reason for a lofty rim, namely to protect us from the whirl.³⁵ Further, the currents from the north, mentioned above, on the one hand, and the Nile flowing towards the north, on the other hand, and geography of the Mediterranean basin in general could suggest a shape of this kind, and one can hear echoes of such a view.³⁶

Whatever are details of this intriguing tradition,³⁷ doxographers knew the idea of a concave earth, which could facilitate inadequate interpretation of the information, already truncated, they possessed about the views of Archelaus and Democritus.

³⁴ Burnet (*ad loc.*) suggested to “read καρδοπίω from Hesychius Καρδόπιον· τῆς καρδόπου τὸ πῶμα, ‘the lid of a kneading-trough’” because this would better correspond to ἐπι-πωματίζειν from the passage of the *De Caelo* 294 b 14 (quoted above). Burnet’s reading would fit well with my interpretation of the shape of the earth in Archelaus and Democritus, but I am not sure that καρδόπιον goes well with βάρθρον, the container itself rather than its cover is to be put on a support. Plato, then, alludes to a concave earth, if he does not have in mind an inverted container. Plato himself depicts in the *Phaedo* the part of the earth inhabited by us as one of the numerous concavities on the surface of a huge globe.

³⁵ We know about this only from badly preserved polemics (?) of Epicurus – fr. 26. 33, cf. 26. 26–27 Arrighetti. The idea of a surrounding lofty rim, however, is quite compatible with a flat or a shield-like earth, for neither the Ocean, nor the Whirl required making the earth hollow and concave in the middle like an amphitheatre.

³⁶ Aristot. *Meteor.* 352 b 27 says that Darius gave up digging the canal connecting the Red Sea with the Nile because it was found that the sea was higher than the land; a similar account gives Strab. 17. 1. 25. A scholium to Apoll. Rhod. credits Democritus with the view according to which the Nile flows ἀπὸ τοῦ κατὰ μεσημβρίαν ὑπερκειμένου πελάγους (68 A 99 DK; fr. 412 Luria; the name of Democritus is given apparently by mistake, the other sources ascribe to Democritus another view).

³⁷ Note that Xenophanes had something to say about “another earth in the concave hollow of the moon” (Lact. *Div. inst.* 3. 23: Xenophanes... dixit intra concavum lunae sinum esse aliam terram). The whole passage is absent from DK; Diels (Dox. 121, n. 1) mistakenly concluded that Lactantius’ report is nothing but a confusion of two Ciceronian remarks. Note also Diodorus’ report (2. 31. 7) on the shape of the earth according to the views of the

4

If Democritus' earth was not tilted, but had slopes, there is no reason to leave Leucippus' earth to hang oddly at an angle in the middle of the spherical cosmos. Leucippus' earth was τυμπανοειδής. “Drum-shaped” or “tambourine-like” is commonly accepted rendering.

Everything is clear for Guthrie: “the flat tambourine, which appears on vase-paintings, bas-reliefs, etc. was the commonest, if not the only, form of the instrument”.³⁸ All this may be true and yet inconclusive. The only passage I know where τύμπανον appears in connection with the shape of the earth presents it as a truncated cone and the place that the oikumene occupies on it is not the flat top, but one of the curved sides. The passage is found in Aristotle's *Meteorologica*, 362 a 33. *Tympanon* here is the segment of the terrestrial globe between the polar circle (in modernised terminology) and the tropic.³⁹ It is not necessary that this *tympanon* corresponds exactly to Leucippus' τυμπανοειδής earth. But this passage is enough to invalidate Guthrie's argument. The use of *tympanum* as an architectural term in Vitruvius (3. 5. 12 sq.; 4. 7. 5) can be cited to the same effect.⁴⁰ Moreover, another passage in Vitruvius may be revealing for our purpose. We are told that the craftsmen call *tympanum* an *inverted bowl*.⁴¹

Now there is no obstacle to concluding that Leucippus' earth was not tilted, but was rather gently sloping like a flattish hill – a conclusion compatible with Pseudo-Plutarch's wording: παρεκπεσεῖν τὴν γῆν εἰς τὰ μεσημβρινὰ μέρη. There is no evidence which speaks against this interpretation or makes it difficult. But if this interpretation is to be accepted, it reinforces in turn the conclusion that the middle part of Democritus' earth was also convex and not concave.

It follows, as it seems, that the main dispute as to the shape of the earth was not that between proponents of a spherical and flat earth respectively. Anaxagoras was apparently the last important thinker who believed in a flat

Chaldaeans: it is shaped like a boat and hollow (σκαφοειδῆ καὶ κοίλη). Interestingly, Bruno Meissner, “Babylonische und griechische Landkarten”, *Klio* 19 (1925) 96–100, esp. 99; *Idem. Babylonien und Assirien* (Heidelberg 1925) 2, 107 takes it as a reference to an *inverted* boat of the kind which Herodotus (1. 194) describes with the words “round like a shield”.

³⁸ 2, 422, n. 2.

³⁹ Many editions have illustrations, as, for instance, in *The Loeb Classical Library*.

⁴⁰ Cf. also τύμπανιον in Strab. 3. 4. 17 with H. L. Jones' note.

⁴¹ Vitruv. 9. 8. 5: namque aequaliter per id cavum influens aqua sublevat scaphium inversum, quod ab artificibus phellos sive tympanum dicitur (the manuscript *scaphum* was corrected by Turnèbe).

earth.⁴² The competition was between the doctrine of the earth's sphericity, on the one hand, and that of the earth with a *flat foundation*, on the other hand. Both schools agreed that we live on a slope.

One must note, of course, that Aristotle takes once the *τυμπανοειδής* earth as one with a flat surface. While discussing the shape of the earth, he says:

Some think it is spherical, others that it is flat and drum-shaped (*πλατεῖα καὶ τὸ σχῆμα τυμπανοειδής*). For evidence they bring the fact that, as the sun rises and sets, the part concealed by the earth shows a straight and not a curved edge, whereas if the earth were spherical the line of section would have to be circular (293 b 33; here and further Stocks' transl.).

The ingenious argument cited by Aristotle was advanced by Anaxagoras.⁴³ Aristotle's refutation is that "they leave out of account the great distance of the sun from the earth and the great size of the circumference, which, seen from a distance on these apparently small circles appears straight". However, Aristotle proceeds, they have another argument. "They say that because it is at rest, the earth must necessarily have this shape". And after a digression, the above quoted passage follows: "Anaximenes and Anaxagoras and Democritus give the flatness of the earth as the cause of its staying still, etc.". Now for the latter argument it is irrelevant whether the earth is like a drum or like a stocky cone, it must have a flat bottom and be significantly larger in breadth than in height. It is also irrelevant for this argument whether we live on the top or on a slope of such a body.

Aristotle's exposition is general and not very precise. The doxographic tradition associates the term *τυμπανοειδής* with Leucippus (67 A 1. 30; 26 DK). He is not mentioned by Aristotle; instead Aristotle names three thinkers for whom the doxographic tradition has something different. Nor does Aristotle make clear how the air is really cut off under the earth.⁴⁴ And what is actually his answer to the air-support argument? The answer is that it is not worth answering. "In general, our quarrel with those who speak of movement in this way cannot be confined to the parts", says Aristotle and proceeds to a further point in his discussion (294 b 31). It was clear for him that any shape of the earth other than spherical was out-of-date nonsense (cf. *Meteor.* 365 a 20–34). He had no reason to bother himself with a detailed presentation and refutation

⁴² He also was probably one of the very few. A truly flat earth is not attested unambiguously for another Presocratic.

⁴³ See above, n. 29.

⁴⁴ *ἐπιωματίζειν*, "to cover like a lid", goes back most likely to Anaximenes, in whom the celestial bodies did not go under the earth.

of a point of view he was not interested in. He could easily, therefore, associate Leucippus' term *τυμπανοειδῆ* with Anaxagoras' version of the notion of a flat-bottom earth. He did not write, after all, for future historians of Greek science and philosophy. As a result, the difference between the two kinds of flat earth, the one with a flat surface on which we live (the flat earth proper) and the other with a flat bottom, has been underestimated for centuries.

5

We return now to Archelaus' argument. How is it possible to know that the sun does not rise and set simultaneously for all people on the earth? Even Tannery did not raise this question. But such knowledge was in fact by no means trivial.

The idea itself was old. Anaximenes, followed by Xenophanes, held the view that disappearance of the sun is caused by increasing distance from it (13 A 6. 7 DK; 21 A 41 a DK). The necessary inference from this was that the sun would "set" for those farther towards the west later than for us; and vice versa it would "rise" earlier for those towards the east than for us. But here non-simultaneous risings and settings of the sun are an inference from a theory (a peculiar and soon abandoned one), not from an ascertained fact; it is other way round in Archelaus.

The same conclusion about risings and settings of the sun could and must have been drawn from observation (not just a theory) of unequal length of the day in various places – that is, in modern terminology, various latitudes. If a summer day in Olbia or Panticapaeum is longer than in Miletus or Athens, then it is impossible for the sun to rise and set simultaneously for the Greeks and for the Scythians. *Climata* in *Turba's* testimony may imply a reference to the four slopes of the earth's hill, but the inference from the variation of the length of the day would have been still not immediately obvious, whereas Archelaus' argument implies a reference to something entirely clear and unambiguous.

I find it more likely that Archelaus' confidence that the sun does not rise and set simultaneously for all people was based on precisely that kind of fact which is regularly referred to in the texts reproducing his argument, namely on simultaneous observations of solar eclipses in distant places. The texts regularly cite lunar eclipses as well, but the moon is not mentioned in either Hippolytus or the *Turba Philosophorum*.⁴⁵

⁴⁵ Solar eclipses are cited in Ptol. *Synt.* 1. 4 (though Ptolemy's emphasis is lunar ones); Cleomed. p. 28 Todd; 76 Ziegler; Plin. 2. 180; Mart. Cap. 6. 594. All these texts as well as Schol. in Arat., Theon and Manilius (mentioned above) cite lunar eclipses as well.

The preoccupation with solar eclipses marks the very beginning of Greek science.⁴⁶ Archelaus' teacher Anaxagoras seems to have made a remarkable use of solar eclipses for a further purpose, namely to determine the size of both the sun and the moon relative to the earth. He concluded, apparently from the breadth of the shadow cast by the moon during a solar eclipse, that the moon is about the size of the Peloponnese, while the sun is much larger.⁴⁷ It is thus less surprising that a disciple of Anaxagoras made another remarkable use of the same phenomenon, arriving incidentally at a conclusion refuting the teacher's view of the shape of the earth: but this is not unusual for early Greek science.

The main preconditions for the observations we are talking about were the existence of the Persian empire and contacts of the Greeks with the Persian court. We are in a position to be more specific about what kind of data could be available to Archelaus. Modern theory of eclipses allows conclusions sufficiently safe for our purpose.⁴⁸

One should probably not look for a solar eclipse, however spectacular, which reached its maximum phase at, say, 3 P. M. in Athens and at 4. 30 P. M. in Ecbatana or Persepolis, for this would hardly be consistent with what we can say about time recording among the Greeks at this period. One should rather select eclipses which were observed at sun-rise or sun-set; as such they could be observed, of course, in only one of two distant places. Sun-rise and sun-set eclipses would have provided clear points for comparison. Imagine a Greek telling a Persian that the sun had recently risen half-obscured (or became such very soon after it had risen). Imagine, then, their common surprise when they established that the sun suffered an eclipse at the same day in Ecbatana (or Susa, or Babylon) too, but in what was otherwise quite a usual morning; nothing indicated the forthcoming obscuration of the sun, which happened

⁴⁶ Dmitri Panchenko, "Thales's Prediction of a Solar Eclipse", *Journal for the History of Astronomy* 25 (1994) 275–88; idem, "Thales' Theory of Solar Eclipses and the Birth of Theoretical Science in Early Sixth-Century Ionia", *Hyperboreus* 2 (1996) 1: 47–124 (in Russian; English summary: 121–124).

⁴⁷ The idea that Anaxagoras used a lunar eclipse for his statement about the size of the sun was independently suggested by Martin L. West, *Early Greek Philosophy and the Orient* (Oxford 1971) 233, n. 1 and David Sider, "Anaxagoras on the Size of the Sun", *CP* 68 (1973) 128 f. Neither West nor Sider cite the crucial testimony, namely that which makes Anaxagoras assert that the moon is as large as Peloponnese (Plut. *De fac. in orb. lun.* 932 a: Αἰγυπτίους μὲν ἑβδομηκοστούδου οἶμαι φάναι μόνιον εἶναι τὴν σελήνην, Ἀναξαγόραν δ' ὅση Πελοπόννησος; not in DK). The eclipse which would have allowed Anaxagoras' estimation occurred on February 17, 478 B. C. (here and further calculations of eclipses by Marina Lukashova, Institute of Theoretical Astronomy, Russian Academy of Sciences, St Petersburg).

⁴⁸ See F. Richard Stephenson, *Historical Eclipses and Earth's Rotation* (Cambridge 1997).

when the sun was already relatively high in the sky. Reports of such a kind would not merely provide a clear point for comparison; they would also suggest immediately that the sun-rise or sun-set did not occur at the same time in various countries.

The eclipse of September 1, 488 B. C. is the most promising case. The sun rose obscured in Ionia (the maximum phase for Miletus 0. 932), while in Ecbatana (max. 0. 792), it began about one hour and reached its maximum about two hours after the sun-rise.⁴⁹ Archelaus was probably very young in 488 B. C., but some other solar eclipses should not have escaped his attention. The solar disk emerged obscured on October 4, 434 B. C. in Athens (max. 0. 735, 11 min. after the sun-rise). The obscuration was visible only about two hours after the sun-rise in Ecbatana (max. 0. 756). The Athenians maintained diplomatic relationships with the Persian empire in this period and Athenian ambassadors were sent from time to time to the court of the Great King.⁵⁰ The Athenians also maintained close relationships with the Bosporan kingdom.⁵¹ In Panticapaeum, its capital city, the eclipse of October 4, 434 B. C. was almost total (max. 0. 990) and as such must have been widely reported. But here, unlike in Athens, the sun rose as usual, the eclipse began a few minutes after the sun-rise, became visible somewhat later and reached its maximum 1 h, 8 min after the sun-rise.

The eclipse of August 3, 431 B. C. (max. phase in Athens: 0. 859) was accurately described by Thucydides: “During the same summer, at the beginning of the lunar month (apparently the only time when such an event is possible), and in the afternoon (max. at 17. 25), there was an eclipse of the sun, which took the form of a crescent, and than became full again; during the eclipse a few stars were visible” (2. 28, B. Jowett’s translation). But in Ecbatana the eclipse reached its maximum (0.934) a few minutes before the sun-set and the sun was still eclipsed when it set.

Thus there is no reason to doubt that the data necessary for Archelaus’ argument were available.⁵² The fact, that Aristotle in arguing the sphericity of the earth does not mention Archelaus’ demonstration of convexity of the surface we live on, need not mean that such a demonstration had not yet been

⁴⁹ The Persian kings usually spent the hottest part of the year in Ecbatana (Xen. *Anab.* 3. 5. 15; *Cyr.* 8. 6. 22; Athen. *Deipn.* 513 f.).

⁵⁰ Ar. *Acharn.* 64; cf. Strab. 1. 3. 1.

⁵¹ That this was already so in the 430 s is quite likely. See Georg Busolt, *Griechische Geschichte* (Gotha 1987) III 583–88; Karl Julius Beloch, *Griechische Geschichte* (Strassburg 21914) II. 1, 199 with n. 2; II. 2, 216.

⁵² The possibility that Archelaus observed the eclipses of 434 and 431 B. C. in Lampsacus and not in Athens makes little difference.

discovered. Just few of the authors cited above make any mention in arguing the sphericity of the earth of Aristotelian famous proof involving the shadow observed during lunar eclipses; yet they all lived after Aristotle. Apparently Aristotle did not want to use the argument of the rival school, the school which in fact denied the sphericity of the earth. In the course of time the rivalry lost its actuality, and Archelaus' argument was appropriated by the winners.

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Bibliotheca Classica Petropolitana

Согласно Ипполиту, Архелай учил, что Земля вогнутая, и в доказательство ее вогнутости ссылался на то, что “солнце восходит и заходит не одновременно для всех, что должно было бы происходить, если бы Земля была ровная”. Если Земля Архелая подобна амфитеатру, выходит, что обитатели Иберии увидят солнце взошедшим раньше, чем обитатели Индии. Как можно было прийти к такому парадоксальному заключению? Этот вопрос, поднятый еще Полем Таннери, до сих пор оставался без ответа. В статье доказывается, что парадокс на совести Ипполита (или более раннего доксографа), а не Архелая. Различные косвенные соображения подкрепляются прямым свидетельством, уцелевшим в средневековом алхимическом трактате “*Turba Philosophorum*”: согласно Архелая, Земля имеет форму холма. Сходную форму постулировал для Земли и Левкипп. Земля Демокрита, очевидно, походила на щит, обращенный кверху выпуклой стороной. Представление же о Земле как о плоском диске, судя по всему, не было влиятельным среди досократиков.