PHILOSOPHICAL TRANSACTIONS.

VII. *On the Eclipses of* Agathocles, Thales, *and* Xerxes.

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Section I. *Preliminary.—On the Elements of the Lunar Tables.*

1. Till the beginning of the present century, neither the mechanical theory of the moon's motion, nor the numerical determination of her principal elements, nor the lunar tables founded on these, were sufficiently accurate for the computation of a distant eclipse. And (perhaps in consequence of the evident imperfection of these essential grounds of calculation) the mode of treating chronological eclipses was, in most instances, extremely lax. The general result of these deficiencies is, that in any point of the slightest delicacy, the calculations made before 1810 are absolutely worthless.

2. The extension and general improvement of the lunar theory by Laplace, and in particular the determination of the secular equations depending on the square of the time, very greatly altered the state of lunar and chronological science. Partly by the stimulation of foreign academies, partly by individual enterprise, lunar tables were soon produced which embodied the principal results of the new theory, and which were founded on more numerous and more carefully reduced observations than had been used before. The extensive tables by Bürg, printed by the Bureau des Longitudes in 1806, and the smaller tables by Oltmanns from the same elements, printed in the fourth supplementary volume of the Berliner Jahrbuch in 1808, will long be remarked as important steps in lunar calculation.

3. The first valuable deduction which was drawn from these, in reference to chronological computation, was the series of calculations in the paper by our late Fellow, Mr. Francis Baily, "On the Solar Eclipse which is said to have been predicted by Thales," communicated to the Royal Society on 1811, March 14, and printed in the Philosophical Transactions for 1811. Although there can now be no doubt that the eclipse on which Mr. Baily fixed was a wrong one, yet this paper (the first, I believe,

of Mr. BAILY's astronomical publications) must be considered as possessing the highest value; for its due appreciation of the characteristic circumstances of a total eclipse, for its accuracy of computation, and for the caution and good faith with which the results are announced. Mr. BAILY, in the first place, pointed out that only a *total* eclipse could satisfy the account of HERODOTUS, and that a total eclipse *would* suffice. He lived to witness the total eclipse of 1842, but he observed it from a room of a house, where probably he could scarcely remark the general effect of the eclipse. I have myself seen two total eclipses (those of 1842 and of 1851), being on both occasions in the open country; and I can fully testify to the sudden and awful effect of a total eclipse. I have seen many large partial eclipses, and one annular eclipse concealed by clouds; and I believe that a body of men, intent on military movements, would scarcely have remarked on these occasions anything unusual. Mr. BAILY then, adopting BÜRG's tables, exhibited in detail the results of computation of the eclipses of B.C. 585, May 28; 583, October 1; 607, July 30; 597, July 9; 601, September 20; 603, May 18; 626, February 3; and 610, September 30; and stated that he had computed all the eclipses which seemed likely to have been visible in Asia Minor from B.C. 650 to B.C. 580. He found that only the eclipse of 610, September 30, passed over Asia Minor; that the centre of its shadow crossed the river Halys at its mouth, passing a short distance south of the Caspian Sea; and he adopted it as the true eclipse of THALES. But he then subjoined a computation which threw doubt on the whole. Upon applying the elements of the same tables to the computation of the eclipse of AGATHOCLES, B.C. 310, August 15, he found that they would not give a total eclipse for any place in which it was possible to locate AGATHOCLES at the time when, according to the historical record, the shadow passed over him. Mr. BAILY inferred from this that the tabular motion of the moon's node must be altered; and he admitted, as a probable effect of such an alteration, that the eclipse of B.C. 610 might be found insufficient for the history of HERODOTUS. But he confidently believed that no other eclipse between B.C. 650 and 580 would be made to pass centrally over any part of Asia Minor.

4. Since I first read this paper, I have always attached greater importance to the last portion of it than to any other part. It has always appeared to me that not the eclipse of THALES but that of AGATHOCLES ought to be considered as the true cardinal eclipse for chronology and lunar astronomy. And I have long since contemplated the recalculation of the latter eclipse with the view of obtaining correct elements for the computation of the former.

5. About the same time in which Mr. BAILY was employed in his calculations, Mr. OLTMANNS was also engaged (apparently without any knowledge of Mr. BAILY's labours) on the same subject. His paper was presented to the Berlin Academy on 1812, November 26, and is printed in the Berlin Memoirs 1812–1813. He points out (as Mr. BAILY had done) that a total eclipse is required: he insists also that it must have been visible as a large eclipse in Ionia; he then, using his own tables

(equivalent to Bürg's), exhibits the detailed elements of several eclipses, and finds that the eclipse of B.C. 610, September 30, was total on the Halys and at Erzeroum (a result agreeing precisely with Mr. Baily's), and, like Mr. Baily, he adopts that as the true eclipse of Thales. He then subjoins a very valuable table, exhibiting roughly the track of the central shadow in every eclipse, whether total or not (113 in number), as computed by means of the same tables, from B.C. 631 to 585.

6. The successive alterations in the adopted motions of the moon's node have been nearly as follows. I must premise that there is much confusion among the original writers, from the circumstance that some in speaking of secular motions refer that term to a Julian century, while others use an ordinary Gregorian century, which differs from the Julian by one day, and produces a difference of 3′ 16″·4 in the motion of the node. I have endeavoured to remove this obscurity by giving the motion in all cases for a Julian century.

	°	′	″
Lalande, in the third edition of his Tables, 1792, had made the secular regression of the moon's node	134	11	15
Laplace, in the Additions to the Connaissance des Temps, An. VIII., from Albatenius' discussion of Ptolemy, found that the motion was to be diminished to	134	8	25
Bürg and Oltmanns, 1806 and 1808, adopted	134	11	42
Bouvard, Monatliche Correspondenz, 1811, May, found from the discussion of numerous eclipses	134	9	42
Burckhardt's Tables, 1812, adopt	134	10	12
Oltmanns, Berliner Jahrbuch, 1817 (printed about three years earlier), found from eclipses in 1239 and 1241	134	10	28
Wurm, Zeitschrift für Astronomie, 1817, January and February, found from twelve ancient lunar eclipses	134	8	23·8
and from eight total or annular solar eclipses	134	8	25·6
Damoiseau's Tables, 1824, adopt	134	9	57·5

7. In the Berliner Jahrbuch, 1824, is a paper by Oltmanns, dated 1821, May 15, in which for the first time Mr. Baily's researches are mentioned. M. Oltmanns remarks that the close agreement between Mr. Baily's results and his own on the eclipse of Thales proves the correctness of their calculations; and then he proceeds to say that the researches of Bouvard, Burckhardt, and Wurm, as well as his own, show that the secular regression of the node must be diminished 2′ (or reduced to 134° 9′ 42″); that with this the eclipse of Agathocles was possible, supposing Agathocles near Cape Passaro; that to make the eclipse central there the regression must be further diminished (as I understand him) by 18″, and to make it barely possible it must be increased by 9″. But after insisting on the certainty of this correction of the node, and after having called attention to his former calculations on the eclipse of Thales, he never so much as hints that his former conclusions must now necessarily be erroneous. I am wholly unable to account for this extraordinary silence.

8. In the Ergänzungs-Heft to the Astronomische Nachrichten, published in 1849, Professor HANSTEEN has given a most interesting discussion of the total eclipse which occurred at the battle of Stiklastad, A.D. 1030, August 31. The certainty as to the exact spot on which this battle was fought, and the attainable precision of the astronomical determination (for the eclipse was annular when it commenced upon the earth, and the dark shadow was therefore extremely small at Stiklastad), will render this eclipse unusually valuable. Professor HANSTEEN infers from it the value of the secular regression of the node $134^\circ\ 8'\ 28''\cdot5$; but as it appears that in the calculation (which was avowedly made rather for the verification of history and chronology than for the correction of the lunar elements) BURCKHARDT's tables were used without alteration, and as we shall hereafter give reason for supposing that, in one important point, these tables are incorrect, this result is not entirely free from suspicion. It is much to be wished that Professor HANSTEEN would calculate this eclipse with special reference to the correction of the elements of the moon's motion.

9. In the year 1846, the reduction of the Greenwich Lunar Observations from 1750 to 1830 was nearly completed under my direction, and I was able to exhibit the apparent errors of the moon's epoch of mean longitude to Professor HANSEN. The immediate result of this was, that Professor HANSEN discovered two inequalities of long period in the moon's motion, produced by the attraction of Venus. Their formulæ are given in the Astronomische Nachrichten, No. 597. The values of the coefficients, as I understand, are not entirely free from doubt.

10. In a paper communicated to the Royal Astronomical Society on 1848, June 9, and printed in vol. xvii. of their Memoirs, I gave the principal results of the Lunar Reductions above cited. It is unnecessary to recapitulate here the corrections to the various elements of the moon's orbit for different years; I shall only remark, that though I do not doubt that the mean motion of the node may be found from them far more accurately than it was ever before found from meridional observations, yet I conceive it to be still open to correction from observations of distant eclipses. Indeed, the uncertainty, as to the part of the field of view at which the Greenwich observers in BRADLEY's time were accustomed to observe the moon's declination, leaves considerable uncertainty as to the place of the node.

11. In alluding to these corrections, it is proper to advert to the changes which their apparent values must receive from HANSEN's new inequalities. And first, as to the change in the correction to the moon's motion of mean longitude. HANSEN's inequalities affect the apparent error of epoch very differently in the first part and in the last part of the interval through which the reductions extend, the numerical amount of their influence going through a gradual change without repeated reversion of sign. For the time, therefore, through which the reductions extend, these inequalities produce an apparent alteration in the moon's mean motion; and therefore, when, in the comparison of observations with theory, they are duly taken into account, the resulting value of the moon's secular motion in longitude will be sensibly different

from that which would have been found if they had not been considered. This change is fully recognized in the paper in volume xvii. of the Royal Astronomical Society's Memoirs.

12. Secondly, as to the correction to the motion of the moon's node. The comparison, between an observed latitude of the moon (supposed near the node) and the corresponding tabular latitude of the moon as calculated from DAMOISEAU's tables, gives in fact a comparison between the true argument of latitude and DAMOISEAU's argument of latitude; and therefore it gives the sum of two corrections to two different elements of DAMOISEAU's tables; namely, the correction to DAMOISEAU's longitude of the moon, and the correction to DAMOISEAU's supplement of longitude of moon's node. And when, from the groups of results, we infer the secular correction to the motion of the argument of latitude, we have found the sum of two corrections; first, the secular correction to DAMOISEAU's mean motion of the moon, such as will best reconcile DAMOISEAU's longitude of the moon, unaffected by new inequalities, with the observed longitude of the moon, during the period to which the reductions apply; and, secondly, the secular correction to DAMOISEAU's regression of the node.

13. Now for the difference between DAMOISEAU's longitude unaffected by new inequalities, and the observed longitude, we must refer to the second column of the table, Royal Astronomical Society's Memoirs, vol. xvii. p. 35; and, comparing the first four numbers with the last four, we find the correction to DAMOISEAU's motion of the moon during 38·1 years $=-0''\cdot30$. But in page 54, the correction to DAMOISEAU's motion of argument of latitude during the same time is $-24''\cdot26$. Hence the correction to DAMOISEAU's regression of the node during that time is $-24''\cdot26+0''\cdot30=-23''\cdot96$, or the secular correction is $-62''\cdot9$. Applying this to DAMOISEAU's secular regression in a Julian century (namely, 134° 9′ 57″·5), we find the corrected regression 134° 8′ 54″·6, which is probably the most accurate that can yet be deduced from meridional observations.

14. But, in correcting DAMOISEAU's tables for further use, we must not apply the quantity $-62''\cdot9$ to his secular motion of argument of latitude. The moon's tabular longitude at any time, putting H for the value of HANSEN's inequalities at that time, will require (see page 36 of the same Memoir) the correction $+39''\cdot3\times$ number of centuries $+$H; and as the tabular supplement of node requires the correction $-62''\cdot9\times$ number of centuries, the tabular argument of latitude (which is the sum of moon's longitude and supplement of node) will require a correction equal to the sum of these two corrections, or $-23''\cdot6\times$ number of centuries $+$H. For a distant eclipse, the quantity H may be safely neglected.

15. Thirdly, as to the correction to the motion of the moon's perigee. The same considerations, in every respect, which have been used for determining the correction to the motion of node and to the motion of argument of latitude, are to be used for determining the correction to the motion of perigee and to the motion of mean anomaly. Thus, in p. 40 of the Memoir above cited, the apparent correction of motion

of anomaly in 38·1 years is $-12''\cdot03$: by the second column of the table on p. 35, the apparent correction of mean motion in the same time (the tabular values being unaffected by HANSEN's inequalities) is $-0''\cdot30$; hence the true correction to the motion of perigee (estimated as a regression) in 38·1 years is $-12''\cdot03+0''\cdot30=-11''\cdot73$. And the true correction to the moon's motion of mean longitude in 38·1 years is $+14''\cdot99$. Therefore the true correction to the motion of the mean anomaly in 38·1 years is $+14''\cdot99-11''\cdot73=+3''\cdot26$; and the true secular correction is $+8''\cdot56$. This supposes that HANSEN's inequalities in longitude are not accompanied with sensible inequalities in the place of perigee.

16. The position of the moon at any time, as affecting the circumstances of an eclipse, will depend on the moon's mean longitude, the longitude of perigee, and the longitude of node. The values of these three elements for any late year are known with very great accuracy (their values for certain years are given in the Memoir repeatedly cited); and the annual motions of mean longitude and longitude of perigee for a Julian century at the present time are very accurately known; in that of the longitude of node there is a very minute uncertainty. But the secular motion of each of these elements changes from century to century; and terms are thus introduced into the expression for each of these elements depending on the square and higher powers of the time. LAPLACE was the first who computed (from theory) the coefficients of these terms; and his numbers were adopted, with insignificant alterations, in BÜRG's and BURCKHARDT's tables. DAMOISEAU, on repeating the investigation, obtained different values for the coefficients; in particular, he introduced in the coefficient which relates to the place of perigee a change of such magnitude as very greatly to modify the circumstances of any calculated distant eclipse. PLANA and HANSEN, by independent investigations conducted in different ways, have in general confirmed these alterations; the result, however, of HANSEN's last investigation differs somewhat from that of his former investigation, though by a very much smaller quantity than the difference of each from LAPLACE's values. I shall give here the coefficients of the square of the number of centuries obtained by these writers; the signs of those numbers which relate to perigee and node being applicable to progression of perigee and regression of node. The reader must remark that a change of 1″ in the coefficient for mean longitude, of 9″ in that for longitude of perigee, or of 11″ in that for longitude of node, produces, in the moon's place for a perigeal eclipse at the time of THALES, an effect of about 10′, and that this will alter the place of the eclipse-shadow at a given time not less than 10° on the earth's surface.

LAPLACE, Mécanique Céleste, vol. iii. pages 237, 273, 274.

Coefficient for mean longitude	+10″·18
Coefficient for longitude of perigee	−30·55
Coefficient for suppl. longitude of node	− 7·49

BÜRG'S and BURCKHARDT'S Tables.

Coefficient for mean longitude	$+10''\cdot00$
Coefficient for longitude of perigee	$-29\cdot98$
Coefficient for suppl. longitude of node	$-\ 7\cdot35$

DAMOISEAU, Mém. Savans Etrangers, Third Series, tome i. p. 544, and Tables.

Coefficient for mean longitude	$+10''\cdot72$
Coefficient for longitude of perigee	$-39\cdot70$
Coefficient for suppl. longitude of node	$-\ 6\cdot56$

PLANA, Théorie de la Lune, vol. i. p. 724.

Coefficient for mean longitude	$+10''\cdot58$
Coefficient for longitude of perigee	$-40\cdot23$
Coefficient for suppl. longitude of node	$-\ 6\cdot79$

HANSEN, Astronomische Nachrichten, No. 443.

Coefficient for mean longitude	$+11''\cdot93$
Coefficient for longitude of perigee	$-39\cdot18$
Coefficient for suppl. longitude of node	$-\ 6\cdot49$

HANSEN, Astronomische Nachrichten, No. 597.

Coefficient for mean longitude	$+11''\cdot47$
Coefficient for longitude of perigee	$-36\cdot31$

(The coefficient for suppl. longitude of node is not computed).

17. I believe that I have now stated, without important omission, the progress of Lunar Theory, as bearing on distant eclipses, to the present time; and I shall now proceed with the special calculations of this paper.

SECTION II. *Methods of Computation adopted in this Paper.*

18. The tables used in these computations, for the sun's longitude and the obliquity of the ecliptic, are CARLINI's tables attached to the Effemeridi di Milano, 1833. The precepts of the tables have been strictly followed, with these exceptions; that from Table V. the number has been taken which corresponds to lunar syzygies, and the mean values of Table VI. and Table XIII. have been taken, and the sum of these numbers or $7''\cdot5$ has been used as a constant. The sun's semidiameter has been slightly altered for the change of excentricity of the earth's orbit. The sun's longitude is found for two adjacent hours, and is then changed into right ascension and north polar distance. The following error has been remarked in the printed tables: Table XXX., *for* $16'\ 44''\cdot10$ *read* $16'\ 34''\cdot10$.

19. The lunar tables employed here are the same (except in the epochs) as those used in the Reduction of the Greenwich Lunar Observations. With the exception

of some small inequalities and some small changes of coefficients, entirely insignificant in the computation of an ancient eclipse, they are the same as DAMOISEAU's tables.

20. The arguments which DAMOISEAU distinguishes by the letters u, x, t, z, y, are formed in the following manner. To DAMOISEAU's epochs, for the year in the nineteenth century which differs by a whole number of centuries from the year for which the calculation is to be made, are added the numbers in his Table II. for the whole number of centuries taken backwards, and the corrections for u and z given at the foot of that table, and the corrections proportional to the square of the time in Table III., and the motions for $12^{h}\ 9^{m}\ 21^{s}{\cdot}5$ (to reduce Paris civil time to Greenwich astronomical time), and the numbers for the month, day, and hour of Greenwich mean solar time. The numbers thus formed are called DAMOISEAU's Elements. It will be seen from this statement that I have adopted DAMOISEAU's coefficients of the terms depending on the square of the time. Then the following corrections are added. For u (the mean longitude), the secular motion is increased by $+1^{\backslash}\ 21^{\backslash\backslash}{\cdot}4$, reckoning the years from 1814; the same correction is applied to t (the moon's elongation from the sun). For x (the mean anomaly), the secular motion is increased by $+26^{\backslash\backslash}{\cdot}4$, reckoned from 1788. For y (the argument of latitude), the secular motion is increased by $-72^{\backslash\backslash}{\cdot}8$, reckoned from 1782. These are called, in the subsequent articles, the Greenwich Corrections. By the addition of these, values of u, x, t, z, y are formed which are called the Unvaried Greenwich Elements, and these are the fundamental arguments used for the calculation of the moon's places. The longitude and ecliptic polar distance thus found for a certain hour are altered by the horary motions found from the tables, and longitude and ecliptic polar distance are thus obtained for a second hour. These are converted into right ascension and north polar distance with the obliquity found in the solar calculations. The following error has been remarked in DAMOISEAU's tables: Table II., -2200 years, *for* $113^{g}{\cdot}6634$ *read* $113^{g}{\cdot}8634$.

21. With these right ascensions and declinations of the sun and moon, the circumstances of the eclipse have been computed by the use of WOOLHOUSE's methods in the Appendix to the Nautical Almanac, 1836.

22. The next step is, to examine the effect of a possible change of elements. And here it may be remarked, that when the track of an eclipse is not highly inclined to the parallel upon the earth (which is true with regard to the eclipses here under consideration), a small change in the moon's longitude produces little effect in the track of the eclipse. Partly for this reason, and partly because the place of node appears liable to the greatest uncertainty, I have recognized no error in the moon's place except as depending on a possible error in the argument of latitude. In order to take account of this, I have in each calculation increased the argument of latitude by $20^{\backslash}$ centesimal; and this changed element, taken in combination with the other elements unchanged, constitute the system which I call "Elements with Variation." With this new system of elements, the moon's place is computed and the track of the central part of the shadow is computed, exactly as with the "Unvaried Greenwich Elements." The breadth of the shadow, as laid down on an ordinary chart, is

assumed to be the same as with the "Unvaried Greenwich Elements." The further inferences, as to the multiple, positive or negative, of "variation" (always using that word in the technical and precise sense of "increase of argument of latitude by 20\"") which is best adapted to the circumstances of the problem, are deduced by graphical process, as will be seen hereafter.

23. The whole of the calculations have been made by Mr. H. Breen, Assistant at the Royal Observatory. I have every reason to trust in their accuracy.

Section III. *Eclipse of* Agathocles.

24. The account given by Diodorus, lib. xx., and supported in all important particulars by that of Justin, lib. xxii., is as follows. Agathocles, being blockaded in Syracuse by the Carthaginian fleet, secretly formed the design of invading the Carthaginian territories, and placed men on board ships in the harbour, but was unable for several days to pass the enemy's fleet. At length a convoy of provision-ships appeared; the blockading ships left their station to attack the convoy; Agathocles took the opportunity of leaving the harbour; the Carthaginians immediately left the convoy and followed him; he escaped with difficulty under cover of night; and "the next day there was such an eclipse of the sun that the day wholly put on the appearance of night, stars being seen everywhere." After he had sailed "six days and the same number of nights" he made the African shore, and again barely escaped a Carthaginian fleet (it does not appear whether it was the same as that which had blockaded Syracuse; it was probably a different fleet); and landed at a place called "The Quarries." He shortly took two cities, of which the second (White Tunis) was 2000 stadia from Carthage; it does not appear however whether the distance from Carthage was measured in the most direct line or in reference to the route afterwards pursued by Agathocles; and there is no mention of the distance or direction of the city from the landing-place. It is stated by Diodorus that the troops, before sailing, supposed that they were to make an attack either on Italy or on the Carthaginian part of Sicily; and by Justin, that, while on the voyage, they supposed that they were going on a marauding expedition either to Italy or to Sardinia.

25. The eclipse was evidently total; and the principal task which remains for us, in order to render this eclipse available for the correction of the lunar tables, is, to investigate from these materials the probable place of Agathocles when the shadow passed over him. The first thing is, to discover the position of his landing-place. Mr. Baily supposed this to be in the Gulf of Khabes. By the assistance chiefly of Captain William Henry Smyth, R.N., I am enabled to indicate, and (as I conceive) with perfect certainty, a very different locality. On the west of Cape Bon, at a place called Alhowareah, are quarries of immense extent, proceeding from the sea cliffs and worked into the solid rock, and lighted by holes from above. They are undoubtedly the quarries from which Utica and Carthage were built. "Alhowareah" appears to be a corruption of the Roman name "Aquilaria;" the place at which Curio

landed B.C. 49. It would appear to have been a usual place of landing, at least in coming from Sicily. It is said to be a well-sheltered harbour (which indeed is implied by its use as a shipping port for such large quantities of stone); and the great height of Cape Bon renders it an admirable point to approach from the sea. There can be no doubt that Alhowareah is the place where AGATHOCLES landed. In some maps there is marked in this district a valley called "Wady Abiad," "the white valley;" it is possible that White Tunis may have been situate here.

26. The adoption of Alhowareah as the landing-place of AGATHOCLES leaves the question open whether AGATHOCLES sailed on the north side of Sicily or on the south side. I am entirely indebted to J. W. BOSANQUET, Esq. for the suggestion that AGATHOCLES may possibly have passed the straits of Messina and sailed on the north side of Sicily; and I am also indebted to that gentleman for the heads of the following reasons for supposing that AGATHOCLES really did take the northern course.

(A.) The distance from Syracuse to Alhowareah by the southern route is about 200 nautical miles; that by the northern route about 330 miles. Either of these distances is considerably less than we should expect a fleet to traverse in six days and nights (according to the usual rate of sailing of ancient ships); and, so far, the northern route, as being the longer, is the more probable of the two.

(B.) Selinus, Himera, and other towns in the extreme west of Sicily, had always been Carthaginian. Agrigentum had been maintained in the Carthaginian interest even before the battle of Himera. After that battle, all the Greek cities on the northern coast, and all north of Syracuse on the eastern coast, and even Camarina on the south, submitted to the Carthaginians. Gela alone was firm in the interest of Syracuse. The predominant party there was supported by a Syracusan garrison; and the town was so strongly fortified as to defy the attack of HAMILCAR. The expression "campi Geloi" of VIRGIL, contrasted as it is with "Acragas magnanimûm generator equorum," seems to imply a great breadth of corn-lands; and we know from DIODORUS that the harvest was just gathered in. It cannot, I think, be doubted that the provision-ships, whose approach drew off the attention of the blockading ships, were coming from Gela; in that case, they approached from the south; the blockading ships therefore started towards the south to attack them; and AGATHOCLES, as soon as he passed out from the mouth of the harbour, necessarily went towards the north.

(C.) The belief of the troops that they were on their way to Italy or Sardinia implies that they were on the northern route.

27. I have no doubt that AGATHOCLES did really take the northern course. But as the usual opinion is that he took the southern course, I think it proper to exhibit the results of calculations made on both suppositions. As we do not know the hour of day at which AGATHOCLES sailed out of harbour, and as we have no information on the comparative rate of sailing on the different days, we cannot judge very precisely on the place of AGATHOCLES at the time of the eclipse ($7\frac{1}{2}$ A.M. on the next morning). But it seems likely that the following may be near enough to the truth:

Possible northern position of AGATHOCLES at the time of the total eclipse . . . . Latitude 37° 55′. Longitude E. 15° 30′.
Possible southern position . . . . Latitude 36° 35′. Longitude E. 15° 0′.

28. The calculations of the places of the sun and moon are made in the manner described above, for the times —309, August 14, 19^h and 20^h, Greenwich Mean Solar Time (or, in civil reckoning, B.C. 310, August 15, 7^h and 8^h A.M.). The following are the fundamental arguments of the moon's place for —309, August 14, 20^h, G.M.S.T.

	u.	*x.*	*t.*	*z.*	*y.*
	g	g	g	g	g
DAMOISEAU's Elements	149·64068	26·1319	395·6437	283·4513	1·6953
Greenwich Corrections	—·25737	—·0554	—·2574	....	+ ·1522
Greenwich Unvaried Elements......	149·38331	26·0765	395·3863	283·4513	1·8475
Elements with Variation	149·38331	26·0765	395·3863	283·4513	2·0475

With the Greenwich Unvaried Elements, the following places are obtained:—

	19^h.	20^h.
	° ′ ″	° ′ ″
Obliquity of Ecliptic..................................	23 43 42·0	
Sun's Longitude..	136 33 57·6	136 36 24·1
Sun's Right Ascension	139 4 59·5	139 7 24·7
Sun's North Declination	16 3 39·0	16 2 54·4
Sun's Semidiameter	15 56·7	
Moon's Longitude.....................................	136 1 19·8	136 38 52·6
Moon's North Latitude..............................	16 17·3	19 45·6
Moon's Right Ascension	138 37 44·4	139 16 8·1
Moon's North Declination	16 29 3·3	16 20 58·4
Moon's Equatorial Horizontal Parallax	61 1·4	
Moon's Geocentric Semidiameter..................	16 40·1	
Sun's True Right Ascension, in time	....	9^h 16^m 29^s·65
Sun's Mean Right Ascension, in time............	....	9^h 14^m 10^s·76

From these, the following numbers are deduced:—

Greenwich Mean Solar Time of conjunction in R.A. —309, Aug. 14^d 19^h 45^m 27^s.
R.A. of Sun and Moon at conjunction . . . . 139° 6′ 49″·5.
Sun's North Declination at conjunction . . . . 16° 3′ 5″·2.
Moon's North Declination at conjunction . . . . 16° 22′ 56″·1.
Greenwich Mean Solar Time of Middle of General Eclipse . . . . 19^h 52^m 28^s.

Using $\frac{1}{300}$ for the earth's compression, the following coordinates of points on the earth's surface are obtained; which it must be remembered are deduced from Greenwich Unvaried Elements.

Points on the central path of the shadow.

Greenwich Mean Solar Time.	East Longitude.	North Latitude.
h m s	° ′	° ′
18 20 0	7 2	34 37
18 22 30	10 56	35 29
18 25 0	14 15	36 9
18 27 30	17 10	36 41
18 30 0	19 50	37 8

Points on the limits of the total shadow.

Northern Limit.		Southern Limit.	
East Longitude.	North Latitude.	East Longitude.	North Latitude.
° ′ 5 53	° ′ 35 14	° ′ 8 5	° ′ 34 0
9 57	36 9	11 49	34 49
13 24	36 51	15 2	35 27
16 25	37 24	17 52	35 58
19 9	37 52	20 27	36 23

29. From the Elements with Variation the following numbers are obtained:—

	19h.	20h.
Moon's Longitude..................	° ′ ″ 136 1 17·2	° ′ ″ 136 38 50·0
Moon's North Latitude............	17 13·8	20 42·2
Moon's Right Ascension	138 37 59·7	139 16 23·5
Moon's North Declination	16 29 58·3	16 21 53·2

Greenwich Mean Solar Time of conjunction in R.A. —309, Aug. 14^d 19^h 45^m 2^s.
R.A. of Sun and Moon at conjunction . . . . 139° 6′ 48″·5.
Sun's North Declination at conjunction . . . . 16° 3′ 5″·5.
Moon's North Declination at conjunction . . . . 16° 23′ 54″·3.
Greenwich Mean Solar Time of Middle of General Eclipse . . . . 19^h 52^m 24^s.

Coordinates of Points on the central path of the shadow.

Greenwich Mean Solar Time.	East Longitude.	North Latitude.
h m s 18 20 0	° ′ 5 50	° ′ 35 21
18 22 30	9 55	36 16
18 25 0	13 22	36 58
18 27 30	16 23	37 32
18 30 0	19 7	38 0

The breadth of the shadow, as marked on an ordinary map, for the Elements with Variation, will not sensibly differ from that for Greenwich Unvaried Elements.

30. The results of these calculations are laid down on the first map accompanying this paper, Plate XII. The large dots show the two possible positions of Agathocles. The strong line shows the central path of shadow, and the faint dotted lines show the limits of the dark shadow, from Greenwich Unvaried Elements. The interrupted line shows the central path of shadow from Elements with Variation (the term "Variation" signifying an increase of the Mean Argument of Latitude by $0^{g}·20$). The other lines show the positions of the central path of shadow necessary for satisfying respectively the four following conditions:—1. that the Northern boundary of the shadow will touch the Southern position of Agathocles; 2. that the Northern boundary will touch the Northern position; 3. that the Southern boundary will touch

the Southern position; 4. that the Southern boundary will touch the Northern position. The shaded irregular ovals are intended merely to show the breadth of the dark shadow in the direction transverse to the path of shadow, without any relation to the extent of shadow at any one instant in the direction of the path.

31. From an inspection of this map, with some geographical measures, the following conclusions will be easily deduced:—

(*a.*) With Unvaried Elements, the dark shadow passes over the Southern position of AGATHOCLES, but not over the Northern position.

(*b.*) In order that the eclipse may be total at the Southern position, the change of Mean Argument of Latitude must be included between those corresponding to Condition 1 and Condition 3, or between

$$-0{\cdot}55 \times \text{Variation and } +1{\cdot}14 \times \text{Variation.}$$

(*c.*) In order that the eclipse may be total at the Northern position, the change must be included between those corresponding to Condition 2 and Condition 4, or between

$$+0{\cdot}68 \times \text{Variation and } +2{\cdot}38 \times \text{Variation.}$$

The latter is the system of limitations which, for reasons already explained, I am disposed to adopt.

32. Assuming the uncertainty in the circumstances of an eclipse to be due entirely to uncertainty in the place of the moon's node, these statements supply us with an easy method of correcting (within certain limits) the elements for any other eclipse, according as we adopt one or the other position of AGATHOCLES. It is only to be remarked that if, in making the application to another eclipse, we adopt in the calculations for that eclipse (as will be convenient) a Variation of $0^{g}{\cdot}20$, then the factors corresponding to these Conditions must be increased in the same proportion as the interval of time backwards from the present age (when the place of the node is well known) to the age of the eclipse in question. Thus in applying them to the eclipse of THALES we must increase the factors by about $\frac{1}{7}$th part.

SECTION IV. *Eclipse of* THALES, *as recorded by* HERODOTUS.

33. The account of this eclipse given in the first book of HERODOTUS is in substance as follows. "Upon the refusal of ALYATTES (king of the Lydians) to give up some Scythian fugitives to CYAXARES (king of the Medes), the Lydians and the Medes were at war for five years; during which the Medes often defeated the Lydians and the Lydians often defeated the Medes; they had also in this war a sort of night-battle; and while they were still carrying on the war with equal success, and met for battle in the sixth year, it happened that on the battle being joined the day suddenly became night. THALES the Milesian predicted to the Ionians that this change would happen, fixing beforehand this very year, in which the change did occur. The Lydians and the Medes, when they saw that it was night instead of day, ceased from fighting, and on both sides endeavoured more anxiously to obtain peace.

The persons who brought them together were SYENNESIS the Cilician and LABYNETUS the Babylonian."

34. It is to be remarked that this war was one of a different character from that which was subsequently undertaken by CRŒSUS and which ended in his ruin. The war of ALYATTES was a struggle between two nations, in which the Medes apparently made the first movement; and though it is impossible to say how far in so long a time the places of conflict may have been shifted, yet it is likely that they would always have reference to the great lines of military communication between the two warring countries. The war of CRŒSUS, on the other hand, was undertaken to obtain possession of the province of Cappadocia. It must be remembered that the limits of this province, in the geography of HERODOTUS, were very different from those assigned to it in later times, and which are generally traced in our maps. With him, the province (then an independent kingdom) of Cilicia included both banks of the upper part of the Halys (and therefore extended very much further north than in later times); then the Matieni occupied the right bank of the river, and the Phrygians the left; then, from their boundary to the mouth of the Halys, the Cappadocians (who he says were called Syrians by the Greeks) occupied the right bank of the Halys (thus including what was afterwards the kingdom of Pontus) and the Paphlagonians the left. Thus, in the Cappadocian enterprise of CRŒSUS (which, as the attack on Pteria shows, was principally directed against the inhabitants of the coast), it was necessary to pass the Halys near its mouth, and with the difficulties described by HERODOTUS; but in the Median war of ALYATTES there was not necessarily any movement so far north. The circumstance that the armies in this eclipse-battle were accompanied by the forces of their principal allies, and that the kings were present in person ready to make a treaty, shows that it was no skirmish of detachments, but a meeting of the main armies. It will be well therefore to consider in what part of the country such armies were likely to meet. I am indebted to M. PIERRE DE TCHIHATCHEFF and W. J. HAMILTON, Esq., for much of the information on which the following remarks are founded.

35. Asia Minor is bounded on its eastern side by a wide-spreading cluster of mountains, which, apparently, presents to the west an unbroken front, extending from the Euxine Sea to the Gulf of Issus; and on its southern side by a narrow range of mountains joining the former near Issus. The difficulties of passing the eastern mountains appear to be great. There is one road leading from Erzeroum by Sebaste or Sivas towards Cæsarea, and another road nearly parallel to this, thirty or forty miles S.E. of it; but both are rough and pass through very extensive tracts which provide little food. A rough road leads in the S.E. direction from Cæsarea by El Bostan. The best road appears to be that which leads from Sivas to Guroun, and then accompanies one of the feeders of the Euphrates by Melitene or Malatieh. In the southern mountains, the best pass towards the shore of the Mediterranean is that of Tarsus, leading thence by Issus to Antioch or Aleppo. Mesopotamia has only

once (I believe) been invaded from the Euxine Sea; namely, by an army directed by the Byzantine emperor HERACLIUS (A.D. 623), which landed at Trebizond and made its way through the mountains; returning however by the way of Issus. There is only one instance of an army marching along the north coast of Asia Minor, namely, that of the ten thousand Greeks in their return from the Anabasis; but this route was not adopted from choice; and the difficulties which they experienced show that it is not likely that a large army would willingly take that line. It would appear therefore that there are but two routes really practicable for armies; that of Melitene and that of Issus. At Melitene was fought the important battle, A.D. 572, between the Emperor TIBERIUS and CHOSROES NUSHIRVAN. One great battle, that between TIMUR and BAJAZET, A.D. 1402, was fought as far north as Ancyra; it was perhaps preceded by movements on the Melitene road. It is probable also that other marches have been made on the same line. But the far greater number of marches in both directions have been by the pass of Tarsus and the coast line to Issus. This was the route of the younger CYRUS; of ALEXANDER, although he marched from Ancyra; of VALERIAN and JULIAN; of SAPOR in marching from Armenia to the Cappadocian Cæsarea (for which the pass of Melitene would have appeared more direct); of the Crusaders in the first and second crusades; and of many other armies. When, in marching eastward, the valley of Antioch or the more open plains of the Euphrates are gained, it is difficult to define with the same strictness the probable march of a military force. The account of HERODOTUS however conveys the impression that the eclipse-battle took place in or very near to Asia Minor.

36. I conceive therefore that we are limited, as to the battle field, to the country within no great distance of the line from Sardes to Melitene; that it may have been anywhere south of that line, especially near Issus, but that it cannot have been far north of it; and that it cannot have been far east of Issus.

37. The approximate examination of the eclipses which could pass near this tract is very greatly facilitated by the tables in the *Art de vérifier les dates*, but still more by the calculations of Mr. BAILY and Mr. OLTMANNS. It is only necessary to observe that the correction of the moon's elements increases the argument of latitude (by which the track of the shadow at every eclipse in ascending node will be thrown three or four degrees northward, and that at every eclipse in descending node will be thrown as much southward); and that it increases the secular equation of anomaly, and thus increases the moon's longitude at every perigeal eclipse (by which the track of the shadow in every eclipse will be thrown several degrees to the east). Thus I have examined every total eclipse in Mr. OLTMANNS' table, extending from B.C. 631 to B.C. 585; and find only one (namely, that of B.C. 585, May 28*) which can have passed near to Asia Minor; that of B.C. 610, Sept. 30, which was adopted by Messrs.

* The first publication of results relating to the eclipse of B.C. 585, derived from careful calculations on good elements, so far as I know, was that by J. R. HIND, Esq., in the Athenæum for 1852, August 28, during the preparation of the present memoir.

BAILY and OLTMANNS, is now thrown north even of the sea of Azov. I have likewise formed the first approximate elements of the eclipses from B.C. 630 to B.C. 576, by the use of M. LARGETEAU's very convenient tables inserted in the Additions to the Connaissance des Temps, 1846, and am led to the same conclusion.

38. I shall now proceed with the computation of the eclipse of B.C. 585, May 28. The elements are formed precisely in the same manner as those for the eclipse of AGATHOCLES. The following are the primary numbers for the moon, for −584 (or B.C. 585), May 28, 2^h, Greenwich Mean Solar Time.

	u.	*x.*	*t.*	*z.*	*y.*
	g	g	g	g	g
DAMOISEAU's Elements	67·37639	388·0970	1·0941	200·9173	4·6101
Greenwich Corrections	—·29112	—·0626	—·2911	....	+·1723
Greenwich Unvaried Elements	67·08527	388·0344	0·8030	200·9173	4·7824
Elements with Variation	67·08527	388·0344	0·8030	200·9173	4·9824

With the Greenwich Unvaried Elements, the following places are obtained:—

	2^h.	3^h.
Obliquity of Ecliptic	23° 45′ 55″·6	
Sun's Longitude	59 34 37·0	59° 37′ 0″·0
Sun's Right Ascension	57 18 49·9	57 21 18·7
Sun's North Declination	20 20 5·3	20 20 36·4
Sun's Semidiameter	15 44·4	
Moon's Longitude	59 23 41·1	60 1 34·9
Moon's North Latitude	17 4·5	20 34·8
Moon's Right Ascension	57 3 27·9	57 42 11·2
Moon's North Declination	20 34 21·8	20 46 1·1
Moon's Equatorial Horizontal Parallax	61 18·8	
Moon's Geocentric Semidiameter	16 44·8	
Sun's True Right Ascension, in time	3^h 49^m 15^s·32	
Sun's Mean Right Ascension, in time	3^h 58^m 23^s·04	

From these, the following numbers are deduced:—

Greenwich Mean Solar Time of conjunction in R.A. −584, May 28^d 2^h 25^m 27^s.
R.A. of Sun and Moon at conjunction . . . . 57° 19′ 53″·0.
Sun's North Declination at conjunction . . . . 20° 20′ 18″·5.
Moon's North Declination at conjunction . . . . 20° 39′ 18″·3.
Greenwich Mean Solar Time of Middle of General Eclipse . . . . . 2^h 15^m 29^s.

From which the following coordinates of points are obtained:—

Points on the central path of the shadow.

Greenwich Mean Solar Time.	East Longitude.	North Latitude.	Sun's Zenith Distance.
h m s	° ′	° ′	° ′
3 48 0	23 1	39 46	71 27
3 49 0	24 56	39 14	73 11
3 50 0	27 3	38 37	75 8
3 51 0	The formulæ fail.		77 22
3 52 0	32 26	36 54	80 5
3 53 0	36 34	35 29	83 54

Points on the limits of the total shadow.

Northern Limit.		Southern Limit.	
East Longitude.	North Latitude.	East Longitude.	North Latitude.
° ′	° ′	° ′	° ′
24 35	40 29	21 37	39 2
26 38	39 53	23 25	38 32
28 56	39 12	25 24	37 58
31 39	38 20	27 37	37 18
35 9	37 9	30 14	36 29
42 14	34 36	33 33	35 22

39. From the Elements with Variation, the following numbers are obtained:—

	2^h.	3^h.
	° ′ ″	° ′ ″
Moon's Longitude..................	59 23 38·6	60 1 32·3
Moon's North Latitude............	18 1·1	21 31·4
Moon's Right Ascension	57 3 12·0	57 41 55·5
Moon's North Declination	20 35 16·4	20 46 55·7

Greenwich Mean Solar Time of conjunction in R.A. −584, May 28^d, 2^h 25^m 53^s.
R.A. of Sun and Moon at conjunction . . . . 57° 19′ 54″·1.
Sun's North Declination at conjunction . . . . 20° 20′ 18″·7.
Moon's North Declination at conjunction . . . . 20° 40′ 18″·1.
Greenwich Mean Solar Time of Middle of General Eclipse . . . . 2^h 15^m 24^s.

Coordinates of Points on the central path of the shadow.

Greenwich Mean Solar Time.	East Longitude.	North Latitude.
h m s	° ′	° ′
3 48 0	24 36	40 22
3 49 0	26 39	39 46
3 50 0	28 57	39 5
3 51 0	31 41	38 12
3 52 0	35 13	37 1

It will be remembered that the term "Variation" here has the technical sense of "increase of the mean argument of latitude by 20′." And it must be remarked that, to find the positions of the path of shadow which correspond respectively to Conditions 1, 2, 3, 4 in the eclipse of Agathocles, the effects of "Variation" must be multiplied by −0·63, +0·78, +1·31, +2·72.

40. In the second map which accompanies this paper (Plate XIII.), I have shown by a strong line the central path of the shadow corresponding to Unvaried Elements, and by an interrupted line the path corresponding to Elements with Variation of 20′ in the Argument of Latitude; and also, by finer continuous lines, the paths corresponding to Conditions 1, 2, 3, 4 in the eclipse of Agathocles; together with those that correspond to Central eclipse on the Southern position of Agathocles and

Central eclipse on the Northern position of AGATHOCLES. The oval whose centre is on the line of Unvaried Elements is intended only to show the breadth of the shadow, which will be sensibly the same for each of the positions of central path. On examining these, the following remarks will at once suggest themselves.

41. If the centre of the shadow followed the line of Condition 1, the shadow would obscure no open country except a very small distance north-east of the Pisidian Mountains; and even there the obscurity would be short. The western towns however from Halicarnassus to Pergamum would be shaded.

If the centre followed the line corresponding to a central eclipse for the Southern position of AGATHOCLES, the shadow would be almost central at what was afterwards Antioch, Celænæ and Pergamum; and there would be a great total eclipse at Issus and Tarsus, and on all the western towns from Ephesus to Troy; and the southern plain of Iconium would be in the shade. But Cæsarea, Melitene, Ancyra, would be in light.

If the centre followed the line of Condition 3, Issus, Tarsus, and a great length of the southern road, would be covered; but the shadow would not extend to Cæsarea, Ancyra, or Melitene. Sardes would now be out of the shadow.

If the centre followed the line corresponding to central eclipse for the Northern position of AGATHOCLES, Issus, Tarsus, Cæsarea, Iconium, would be within the shadow; Melitene, Pergamum, Ancyra, would be in light. Generally, the centre of the peninsula would be in shade.

If the central point followed the line of Condition 4, Melitene would be shaded; Cæsarea and Ancyra would be nearly in the middle of the shadow; and the northern plains would be covered; but the plain of Iconium and the whole western coast south of Lampsacus would be free from shade.

42. Any one of these tracks of the shadow (perhaps excepting that of Condition 1) is compatible with a conceivable place of engagement. In balancing the probabilities, we must in some measure be guided by the extent of ground proper for large military operations which the total shadow would cover. Judging thus, I should fix on a course between that of Condition 3 and that corresponding to central eclipse at the North position of AGATHOCLES as most probable. This selection, it will be remarked, excludes the possibility of AGATHOCLES being at the South position; and therefore, if adopted, would decide absolutely that AGATHOCLES sailed on the north side of Sicily.

43. If in conformity with this selection we suppose that the Unvaried Argument of Latitude ought to be increased by 1·53 × variation of 20ʹ, or by 30ʹ 60ʺ, and if we remark that the interval of time from 1782, when DAMOISEAU's epoch is nearly correct, is −23·66 centuries, it will appear that the secular motion of argument of latitude ought to be diminished by 1ʹ 29ʺ or 42″ nearly. Assuming our motion of mean longitude to be correct, the same correction ought to be applied to the regression of the node. This makes the secular regression of the node for a Julian century equal to 134° 8′ 13″, which is rather less than the smallest of those found by other inves-

tigators. If we had supposed the shadow to follow the line of Condition 3, the number would have agreed very closely with those smallest numbers.

44. In terminating this section, I may remark on the causes of uncertainty which yet remain in the theoretical calculations. The mean motion of the moon is determined by observations which are more completely free from constant error than almost any other observations applicable to one element; and I have no doubt of its extreme correctness. The great theorists of the present age, however, do not agree very closely in the value which they ascribe to the coefficient of the term in the moon's longitude depending on the square of the time. The present motion of the moon's perigee is determined with a certainty only inferior to that of mean motion. But Professor HANSEN in his last published investigations has proposed to alter the coefficient of the squares of centuries in the place of perigee by 3″, which will affect the moon's longitude in these eclipses by more than 3′, and will produce an effect opposite to that of regression of node in the eclipse of AGATHOCLES, but combining with it in the eclipse of THALES. The determination of the movement of the node from observation is liable to uncertainty only from the negligence of the Greenwich observers in the last century, who did not carefully observe the zenith distance of the moon's limb at the precise instant when it passed the meridian; and the effect of this error may be considerable. The theoretical term depending on the square of the time appears (if we may so infer from the consent of the investigators) to be well determined.

45. I conclude therefore that the terms to which at present it is most desirable that the attention of theorists should be directed, are those in the mean longitude and in the longitude of perigee depending on the square of the time. A careful discussion of eclipses will then supply, what meridional observations at present are hardly able to supply with the requisite accuracy, the motion of the node.

SECTION V. *Eclipse recorded by the Persian Historians.*

46. In Sir JOHN MALCOLM's History of Persia, Chapter VII., is a comparison of the Persian history, as recorded in Persian poetry (founded undoubtedly on authentic history, though with many changes and very great omissions), with that recorded by Greek writers. It appears that the KAI KAOOS of the Persians is the same as the ASTYAGES of the Greeks, or that the events of his reign are those of both ASTYAGES and CYAXARES; and Sir JOHN MALCOLM adds, "the most remarkable agreement is in the expedition of KAI KAOOS to Mazanderam. We are told by the Persian poet that in a battle which was fought in that province, the prince and his army were struck with a sudden blindness, which had been foretold by a magician."

47. In the range of years through which my examination has extended, there was no total eclipse in Mazanderam, and only two which could be visible in the eastern dominions of Persia. One was the eclipse of B.C. 610, Sept. 30; of which the central path, as computed by J. R. HIND, Esq., from elements not very unlike mine (which,

as well as every part of the results, Mr. HIND has most obligingly communicated to me), passed over Kœnigsberg, Astrakhan, and Khiva. The other is that of B.C. 603, May 17, which crossed the Persian Gulf in a north-easterly direction.

48. I imagine therefore that if this be a record of a total eclipse (which I see no sufficient reason for doubting), it relates to the same eclipse as that recorded by HERODOTUS. It appears, from Sir JOHN MALCOLM's remarks on the Persian historical traditions in general, that the names of provinces are in many instances given erroneously.

SECTION VI. *Eclipse of* XERXES.

49. In the spring of the same year in which the battle of Salamis was fought (to which the date B.C. 480 is usually assigned), there occurred a phenomenon which is thus described by HERODOTUS, Book vii. "With spring, the army [of the Persians], being ready, set out from Sardes on its march to Abydos; and as it was setting out, the sun leaving his seat in heaven was invisible, when there were no clouds but a perfectly clear sky; and instead of day it became night. XERXES, who saw this and heard about it, felt some anxiety, and inquired of the Magi what the appearance portended; they replied that the deity prognosticated to the Greeks the desertion of their cities; saying that the sun was the prognosticator for the Greeks, the moon for the Persians. When XERXES heard this he was very joyful, and proceeded on his march."

50. This account, interpreted as a record of a total eclipse of the sun, has given great trouble to chronologers, and not without reason. The only solar eclipse which it is worth while even to examine is that in the morning of the 19th of April, B.C. 481. The numbers computed from Greenwich Unvaried Elements are as follows:—

For −480, April 18, 16h, Greenwich Mean Solar Time.

	u.	*x.*	*t.*	*z.*	*y.*
	g	g	g	g	g
DAMOISEAU's Elements	21·90139	44·9528	397·9207	156·6612	191·9616
Greenwich Corrections	−·27849	−·0599	−·2785	....	+·1648
Greenwich Unvaried Elements	21·62290	44·8929	397·6422	156·6612	192·1264

	16^h.	17^h.
	° ′ ″	° ′ ″
Obliquity of Ecliptic	23 44 56·7	
Sun's Longitude	22 47 45·1	22 50 9·1
Sun's Right Ascension	21 2 27·8	21 4 42·9
Sun's North Declination	8 58 37·3	8 59 31·4
Sun's Semidiameter	15 48·2	
Moon's Longitude	22 37 22·9	23 14 5·5
Moon's North Latitude	19 34·8	16 12·0
Moon's Right Ascension	20 45 16·4	21 21 1·9
Moon's North Declination	9 12 51·7	9 23 31·5
Moon's Equatorial Horizontal Parallax	60 19·3	
Moon's Geocentric Semidiameter	16 28·6	
Sun's True Right Ascension, in time	1^h 24^m 9^s·85	
Sun's Mean Right Ascension, in time	1^h 26^m 7^s·57	

Greenwich Mean Solar Time of conjunction in R.A.	−480, April 18^d, 16^h 30^m 47^s.
R.A. of Sun and Moon at conjunction	21° 3′ 37″·4.
Sun's North Declination at conjunction	8° 59′ 5″·0.
Moon's North Declination at conjunction	9° 18′ 20″·0.
Greenwich Mean Solar Time of Middle of General Eclipse	16^h 21^m 18^s.

And from these,

Beginning of Central Eclipse on the Earth	14^h 41^m 47^s
in Longitude 49° 17′ East, Latitude 1° 25′ North.	
Central Eclipse at Noon	16^h 30^m 47^s
in Longitude 111° 49′ East, Latitude 27° 49′ North.	
End of Central Eclipse on the Earth	18^h 0^m 51^s
in Longitude 173° 13′ East, Latitude 34° 2′ North.	

51. If a diagram is constructed to exhibit the path of the shadow in this eclipse over the earth, and if it is remarked that the longitude of Sardes is about 28° East, it will be found that there could not be even a partial eclipse for Sardes, the whole penumbra having entered completely upon the earth before sunrise at Sardes. Nor, if the calculations above are correct (as I have great reason to believe), does it appear possible by alteration of secular movements to make an eclipse visible at Sardes. For if the moon's longitude were diminished, to make this eclipse possible, it must also be diminished in B.C. 585, and that would make the eclipse of THALES impossible, as the moon would not then have entered upon the sun's disk before sunset.

52. Abandoning then the idea of explaining this account by a solar eclipse, I have examined into the possibility of referring it to some other phenomenon. First, I cannot doubt that there was something unusual and alarming, as the solemn consultation of the Magi by XERXES seems to have been a matter of notoriety. Secondly, HERODOTUS repeatedly expresses himself doubtful on matters of detail which occurred during the movements of XERXES on the eastern side of the Ægean sea. Thirdly, the notion that the Sun was the peculiar divinity of the Greeks and the Moon that of the Persians, is entirely opposed to all that we know of the religious ideas of the Persians generally, or of XERXES in particular. For instance, when XERXES was preparing to cross the Hellespont, he waited for the rising of the Sun, and then addressed to the Sun his prayers for success. The Greeks however appear to have attached great importance to the appearance of the Moon, as is evident from their terror, and its calamitous consequences, at the lunar eclipse in the Syracusan war (THUCYDIDES, book vii.). The reply of the Magi therefore, which (as given by HERODOTUS) is, on the face of it, absurd, would seem to be much more plausible if we suppose that the information received by HERODOTUS was wrong in one particular, and that the observation in question was an eclipse of the moon, instead of the sun.

53. Now there was an eclipse of the moon on the morning of the 14th of March, B.C. 479, which answers well to the conditions of the history. The elements of computation are, for −478, March 13, 15^h, Greenwich Mean Solar Time.

	u.	x.	t.	z.	y.
	g	g	g	g	g
DAMOISEAU'S Elements	181·75704	118·9084	197·7783	116·6227	392·6488
Greenwich Corrections	—·27849	—·0599	—·2785	....	+·1648
Greenwich Elements Unvaried......	181·47855	118·8485	197·4998	116·6227	392·8136

	14^h.	15^h.
Sun's Longitude	347° 26′ 10″·7	347° 28′ 37″·2
Moon's Longitude..................	167 23 0·0	167 55 2·2
Moon's South Latitude	12 10·4	9 12·8

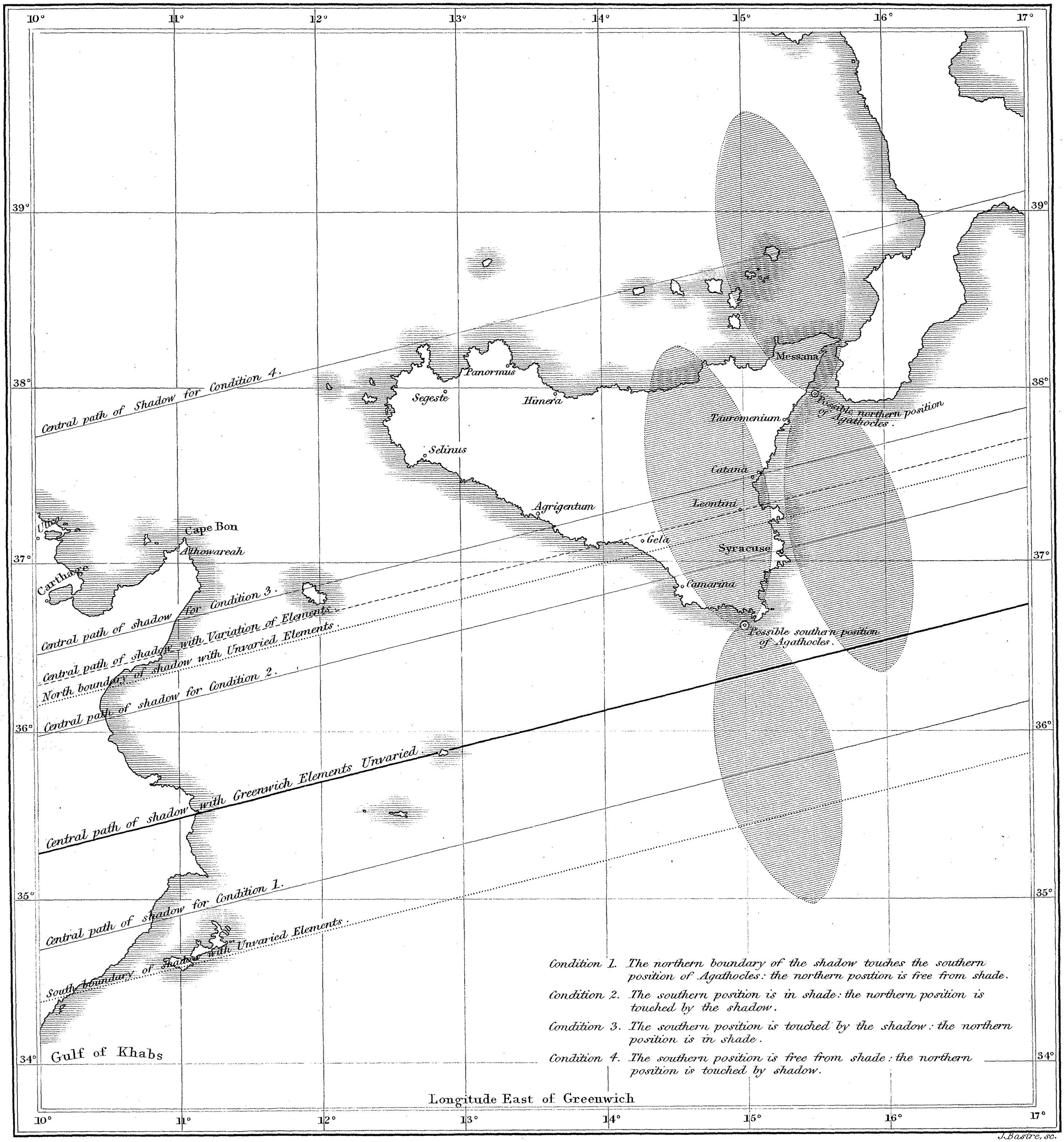
The opposition in longitude occurred therefore at $14^h\ 6^m\ 28^s$ Greenwich Mean Solar Time, or about $15^h\ 59^m$ Sardes Mean Solar Time; and the Moon's South Latitude was 11′ 51″·1; which would be reduced to about 10′ 35″ by the corrections at which I arrived in Section IV. It was therefore a total eclipse, nearly central (the moon's limb being at least 16′ within the inner boundary of the penumbra), and it is probable that the moon disappeared completely, and was lost for nearly two hours.

54. I think it extremely probable that this really was the eclipse to which the account of HERODOTUS refers. But for its adoption it is necessary to bring down the date of the battle of Salamis one year later than in the chronology generally received.

G. B. AIRY.

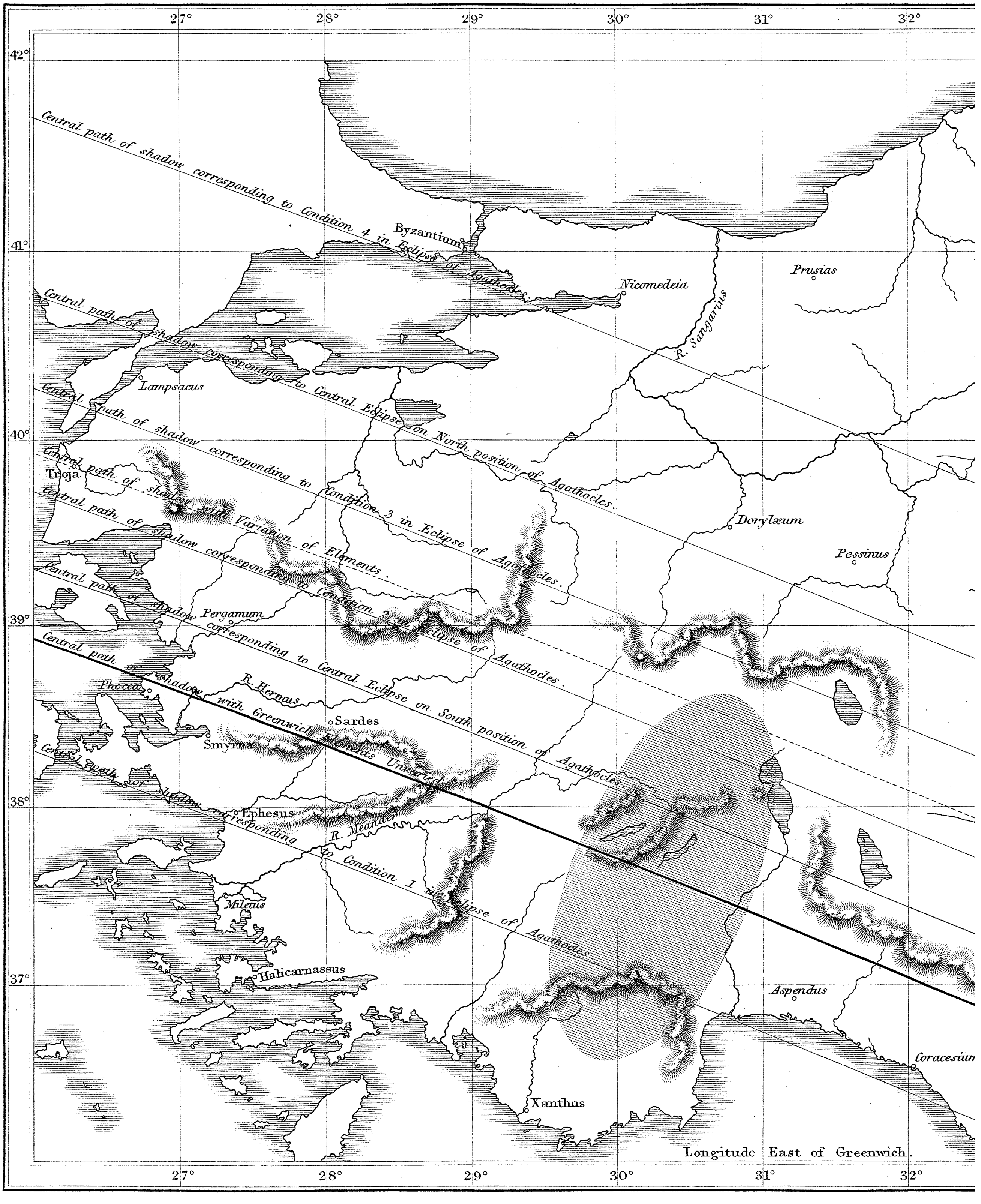
Royal Observatory, Greenwich,
1852, *December* 10.

MAP TO ILLUSTRATE THE ECLIPSE OF AGATHOCLES.

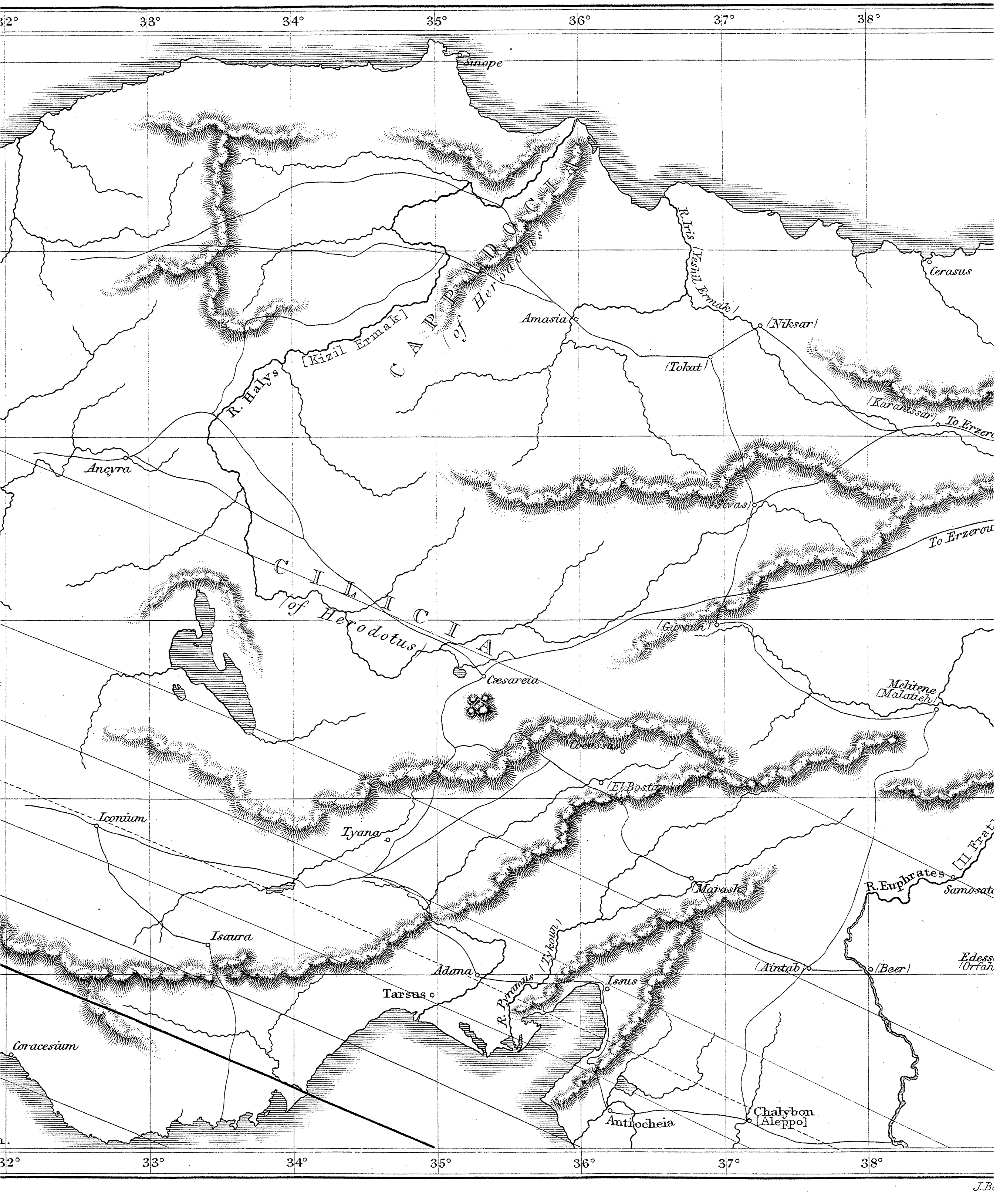


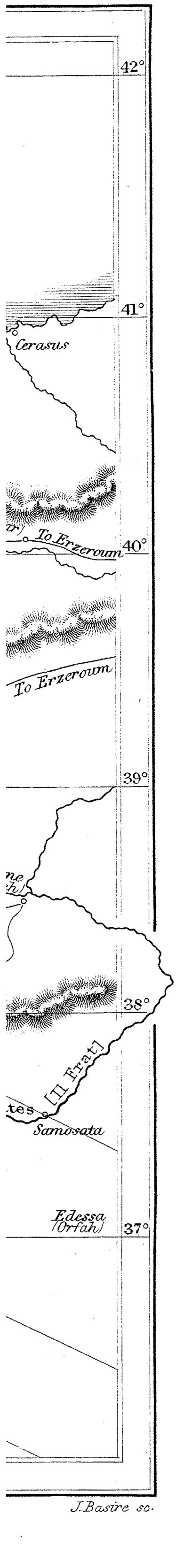
J. Basire, sc.

MAP TO ILLUSTRATE TH



E THE ECLIPSE OF THALES.




42°
41°
Cerasus
To Erzeroum
40°
To Erzeroum
39°
38°
[Il Frat]
Samosata
Edessa
(Orfah)
37°

J. Basire sc.

MAP TO ILLUSTRATE THE ECLIPSE OF THALES.