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ASTRONOMICAL INSTRUMENTS IN THE DELHI MUSEUM

BY
G. R. KAYE.

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DELHI MUSEUM ASTRONOMICAL INSTRUMENTS.

THE Director General of Archaeology recently purchased from a resident of Delhi three astrolabes and a small brass celestial sphere, which have now been placed in the Delhi Museum. Of these instruments the sphere is inscribed with the maker's name and date as follows: *Dia al-Dīn Muhammad ibn Mullā Qāsim Muhammad ibn Ḥāfiẓ 'Īsā ibn Shaikh Allāhdād, Humāyūnī, Sana 1087.*

This person appears to have belonged to a family of astrolabe makers of Lahore. He himself was the maker of the very accurate instruments shown in figures 6 and 19 of my *Astronomical Observatories of Jai Singh*, and an uncle of his, described as Muhammad Muqim ibn 'Īsā ibn Allahdād, Usṭūrlābī Humayūnī of Lahore, made in A.H. 1053 an instrument now in the possession of Mr. Lewis Evans,[1] and there is another of his instruments, dated A.H. 1070, in the British Museum.[2]

2. None of the three Delhi astrolabes bears either the maker's name or any date, but, as will be shown below, such instruments, when accurately constructed, bear clear evidence, based upon the precession of the equinoxes, of the period of construction. The known history of the instruments,[3] the date on the small sphere which accompanies them (approximately A.D. 1676), and their general design are other factors bearing on the period of their construction. The oldest of these Delhi astrolabes is inscribed in Kūfic characters and belongs to the thirteenth century A.D.; another belongs to the end of the fifteenth century; and the third, which is inscribed in Devanāgarī characters, belongs to about the end of the seventeenth century. All these instruments contain many details of astronomical and archaeological interest. The workmanship on two of the astrolabes is excellent; while the third, although of

[1] To whom I am indebted for an excellent photograph of the instrument.

[2] Number 12 of the unpublished list kindly lent to me by Sir Hercules Read.

[3] The late owner of the instruments states that his great-great-grandfather 'was keenly interested in the science of the heavenly bodies' and that 'somewhere in the 17th century A.D. he collected the astrolabes, together with an excellent selection of astronomical literature.'

much cruder design than the others, is possibly one of the earliest inscribed in Devanāgarī characters.

A. Thirteenth Century Astrolabe inscribed in Arabic (Kūfic) characters.

3. This is a brass instrument 5·7 inches (14·2 cm.) in diameter, and 2 mm. thick. Besides the body of the instrument, termed the *umm* or *mater*,[1] it consists of only the *'ankabūt* (*aranea* or *rete*) and the sighter or alhidade, and is inscribed with Kūfic characters. The 'ankabūt has 29 *shaẓāya* or star points each inscribed with the name of a star, and the ecliptic circle graduated and inscribed with the twelve names of the signs of the zodiac.[2] Of the 29 shaẓāya eleven have white metal bosses, and there are also four larger bosses which serve as handles for rotating the 'ankabūt. The venter or inner surface of the mater is engraved with a projection of the celestial sphere. The rim is graduated in degrees, which are numbered in groups of five up to 360, starting from the top or south point and proceeding through the west point on the right, the north and east in order. The back of the instrument has the upper half of the rim also graduated in degrees. The upper two quadrants of the back contain a Zarqālī projection of a portion of the sphere; the lower left quadrant contains a graphic table of sines; and the edge of the lower right quadrant is inscribed with a shadow scale. The alhidade or sighter has two fixed sighting pieces, each with two sighting holes. The alhidade appears to have been made later than the rest of the instrument and is not graduated. The workmanship is excellent throughout except for some apparent mistakes in numbering the graduations; but the metal has become slightly pitted in parts. The instrument was made about A.D. 1280. Such is a description of the instrument in bare outline, which requires amplification in certain directions.

4. *The 'ankabūt.'*—The open net-work disc, examples of which are shown in figures 1, 3, 5 and 10, is by the Muslims appropriately termed 'ankabūt' ('spider') or shabakah ('net') and by mediæval western scholars *aranea* or *rete*. It is essentially a star map of the heavens and always includes the ecliptic, and can be rotated. It is reticulated in order to render the co-ordinates marked on the disc below visible. Each shaẓiyya ('splinter') or denticulus marks the positions of a star, generally with a considerable degree of accuracy. Right ascension may be marked by lines joining the centre to the graduated circumference; declination circles are sometimes given as in figures 7 and 11; the graduations on the ecliptic circle give longitudes, and a special disc containing projections of circles of latitude and longitude is sometimes provided (Figure 8).

The names and positions of the stars on instrument A are given below, together with their modern names where there is no doubt about the identification, and also the positions according to Ulugh Beg. The names are explained in the annexed glossary.

---

[1] The traditional nomenclature is both Arabic and mediæval Latin. This is confusing but cannot now be well avoided. Even in Chaucer's time the mixture was in evidence.

[2] These names are the same as those given in paragraph 18 below.

Star List of Astrolabe A.

Name on the instrument.	Modern name.		Magnitude.	On the Instrument.		Ulugh Beg.		Long. Diff.	No. in Baily.
				Long.	Lat.	Long.	Lat.		
				°	°	° ′	° ′	° ′	
1. Matn Qīṭus		......	...	$12\frac{1}{2}$	—20				
2. Ghūl	26β	Persei, *Algol*	2·6	47	—22	48 55	+22 0	1 55	201
3. Dabarān	87α	Tauri, *Aldebaran*	1·1	60	—5	62 31	—5 15	2 31	391
4. ʻAiyūq	13α	Aurigæ, *Capella*	0·2	73	$+22\frac{1}{2}$	74 43	—22 42	1 43	221
5. Qadam al-Jauzā	19β	Orionis, *Rigel*	0·3	$69\frac{1}{2}$	—32	69 25	—31 18	—0 5	764
6. Mankib	58α	Orionis, *Betelgeux*	1·0	80	—17	81 13	—16 45	1 3	732
7. Al-ʻAbūr	9α	Canis, Majoris, *Sirius.*	—1·6	95	—39	96 19	—39 30	1 19	815
8. Ghumaisā	10α	Canis Minoris, *Procyon.*	0·5	106	—16	108 22	—16 0	2 22	845
9. Yad al-Dubb	9ι	Ursæ Majoris	...	113	+30	114 55	+29 21	1 55	20
10. Zabānā	65α	Cancri	...	$120\frac{1}{2}$	—5	125 40	—5 21	4 30	451
11. ʻUnq al-Shujāʼ	30α	Hydræ, *Alphard*	2·2	138	—21	139 31	—22 30	1 31	902
12. Rijl	33α	Ursæ Majoris	...	129	30	131 40	+29 45	2 40	28
13. Qalb	32α	Leonis, *Regulus*	1·3	140	...	142 13	+0 9	2 13	466
14. Janāḥ al-Ghurāb	4γ	Corvi	...	$177\frac{1}{2}$	—13	182 46	—14 18	5 16	928
15. Al-Āʻzal	67α	Virginis, *Spica*	1·2	194	—2	196 10	—2 9	2 10	507
16. Qāïd	85η	Ursæ Majoris	...	170	+55	169 10	+54 9	—0 50	35
17. Al-Rāmiḥ	α	Boötis, *Arcturus*	0·2	195	$+31\frac{1}{2}$	196 31	+31 18	1 31	110
18. Fakkah	5α	Cor. Borealis, *Alphecca.*	2·3	$210\frac{1}{2}$	+46	214 34	+44 30	4 4	111
19. ʻUnq al-Haiyah	28β	Serpentis	...	220	+34	222 13	+34 15	2 13	264
20. Qalb al-ʻAqrab	21α	Scorpii, *Antares*	1·2	241	—3	242 16	—4 30	1 16	550
21. Al-Ḥawwā	?27κ	Ophiuchi	2·1	244	+32	243 40	+32 0	—0 20	232
22. Wāqʻī	3α	Lyræ, *Vega*	0·1	276	+64	278 19	+62 0	2 19	148
23. Al-Ṭāïr	53α	Aquilæ, *Altair*	0·9	291	+30	294 10	+29 15	3 10	286
24. Ridf*		......	...	338	+61				
25. Zanab al-Jadī	40γ	Capricorni	...	311	—2	314 13	—2 30	3 13	620
26. Kʻab al-Faras	?10κ	Pegasi	...	$326\frac{1}{2}$	+38	331 31	+36 27	5 1	332
27. Mankib	53β	Pegasi, *Sheat*	...	350	+31	351 37	+30 51	1 37	315
28. Khaḏib	11β	Cassiopeiæ	2·4	20	+50	28 1	+50 48	8 1	?188
29. Zanab Qīṭus		......	...	348	$—6\frac{1}{2}$				

* The point appears to have been broken.

The Age of Astrolabe A.

5. In consequence of the precession of the equinoxes the positions of the stars relative to the line of equinoxes (AB in figure 10) varies in the different instruments according to the period for which they are constructed. Thus, if an astrolabe is accurately made, it contains in its star map engraved on the 'ankabūt a definite record of the date of its construction. Since, however, the precession of the equinoxes approximates to 50·2 seconds of arc in a year,[1] and since the error in reading any individual star position may amount to as much as, say, half a degree, our estimate of the age of an instrument may be out by a few years; but, within reasonable limits, the estimate is reliable. Not all the stars are of equal value for this purpose of comparison. The better known stars were presumably the more correctly located, and for the purpose of comparison those not very far from the ecliptic are perhaps the more suitable. Also it is convenient to compare the star positions as recorded on the instrument with a record of not too distant a date: the types of error on the instrument are likely to be similar to those of a catalogue of the period, etc. These considerations have led to the use of Ulugh Beg's catalogue as a standard of comparison. Ulugh Beg's records are not perfectly accurate but we now know the amount of inaccuracy in each case,[2] and the catalogue gives longitudes, which are much more convenient for comparison than the right ascensions and declinations given in modern catalogues.

Since the instrument error may amount to about half a degree it is useless for us to consider the effect of the proper motion of the stars. The average error in longitude of Ulugh Beg's records is about —12 minutes, and thus would make but little appreciable difference to our estimate. Since latitude does not vary with precession the latitudes on the instrument and those given in Ulugh Beg's catalogue should be nearly the same. We thus have a criterion of accuracy of the instrument, and the latitudes as compared in the above table show that the degree of accuracy claimed for the instrument is in no way exaggerated.

The following list gives the longitude of each of the identified stars on the instrument whose distance from the ecliptic is not more than 30 degrees, and it shows the difference in longitude between the record on the instrument and that of Ulugh Beg.

—	Magnitude.	Longitude.		
		On instrument.	Ulugh Beg.	Differences.
		°	° ′	° ′
2. Algol, 26β Persei	12·6	47	48 55	1 55
3 Aldebaran, 87α Tauri	1·1	60	62 31	2 31
4. Capella, 13α Aurigæ	0·2	73	74 43	1 43

[1] The generally accepted value is 50·256—0·000222T seconds, where T is the number of years before A.D. 1900.

[2] See the admirable edition of Ulugh Beg's Star Catalogue by Mr. E. B. Knobel, recently published by the Carnegie Institution of Washington.

—	Magnitude.	Longitude. On instrument	Longitude. Ulugh Beg.	Longitude. Difference.
		°	° ′	° ′
6. Betelgeux, 58α Orionis . . .	1·4	80	81 13	1 13
8. Procyon, 10α Canis Minoris . .	0·5	106	108 22	2 22
13. Regulus, 32α Leonis . . .	1·3	140	142 13	2 13
15. Spica, 67α Virginis	1·2	194	196 10	2 10
20. Antares, 21α Scorpii . . .	1·2	241	242 16	1 16
23. Altair, 53α Aquilæ	0·9	291	294 10	3 10

The average difference in longitude is approximately —2° 3′, which corresponds very nearly to —148 years. Ulugh Beg's catalogue was constructed in A.D. 1437 and the rough process followed gives A.D. 1289 as the approximate date of the instrument. The method of calculation is, however, open to criticism. All the stars selected have not the same values for purpose of comparison. If, for example, we had excluded all stars of less than the first magnitude, the resulting date would have been A.D. 1270, in spite of the positive precession shown by number 5 (β Orionis). Also we might, with justification, have taken the 'mode' instead of the 'average' of the differences; we have neglected the proper motions, Ulugh Beg's errors, etc., etc.

The following table gives a comparison of three of the best known stars at greater intervals :—

—	Longitude. A. Instrument.	Longitude. B. Ptolemy, A.D. 58	Longitude. C. 1919.	Difference. A—B.	Difference. A—C.
	°	° ′	° ′	° ′	° ′
Aldebaran . .	60	42 40	68 38	+17 20	—8 38
Regulus . . .	140	122 30	148 42	+17 30	—8 42
Spica . . .	194	176 40	202 43	+17 20	—8 43

The averages of these differences of longitude give about +1250 and —622 years approximately; and the resulting dates are 58+1250 or A.D. 1308, and 1919—622 or A.D. 1287.

B. Astrolabe inscribed in Arabic (Naskhi) characters, circa A.D. 1500.

6. This is a plane astrolabe of the ordinary type, made in brass gilt. Its diameter is 3·75 inches (=9·5 cm.) and it is ·3 inches or 7 mm. thick, and is inscribed in naskhi characters. It contains, besides the 'ankabūt, six plates, inscribed on both sides with sex-partite projections for certain latitudes, and other special projections. The venter is blank. The 'ankabūt has 18 points, to only 16

of which, however, star names are attached; and it has the usual ecliptic circle inscribed with the names of the signs of the zodiac[1] and graduated. The 'ankabūt has been broken in two[2] and rather clumsily repaired: the left top part is the more modern and is slovenly engraved. The obverse rim of the mater is graduated in degrees and is numbered in groups of five up to 360, starting from the top and proceeding clock-wise. The reverse is beautifully engraved: the edge is graduated in degrees. each quadrant being numbered separately from 5 to 90. The inner space of the left top quadrant contains graphs of the unequal or temporal hours; that of the right top quadrant a graphical table of inverse sines and consines: the left bottom quadrant contains what may be described as a set of polar co-ordinates; the remaining quadrant shows square and circular shadow scales. The alhidade or sighter has two fixed sighting pieces with single sighting holes. The workmanship, except for the repaired portion of the 'ankabūt, is excellent throughout, and the gilding has helped to preserve the engraving.

Star List of Astrolabe B.

Name on Instrument.	Modern name.	Magnitude.	Instrument.		Ulugh Beg.	
			Long.	Lat.	Long.	Lat.
			°	°	° ′	° ′
1. Dabarān . .	87α Tauri, *Aldebaran* .	1·1	63	—5	62 31	—5 15
2. Rijl . . .	19β Orionis, *Rigel* . .	0·3	70	—29	69 25	—31 18
3. Yad . . .	58α Orionis, *Betelgeux* .	1·0	82	—16	81 13	—16 45
4. Yamānīh . .	9α Canis Majoris, *Sirius* .	—1·6	97	—36	96 19	—39 30
5. Shāmīh . .	10α Canis Minoris, *Procyon*	0·5	109	—14	108 22	—16 0
6. Fard . . .	30α Hydræ, *Alphard* . .	2·2	140	—21	139 31	—22 30
7 Qalb . . .	32α Leonis, *Regulus* . .	1·3	142	0	142 13	+0 9
8. A'zal . . .	67α Virginis, *Spica* . .	1·2	198	—1	196 10	—2 9
9. Rāmiḥ . .	α Bootis, *Arcturus* .	0·2	197	+33	196 31	+31 18
10. Fakkah . .	5α Coronæ Borealis, *Alphecca*.	2·3	219	+47	214 34	+44 30
11. Qalb al-'aqrab .	21α Scorpii, *Antares* . .	1·2	243½	—3	242 16	—4 30
12. Hawwā . .	55α Ophiuchi . . .	2·1	258	+35	255 13	+35 51
13. Wāqi' . . .	3α Lyræ, *Vega* . .	0·1	280	+69	278 19	+62 0
14 Ṭāir[3] . . .	53α Aquilæ, *Altair* . .	0·9	292	+28	294 10	+30 0
15. ——[3]	......	...	314	+27	...	...
16. Kaffa . . .	......	...	349	+55	...	...

[1] The names of the signs are the same as those given in paragraph 18 below.

[2] At longitudes 15° and 255° on the ecliptic circle.

[3] These are on the repaired part and are very badly engraved.

7. By the same process as in paragraph 5, from the following elements, we obtain an approximate date for astrolabe B.

—	Magnitude.	Longitude. Instrument.	Longitude. Ulugh Beg.	Difference.
		°	° ′	° ′
1. Aldebaran, 87*α* Tauri . .	1·1	63	62 31	+0 29
7. Regulus, 32*α* Leonis . .	1·3	142	142 13	—0 13
8. Spica, 67*α* Virginis . .	1·2	198	196 10	+1 50
11. Antares, 21*α* Scorpii . .	1·2	243½	242 16	+1 14

These stars give an average precession of +53·2 minutes *after* the time of Ulugh Beg's catalogue (A.D. 1437) or approximately A.D. 1500. Or, as before, taking only those stars that are of not less than the first magnitude[1] we have :

—	Magnitude.	Instrument.	Ulugh Beg.	Difference.
		°	° ′	° ′
2. Rigel, 19*β* Orionis	0·3	70	69 25	+0 35
4. Sirius, 9*α* Canis Majoris . .	—1·6	97	96 19	+0 41
5. Procyon, 10*α* Canis Minoris .	0·5	109	108 22	+0 38
9. Arcturus, *α* Bootis . . .	0·2	197	196 31	+0 29
13. Vega, 3*α* Lyræ	0·1	280	278 19	—1 41

The average precession is here very nearly 49 minutes which gives A.D. 1495 as the approximate date of the instrument.

The Tablets of Astrolabe B.

8. There are six brass gilt tablets, each 3·2 inches (8·1 cm.) in diameter and about a millimetre thick. Each tablet is engraved on both sides with projections of co-ordinates and other elements that can be used in conjunction with the 'ankabūt tablet. Of these projections nine are for latitudes from 0° to 40°; one is nominally for latitude 90° and therefore gives declination circles; one is nominally for latitude 66° 30′ and therefore gives celestial latitudes; and one is for horizons from 8° to 71°. On two of the surfaces double projections are given, thus making fourteen different projections in all.

The theory and use of these projections will be described in due course, but at present formal descriptions only will be given. To facilitate this I have numbered the tablets in a convenient order and have distinguished the obverse and reverse of each by the letters *a* and *b*.

[1] Altair is omitted because the repaired portion of the 'ankabūt, on which it lies, is very inaccurate.

I^{a} is marked *ba 'ard S*[1] ('for latitude 90°') and is engraved with declination circles. These are concentric circles whose centre is the centre of the disc (north pole). The circles are numbered thus from the outer tropic:

A B C

23 | 30 | 18 | 12 | 6   6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 60 66 72 | 78 | (84) | (90)

where A is the tropic of Capricorn, B the equator and C the pole. The readings thus give positive and negative declinations. See figure 11.

I^{b} is marked *'ard istuwa sā 'ātah ĪB* or 'zero latitude: hours 12' and exhibits co-ordinates for zero latitude. Almucantarats for every six degrees and azimuth circles for every fifteen degrees, and the 12 unequal or temporal hour lines are drawn and numbered. The two tropics (A and C) and the equator (B) are shown. See figure 12.

II^{a} is marked *'ard IḤ sā'ātah IJ-H* or 'latitude 18: hours 13-5.' Besides the almucantarats, azimuths and temporal hour lines, there are also the equal hour lines (dotted); and the horizon is marked on the right *al-maghrib* ('the west'), and on the left *al-mashriq* ('the east'). Figure 13.

II^{b} is marked *ba'ard K sā'ātah IJ-IJ* or 'for latitude 20°: hours 13—13'.' Otherwise it is exactly of the same type as II^{a}. Figure 14.

III^{a} is marked *'ard KA-M sā'ātah IJ-KA* or 'latitude 21° 40': hours 13—21'.' (Note that 21° 40' N. was the generally accepted latitude of Mecca.) Figure 15.

III^{b} is marked *'ard KJ sā'ātah IJ-KH* or 'latitude 23°: hours 13—25'.' Otherwise as the preceding. Figure 16.

IV^{a} is marked at the top *'ard KH sā'ātah IJ-LD* or 'latitude 25°: hours 13—34'.' The azimuth lines are shown below the horizon only, otherwise it is of the type of II and III. Figure 17.

IV^{b} exhibits two independent sets of almucantarats and temporal hour lines only. At the top of the tablet is written *'ard KH sā'ātah IJ-MW* or 'latitude 28°: hours 13—46,' and the corresponding projection is given. At the bottom is written *'ard L sā'ātah IJ-NW* or 'latitude 30°: hours 13—56'.' The east and the west are marked twice over, being reversed for the second projection. See Figure 18.

V. Tablet V is divided into two parts along the meridian line. This permits the use of either of the projections with one of the special tablets. The actual projections are of the same type as II and III

(*a*) is marked *'ard LB sā'ātah ID-W* or 'latitude 32°: hours 14—6'.' Figure 19.

(*b*) is marked *'ard LW sā'ātah ID-KZ* or 'latitude 36°: hours 14—27'.' Figure 20.

VI^{a}. The obverse of this tablet is superficially of the same type as IV^{b} *i.e.*, there are two separate projections on the one surface. The upper projec-

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[1] The Arabic letters used as numerals are here transliterated by capital letters. The notation is given on plate VI.

tion is marked *'arḍ M sā'ātah ID-NA* or 'latitude 40° : hours 14—51'.' The other projection is marked *ba'arḍ SW-L* or 'for latitude 66°—30'.' It is thus a projection for the complement of the obliquity and shows celestial latitudes. In some instruments[1] such a projection is marked as 'the measure of the 'ankabūt.' Figure 21.

VI[b] is a 'tablet of horizons (*ṣafīḥah āfāqiyah*).' There are the usual circles of the tropics and the equator, the meridian line and the east and west line, and there are four groups of horizon lines, each drawn for a separate latitude, and each group consisting of 16 horizons. (Figure 22.) Along the diameters of the disc these lines are numbered in Arabic numerals,[2] while along the circle of Capricorn they are numbered in the abjad notation. The groups are arranged thus :—

8	12	16	.	.	.	60	64	68
9	13	17	.	.	.	61	65	69
10	14	18	.	.	.	62	66	70
11	15	19	.	.	.	63	67	71

The following table summarises the elements given on these tablets :—

	I[a]	I[b]	II[a]	II	III[a]	III[b]	IV[a]	IV		V	V		VI[a]	VI[b]
Latitude.	90°	0°	18°	20°	21° 40′ Mecca.	23°	25°	28°	30°	32°	36°	40°	66½°	Horizons.
Longest day.(*a*) *Hours* .		12	13	13	13	13	13	13	13	14	14	14		
Longest day.(*a*) *Minutes*.		0	5	13	21	25	34	46	56	6	27	51		

C. Hindu Astrolabe.

9. The Hindu astrolabe (figures 5 and 6) is 7 inches or 17·2 cm. in diameter and ·3 inches thick. It is of the same type as B but is inscribed in Devanāgarī characters. Besides the 'ankabūt it contains two discs with the usual projections, but, apparently, it was made for three such discs. The Venter is blank except for four names that appear to have been engraved there as memoranda. The 'ankabūt has 37 points of which 21 only have star names attached, and one point is broken. The ecliptic circle is roughly graduated and is inscribed with the names of the 12 signs. The obverse edge is graduated in degrees which are numbered in groups of three starting from the east point on the left and proceeding counter-clockwise. The back has only the upper edges graduated, the bottom edge being blank. The upper left quadrant contains a rough sine table ; the right quadrant is marked only with equi-distant concentric quarter circles ; and the lower half contains the square shadow scale. The alhidade has fixed sighting pieces each carrying two sighting holes. Compared with A and B the workmanship of this instrument is extremely crude.

[1] *E.g.*, figure 8 shows such a projection which is inscribed *Safiḥah mīzān al-'ankabūt* or 'tablet of the measure of the 'ankabūt.' This particular tablet belongs to the Jaipur 'B' astrolabe shown in figures 6 and 8 of my *Astronomical Observatories of Jai Singh*.

[2] This is the only tablet on which numerical symbols are employed. In all other cases the *abjad* notation is used.

(*a*) For the connexion between the longest day and latitude see my *Hindu Astronomy* § 64.

Star List of Astrolabe C.

Name on instrument.	Modern name.	Instrument. Long.	Instrument. Lat.	Ulugh Beg. Long.		Ulugh Beg. Lat.	
		°	°	°	′	°	′
1. Samudrapaksha . . .	?8ι Ceti	356	—11	353	55	—10	30
2. Manushyaśīrsha . . .	26β Persei, *Algol* . . .	54	+23	48	55	+22	0
3. Rohiṇī	87α Tauri, *Aldebaran* . .	67½	—5	62	31	—5	15
4. Manu......(broken) . .	......	...	...	...		...	
5. Mithuna......dadakshiṇa .	19β Orionis, *Rigel* . .	71	—30½	69	25	—31	18
6. Hasta	......	82	—11	...		...	
7. Mithuna	......	98	—11	...		...	
8. Ārdrā Lubdhaka . .	9α Canis Majoris *Sirius* .	97	—39	96	19	—39	30
9. Lubdhakabaṁdhu . .	10α Canis Minoris, *Procyon* .	110½	—15	108	22	—16	0
10. Maghā	32α Leonis, *Regulus* . .	143	—0½	142	13	+0	9
11. Uttara Phalgunī . .	......	151	?+18	...		...	
12. Viśākhā	......	150	+48	...		...	
13. Mātṛimaṁḍala . . .	......	180	+20	...		...	
14. Chitrā	67α Virginis, *Spica* . .	201	—1½	196	10	—2	9
15. Svātī	α Bootis, *Arcturus* . .	207	+30½	196	31	+31	18
16. Dhanuḥ koṭi . . .	......	245	−31	...		...	
17. Abhijit	3α Lyræ, *Vega* . . .	280	+61	278	19	+62	0
18. Śravaṇaḥ	53α Aquilæ, *Altair* . .	296	+29	294	10	+29	15
19. Kakuṁdapuchha . . .	?50α Cygni, *Deneb* . .	333	+60	328	46	+59	42
20. Āśvanābha	21α Andromedæ . . .	7	+26	6	28	+25	21
22. Pūrvābhadrapada . .	......	3	+16	...		...	

10. Of these names 11 are names of nakshatras and their positions agree generally with the usual identifications;[1] but *Hasta* does not refer to the nakshatra of that name and here possibly indicates a hand of Orion. *Mithuna* is the name of the sign Gemini and *Mithuna...dakshiṇa* refers to Rigel as south of that sign. *Dhanus* is also the name of a 'sign' and *Danuḥ-koṭi*, 'the end or tip of the bow,' appears to be used appropriately. *Samudrapaksha*, 'marked with a fin,' is possibly ι Ceti; *Manushyaśīrsha*, 'a human skull' is equivalent to Ulugh Beg's 'demon's head'; *Ārdrā Lubdhaka* is said to be a name for Cauda Draconis, but here it marks Sirius 'the star in the mouth of the dog'; Lubdhaka is the hunter in the Rohiṇī myth[2] and *Lubdhaka-bandhu* is the hunter's relation, and is applied to Procyon. *Mātṛimaṇḍala* is evidently meant to indicate the circle of latitude of Virgo, on which the star lies. *Kakumdapuchha*

[1] See my *Hindu Astronomy*, Appendix II. [2] *Ib.*, Appendix I.

possibly is meant as an equivalent of Cauda Cygni, but it is marked on the 'ankabūt by a bird's beak. The term *Aśvanābha* indicates some connexion with a celestial horse and is the principal star[1] in Pegasus.

Besides these star names are certain names written on the 'ankabūt that are not connected with any pointer. Near Rohiṇī is written *Shaṇmukha*, 'having six mouths,' perhaps for Kṛittikā (the Pleiades); on the extreme edge (long. 160°-170°) is inscribed '*Kakaskaṁdha*,' 'the crow's shoulder,' possibly for one of the stars of the constellation Corvus; and on the ecliptic, near Capricornus, is (?) *Dhanuḥśarāgum* which possibly is to indicate the Muri or pointer at the top of the ecliptic circle.

Some other names are engraved on the venter but appear to have no direct connexion with any part of the astrolabe: they are—

Laṁkāyām	0
Adane	11
Tilaṁge	?19
Devagirau	20-34

These appear to be memoranda of certain latitudes, *viz.*, Laṅkā 0. Aden 11. Tilaṅga ?19. Devagirī (the modern Daulatābād, the Tagara of Ptolemy) 20° 34′. Laṅkā is the place of origin of the Hindu geographical co-ordinates, and is 'in Ceylon': the latitude of Daulatābād is approximately 19° 57′ N. and there is little doubt as to the identification; the latitude of Aden is 12° 47′ N. and the identification is possible; Tilaṁga is doubtful.

11. It would be futile to attempt to determine the age of such a crudely constructed instrument as this by means of precession. The average of the differences in longitude would have no value since the probable error is so great. But on general grounds we may suggest the end of the seventeenth or beginning of the eighteenth century as about the period of its construction.

The Tablets of Atrolabe C.

12. Astrolabe C has two tablets only, although from the depth of the rim it is conjectured that the instrument was made for three. I^a is inscribed—

22 Chhāyā 5	Paramadinaṁ 33 30
Karṇaḥ 13	Avaṁtikayām

which means '(Latitude) 22, Shadow 5, Hypotenuse 13, Longest day 33 (ghaṭīs) 30 (palas), At Avanti (Ujjain).' Almucantarats for every three degrees are drawn and numbered. The unequal or temporal hour lines are drawn and also the equal hour lines, the latter, as in the Muslim instruments, being dotted. For the hour lines is only one set of numbers. The equal hour lines, of which only 12 are shown on this surface, are badly drawn. Apparently an attempt was made to count the equal hours both from sunrise and sunset! No azimuths are given.

I^b is inscribed—

Palāṁsah 37	Paramadinaṁ 36 24
Chhāyā 9	
Karṇaḥ 15	

[1] Now named *a* Andromedæ.

which may be read 'latitude 37°, longest day 36 (ghaṭīs) 30 (palas), shadow 9, hypotenuse 15.' On this surface the equal hour lines are drawn in the normal fashion but not very accurately. Otherwise the tablet is the same as I[a]. No town is mentioned and the latitude is well outside India.

II[a] is marked—

Palāṁśaḥ 23 | Paramadinaṁ 33 50
Chhāyā 5 6 | Amadāvād
Karṇaḥ 13 3

or, 'Latitude 23,' longest day 33 (ghaṭīs) 50 (palas) Shadow 5-6, hypotenuse 13-3, Ahmedabad. Otherwise it is like I[b].

II[b] is a tablet of horizons (similar to figure 22), but without any graduation numbers.

The most interesting features of these badly drawn tablets are the names of the towns and the methods of expressing their latitudes (*a*) by degrees, (*b*) by longest days, (*c*) by the shadow of a vertical gnomon. The first two methods are general but the third is peculiar. The vertical gnomon is supposed to be 12 units, or 720 minutes long; and its noon-day shadow at the equinoxes is 12 $\tan\phi$, while the hypotenuse formed by the shadow and gnomon is 12 $\cos\phi$, where ϕ is the latitude. The days are expressed in ghaṭīs and palas, of which 60 ghaṭīs=1 day of 24 hours and 60 palas=1 ghaṭī.

We thus have—

Place.	Latitude.	Longest day.	Sin ϕ.
	°	H. M. S.	
I[a]. Ujjain	22	13 24 0	5/13 = ·385
I[b].	37	14 33 36	9/15 ·600
II[a]. Ahmedabad	23	13 32 0	306/783 = ·391

For these latitudes the longest days are, to the nearest minute, $13^h\ 23^m$, $14^h\ 37^m$., and $13^h\ 27^m$.; and the values of $\sin\phi$ are approximately ·375, ·588, ·391. The actual latitude of Ujjain is 23° 10′ 6″ and that of Ahmedabad is given as 23° 2′ N.

The Projections.

13. The mathematical principle on which the tablets, including the rete or 'ankabūt, are constructed is indicated by the term 'stereographical projection.' A pole of the heavens is usually taken as the centre of vision and the plane of the equator as the plane of projection; but occasionally one of the equinoctial points is the centre of vision and the soltitial colure (*i.e.*, the great circle passing through the soltitial points and the poles of the equator) is the plane of projection.

In the ordinary plane astrolabe (like B and C) the point of vision (V in figures 23 and 24) is usually a pole of the equator and the projection is made on the plane of the equator of which *ns* in figures 23 and 24 is a trace. The type of projection employed is thus polar stereographic, in which circles of the sphere usually are circles on the projection, and angles on the sphere are represented by the same angles on the projection.

Let VA_1A_2 be a great circle on the sphere through the point of vision V, and let *ns* lie in the plane of projection. Let A_1A_2 be the diameter of a small circle on the surface of the sphere. The projection of this circle on *ns* will be a circle whose diameter is a_1a_2.

Almucantarats, Celestial Latitude and Declination.

14. If *ns* represent the equator then A_1A_2 may represent the diameter of a circle of altitude, and its trace a_1a_2 that of an almucantarat. The altitude is measured by $OA_2A_1=OA_1A_2=\alpha$, and if VO produced cut A_1A_2 in C then $VCA_2=\phi$ is the latitude. The poles Z and Z′ of the circles of altitude are termed the zenith and nadir.

We have $Oa_1=r.\tan a_1VO=r.\tan\frac{\phi-\alpha}{2}$, and $Oa_2=r.\tan a_2VO=$ $r.\tan\frac{180°-\overline{\phi+\alpha}}{2}=r\cot\frac{\phi+\alpha}{2}$.

When $\phi=90°-\omega$, ($=63\frac{1}{2}$ degrees approximately), then A_1A_2 is parallel to the ecliptic, *i.e.*, it is a diameter of a circle of celestial latitude; and when $\phi=90$ degrees, A_1A_2 is parallel to the equator and is a diameter of a circle of declination. Also if z and z′ are the traces of Z and Z′ we have $Oz'=r.\tan\frac{90-\phi}{2}$ and $Oz=r.\cot\frac{90-\phi}{2}$; and when $\phi=90°-\omega$, $Oz'=r\ \tan\frac{\omega}{2}=r.(\cdot 208)$ nearly, and $Oz=r.\cot\frac{\omega}{2}=r.(4\cdot 808)$ nearly; and when $\phi=90$ degrees, $Oz'=0$ and $Oz=\infty$. When $\alpha=0°$ the almucantarat becomes the horizon and $Oa_1=$ $r.\tan\phi/2$ and $Oa_2=r.\cot\frac{\phi}{2}$.

Azimuths, Celestial Longitude and right Ascension.

15. The great circles which pass through the zenith and nadir and cut the horizon at right angles are called vertical circles. They mark off on the horizon horizontal angles or azimuths and may therefore be called azimuth circles. Their projections are circles passing through the zenith and nadir and also through the appropriate graduations on the horizon. The projections of these graduations are found by joining the corresponding graduations on the equator to the zenith; and the centres of the projected azimuth circles all lie on the line bisecting at right angles the straight line joining the zenith and nadir. Circles of celestial longitude are particular cases of azimuth circles for $\phi=90°-\omega$; and circles of declination, which in the projection are straight lines, are also particular cases for $\phi=90°$.

Figure 25 shows the plane of projection, which is here in the plane of the equator. Since Oe=OV and the angles eOa_1 and VOa_1 are both right angles, we have the angles Oea_1 and OVa_1 equal, and also the angles Oea_2 and OVa_2 equal, and the angle $sOd_1=90°-2a_1VO=(\phi-\alpha)+90°$ and $sOd_2=90°-2a_2VO=(\phi+\alpha)-90°$. This gives a geometrical construction for the almucantar, of which a_1a_2 is a diameter.

But in practice it is perhaps more convenient to calculate the radius of each circle (r′) and its distance (Oc) from the centre of projection, O. We have $Oa_1 = r.\tan\frac{\phi - a}{2}$, $Oa_2 = r.\cot\frac{\phi + a}{2}$, where r is the radius of the equator, and $r' = (Oa_1 + Oa_2)/2$; and $Oc = r' - Oa_1 = Oa_2 - r'$. The following table gives certain values for r′ and Oc for the particular cases when the almucantarats become circles of latitude and declination. (for r=100).

		$a = -30°$	$-20°$	$-10°$	$0°$	$+10°$	$+20°$	$+30°$	$+40°$	$+50°$
$\phi = 90° - \omega$	Oc	95·6	69·2	53·6	43·4	36·4	31·6	28·00	25·4	23·6
	r′	217·6	163·2	132·4	109·0	90·2	75·6	61·0	49·0	28·0
$\phi = 90°$, Oc = o	r′	173·2	142·8	119·2	100·0	83·9	70·0	57·7	46·6	36·4

16. The ʻankabūt and tablets of the ordinary astrolabe such as B and C are all constructed on the basis of polar projections as described above; but the obverse of A (figure 7) is a general projection so constructed as to avoid the necessity for special tablets for each latitude. One such general projection, attributed to Ibrāhīm b. Jahjā al-Naqqas, known as al-Zarqālī (Arzachel), is described in my *Astronomical Observatories of Jai Singh*[1]; but the projection on A differs from that inasmuch as it is made for use with an ordinary polar projection ʻankabūt. The obverse of A may therefore be described as a general polar projection. From one point of view it is connected with the tablet of horizons.

In figure 27 let VAA′ represent a sphere and let V be the centre of vision of the projection. The plane of projection aoa′ is parallel to AA′ which is at right angles to VO. If AA′ represent the equator then V and o are the poles of the equator.

A portion of the projection of the sphere is shown below the line aoa′ and this is exactly the same as that on the obverse of astrolabe A (figure 7). Three sets of circles are projected *viz.*, (i) small circles at right angles to the equator and parallel to the plane of the solstitial colure: in figure 27 one such circle is lettered b_1 b_2; (ii) parallels of declination which are small circles parallel to the plane of the equator and concentric with the pole, *e.g.*, $b_1 \beta b'$ and $a \alpha a'$; (iii) great circles passing through the equinoxes, which under certain conditions may be regarded as horizons, and one of which may be regarded as the ecliptic: examples in figure 27 are $a \alpha a'$ and $a \beta a'$. The uses of (ii) and (iii) are fairly obvious, but at present I cannot indicate definitely the use of (i). Similarly, although it is not difficult to reconstruct the projection shown in the upper half of the reverse of A (figure 2). I do not, at present, understand exactly how it was utilised.

The Hour Lines.

17. The division of the day was two-fold: (i) the time from sunrise to sunset was divided into twelve equal parts, called temporal or unequal hours, since they change in length from day to day and vary with the latitude; (ii) the whole day and night was divided into 24 equal, or equinoctial, or clock hours. This latter is the time division now practically followed in most coun-

[1] P. 27 & Figs. 20 & 21.

tries, but there is still divergence as to the starting point : some reckon from midnight (civil time in most countries), some from midday (until quite recently western astronomers), some from sunrise (*e.g.*, the Muslims and Hindus).

The astrolabe makers generally reckoned from sunrise, and, as their hour lines are generally (but not always) drawn below the horizon, the initial point is that point of the horizon marked *al-maghrib*, 'the west,' *e.g.*, in figures 13, 14, 19, etc. (D to G in figure 16, according to the time of the year).[1]

On the astrolabe the unequal or temporal hour lines are circles passing through points on the equator and tropics so as to divide that portion of each that is below the horizon into twelve equal parts. The circles of the equal hours divide the whole of the equator into twenty-four equal parts, and the portion of the tropic of Capricorn (DEF in fig. 16) below the horizon into parts corresponding to the longest day, and the similar portion of the tropic of Cancer (GKL in fig. 16) into parts corresponding to the shortest day. Thus, in figure 16 which shows a tablet for latitude 23°, there are thirteen equal divisions on the tropic of Capricorn with a remaining part corresponding to 25 minutes—since the longest day is 13 hours 25 minutes ; and the portion of the tropic of Cancer below the horizon is divided into ten equal parts with a remaining part equivalent to 35 minutes—since the shortest day for latitude 23° is 10 hours 35 minutes.

On the reverse of astrolabe B (figure 4) the left top quadrant is occupied by a graphical representation of the unequal or temporal hours. The diagram shown as figure 26 explains how this was used. The hour circles ARO, BO, CO, etc., cut the arc EA at intervals of 15 degrees and all pass through the centre O. The midday hour line is ARO and each of the other lines corresponds to a certain number of hours before or after noon but are numbered as from sunrise.

If AOR is the noonday zenith distance of the sun and if AOQ is the zenith distance of the sun at any instant, then Q, the point of intersection of the altitude line and the arc passing through the point of intersection of the midday hour circle and the noonday altitude line, indicates approximately the temporal hour. (Q here lies nearly midway between the hour lines DO and CO, *i.e.*, within the 3rd morning hour space counting from sunrise, or the 10th, in the afternoon.)

In figure 26 the arc PQO is such that PS=SO, and if the angle SOQ were a multiple of 15 degrees then PQO would be a temporal hour line. Let the angle ROA=z_n, the angle QOA=z, and the angle POA=θ. We then have PS=r/2cosθ, OQ=$2PS\cos z$, OR=r.cosz_n, from which, since OQ=OR, we get

$$\cos z = \cos\theta . \cos z_n = \cos\theta . \cos(\phi - \delta)$$

$$= \cos\theta . \cos\phi . \cos\delta + \cos\theta . \sin\phi . \sin\delta \qquad \text{(i)}$$

But we should have

$$\cos z = \cos h . \cos\phi . \cos\delta + \sin\phi \sin\delta \qquad \text{(ii)}$$

and (i) is not strictly true. But, if $\theta = h$, the difference between (i) and (ii) is $\sin\phi \sin\delta(\cos h - 1)$, which disappears when $\phi = 0$. Formula (i) and the construction on the astrolabe to which it corresponds is, therefore, only applicable to low latitudes.[2]

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[1] This reversal is a matter of convenience only, since the upper portion of the tablet is generally fully occupied with almucantars and azimuth lines.

[2] See DELAMBRE *Astronomie du moyen age*, p. 243 *seq*.

D. Celestial Sphere, dated A.H. 1087.

18. The brass sphere is 6·5 c.m. in diameter and is supported in a stand as shown in figure 9. It was made in A.D. 1676/7 and is inscribed thus—

'amalā ahqar al'ibād Ḍīā al-Dīn Muhammad ibn Mullā Qasīm Muhammad ibn Ḥafiẓ 'Īsā ibn Shaikh Allāhdād, Humāyūni ; sana 1087.[1]

The stand is graduated horizontally only. The four cardinal points are marked, and from the east and west points graduations for every two degrees run right and left; and these are numbered in the *abjad* notation in groups of six up to 90 degrees. The detachable vertical circle lies north and south, and the sphere was pivoted to it through the equatorial poles; but the axis or pivot is now missing. At the north and south of the horizontal circle are grooves in which the pivots could also fit. The detachable vertical circle is not graduated and has the appearance of being of later make than the sphere itself.[2]

On the sphere are inscribed the positions of 92 stars of which all but eleven are named. Also the circles of longitude for each 30 degrees and the ecliptic and equator are given. The ecliptic is marked with the usual signs, and each sign is graduated and the graduations are numbered from six to thirty; while each quadrant of the equator is graduated and numbered from six to ninety.

The names of the signs are—

al—Ḥamal—ARIES.	*al-Mīzān*—LIBRA.
al-Thaur—TAURUS.	*al-'Aqrab*—SCORPIO.
al-Jauzā—GEMINI.	*al-Qaus*—SAGITTARIUS.
al-Saraṭān—CANCER.	*al-Jadī*—CAPRICORNUS.
al-Asad—LEO.	*al-Dalw*—AQUARIUS.
al-Sunbulah—VIRGO.	*al-Ḥūt*—PISCES.

The position of each star is indicated by a dot enclosed in a small circle, thus: ◎; and in most cases the names are quite clearly engraved. The names of the stars with their positions on the sphere are given below; and, in the cases of the stars that can be identified, these positions are compared with those given by Ulugh Beg.

In order to test the accuracy of the sphere and also as a check on the calculations made in paragraphs 5 and 7 above the age of the instrument was recalculated by utilising the same nine stars as were employed in paragraph 5. From Ulugh Beg's time (A.D. 1437) the average precession of these stars is approximately $+3^\circ\ 9'$, which corresponds to about 227 years, and the resulting date is 1437+227=A.D. 1664, as compared with 1676-1677 given in the inscription.

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[1] "The work of the humblest of men, Ḍīā al-Dīn, etc." This is inscribed on the sphere itself, around the south pole.

[2] The lower support is broken and the sphere has been patched in three places. One of these inlaid patches is 2 c.m. by 1·5 c.m., another is 1·2 c.m. square, and the third is a small circle of 2 mm. diameter.

Name on sphere.	Modern name.	On sphere. Long.	On sphere. Lat.	Ulugh Beg. Long.	Ulugh Beg. Lat.	No. in Baily.
		°	°	° ′	° ′	
1. Janāḥ al-Faras[1]	88γ Pegasi	5½	+13	1 22	+12 24	314
2. Sarat al-Faras	δ Peg.=21α And., *Alpheratz*	11	+26	6 28	+25 21	313
3.	43β Andromedæ, Mirach	27	+25	23 13	+25 26	344
4. Akhr al-Nahar	θ Eridani	19	—55	15 40	—53 45	802
5. Masāf al-Nahar	......	?	—55			
6. Ṣadr al-Qītus	89η Ceti	29	—29½	26 43	—28 51	719
7. Muqadam al-Sharatīn	5γ Arietis, *Mesartim*	29	+6½	26 13	+6 36	360
8.	6β Arietis, *Sheratan*	30	+7½	27 7	+7 51	361
9. Kaf al-Khadib	11β Cassiopeæ, *Chaph*	30½	+50½	28 1	+50 48	188
10. Fam al-Qītus	86γ Ceti	36	—12	32 10	—12 18	711
11. ......al-Thuraiya, saḥābī	7κ Persei	50	+40	36 19	+40 0	190
12. Rās al-Ghūl	26β Persei, *Algol*	51	+19½	48 55	+22 0	201
13. Tālī	34γ Eridani	50	—34½	46 40	—33 15	778
14. al-Durā'ī	35γ Cephei	56	+63½	55 31	+64 30	?76
15. Mirfaq al-Thuraiya	33α Persei	59	+29	55 19	+29 21	196
16.		56	—59			
17. 'Aīn al Thaur	87α Tauri, *Aldebaran*	66	—5½	62 31	—5 15	391
18. Rijl al-Jauzā, īsrī	19β Orionis, *Rigel*	72	—30	69 25	—31 18	764
19. Mankib al-Jauzā, īsrī	24γ Orionis	75	—16	73 34	—17 15	733
20. Haqa'h, saḥābī	39λ Orionis	79	—13½	76 31	—13 30	731
21. 'Aiyūq	13α Aurigæ, *Capella*	79	+23½	74 43	+22 42	221
22. al-Jadī	1α Ursæ min.	84	+64	80 19	+66 27	1
23. Mankib al-Jauzā, yumnī	58α Orionis	85	—16	81 13	—16 45	732
24. Rijl al-Jauzā, yumnī	53κ Orionis	84	—31½	78 40	—33 21	?768
25. Mankib al-'annāz'	34β Aurigæ, *Mankalinan*	88	+21½	83 52	+21 30	222
26. al-Suhail	α Argus, *Canopus*	96	—75	95 51	—75 0	889
27.		99	+23½			
28. Shi'rī Yamānīh	9α Can. maj., *Sirius*	99	—40	96 19	—39 30	815
29. Rās Tawām, al-muqadam	66α Geminorum	106½	+9	102 43	+9 54	421
30. Shi'rī Shāmīh	10α Can. min., *Procyon*	110	—19	108 22	—16 0	845

[1] For the meanings of the Arabic names see the annexed glossary.

Name on sphere.	Modern name.	On sphere. Long.	On sphere. Lat.	Ulugh Beg. Long.	Ulugh Beg. Lat.	No. in Baily.
		°	°	° ′	° ′	
31. Ṭarafat al-Safīnah	11ε Argus	121	−42	119 16	−42 42	846
32. Ma'laf, saḥābī	41ε Cancri, *Præsepe*	122½	−¼	119 46	+1 0	446
33. Rās al-Asad	24μ Leonis	137	−12	133 25	−12 21	461
34. Anwar al-Farqadīn	β Ursæ min.	126	−71½	125 25	+73 0	6
35.	γ „ „	138	−73	133 55	−75 9	7
36. Qalb al-Asad	32α Leonis, *Regulus*	145½	−¼	142 13	−0 9	466
37. Fard al-Shuja'	30 Hydræ	141	−22½	139 31	−22 30	902
38. al-Banāt al-Na'sh	50α Ursæ maj.	131	+48	127 25	−49 24	24
39. al-Banāt al-Na'sh	48β „ „	133	−44	131 37	−45 9	25
40. al-Banāt al-Na'sh	64γ „ „	146	−46	142 31	−47 15	27
41. al-Banāt al-Na'sh	69δ „ „	148	+50	143 25	−51 30	26
42. al-Banāt al-Na'sh	77ε „ „	154	−53	150 31	+54 9	33
43. al-Banāt al-Na'sh	79ζ „ „	162	−55	158 4	+56 12	34
44. al-Banāt al-Na'sh	85η „ „	173	+52½	169 10	+54 9	35
45. 'Unq al-Shuja'	39υ Hydræ	151	−25	148 10	−26 0	?903
46. Ẓahr al-Asad	68δ Leonis	156	−13½	153 28	+14 9	478
47. Sa'id al-Asad	15 Com. Ber.	170	−27½	166 4	+28 12	491
48. Sarfah	94β Leonis	172	−11½	163 49	+12 0	485
49. Qā'idat al-Baṭīh	7α Crateris	168	−22	165 55	−22 42	908 ?918
50. Janāḥ al-Ghurāb	4γ Corvi	186	−15	182 46	−14 18	928
51. Minqār al-Ghurāb	1α Corvi	188	−22	184 13	−22 0	925
52. Mufrad al-Rāmiḥ	8η Bootis	196	+28	191 43	+28 0	107
53. Simāk al-Rāmiḥ	16α Bootis, *Arcturus*	202	+32	196 31	−31 18	110
54. Simāk al-'Azal	67α Virginis, *Spica*	200	−1½	196 10	−2 9	507
55 Rās al-'awā	?49δ Bootis	202	+53½			
56.		208	−23			
57.		211	−42			
58.	9α Libræ	220	+¼	217 52	+0 45	526
59. Kaffa		225	+11			
60. 'Unq al-Haiya	27λ Serpentis	228	+26	224 28	+26 39	268
61. Miza Fakkah	5α Coronæ Bor., *Alphecca*	219	+45	214 34	+44 30	111

Name on sphere.	Modern name.	On sphere. Long.	On sphere. Lat.	Ulugh Beg. Long.	Ulugh Beg. Lat.	No. in Baily.
		°	°	° ′	° ′	
62. Rās al-Sabu' . . .	β Lupi	228	−30½	225 25	−30 3	969
63.		237	+57			
64. Rijl Qantaurus .	α Centauri . . .	241	−42	238 1	−41 10	966
65.	β Draconis . . .	244	75½	243 1	75 30	46
66. Rās Tinnin . . .	85ι Herculis . . .	255	68½	252 55	+69 15	137
67. Rās al-Jāthī . . .	64α Herculis, *Ras Algethi* .	250	+38½	247 55	+37 9	119
68. Qalb al-'Aqrab . .	21α Scorpii *Antares* . .	245	−4½	242 16	−4 30	550
69.	35η Ophiuchi . . .	253	+6½	250 37	−6 45	243
70. Rās al-Mijmarah . .	ζ Aræ	253	−36	250 31	−34 0	994
71. Rās al-Ḥawwa . .	55α Ophiuchi . . .	260	+37	255 13	−35 31	232
72. Shaulah	35λ Scorpii	260	−13	255 55	−13 33	562
73.	σ Aræ	260	−22½	257 21	−22 40	988
74.		274	−17½			
75. 'Ain al-Rāmī, saḥābī .	γ Sagittarii . . .	278½	−1	275 7	−0 45	574
76. Nasr Wāqi' . . .	3α Lyræ, *Vega* . . .	282	+62½	278 19	+62 0	148
77. Rakbah al-Rāmī . .	α Sagittarii . . .	282	−19	278 43	−18 36	590
78.	17ζ Aquilæ	290	+36	282 31	+36 15	?292
79.	β Sagittarii . . .	294	−23			
80. Nasr Ṭāir . . .	53α Aquilæ, *Altair* . .	298	+28	294 10	−29 15	286
81. Minqār al-Dajājah . .	?21η Cygni	302	+59	305 16	+54 30	?160
82. Zanab al-Ḥūt . . .	κ Pisc. Aust. = Gruis .	313	−23	310 25	−23 15	1018
83.		310	+28			
84. Zanab al-Jadī . . .	40γ Capricorni . . .	319	−3	314 13	−2 30	620
85. Fam al-Ḥūt . . .	α Pisc. Aust. *Fomalhaut* .	325	−22			
86. Fam al-Faras . . .	8ε Pegasi	328	+24	324 28	+22 0	329
87. Zanab al-Dajājah . .	ω Cygni	335	+65	332 10	+64 21	174
88. Sāq sākib al-māh . .	76δ Aquarii	335	−7½	331 55	−8 18	643
89. Matn al-Faras . . .	54α Pegasi	349	+19	345 55	+19 0	316
90. Batn al-Ḥūt . . .	8κ Piscium . . .	349	+4	345 16	+4 0	676
91. Mankib al-Faras . .	53β Pegasi	354	+30	351 37	+30 51	315
92.	8ι Ceti	357	−11	353 55	−10 30	729
93 Zanab al-Qiṭus . .	16β Ceti	358	−21	355 25	−21 0	730

GLOSSARY

al-‘Abūr .	Sirius.
‘ain .	‘ eye ’ ; *‘aīn al-rāmī*, ν Sagittarii ; *‘aīn al-thaur*, α Tauri or Aldebaran.
‘aiyūq .	‘ goat ’ ; α Aurigæ, Capella or Alhaiot.
ākr .	‘ last ’ ; *ākhir al-nahar*, θ Eridani.
‘anaz .	‘ goat ’ ; *mankib al ‘annāz*, β Aurigæ.
‘ankabūt .	‘ spider ’ ; the star tablet of an astrolabe ; aranea, alhancabuth ; see also *shubakah*.
anwar .	‘ brighter ’ ; *anwar al-Farqadīn*, β Ursæ Min.
‘aqrab .	‘ scorpion’ ; *al-‘aqrab*, the sign Scorpio ; *qalb al-‘aqrab*, α Scorpii or Antares.
‘arḍ .	‘ latitude ’ ; *‘arḍ istuwā*, zero latitude.
asad .	‘ lion ’ ; *al-asad*, the sign Leo ; *qalb al-asad*, α Leonis or Regulus ; *rās al-asad*, μ Leonis.
‘awā .	13th manzil, *rās al-‘awā*, ? δ Bootis.
‘azal .	‘ unarmed ’ ; *al-‘azal*, α Virginis or Spica.
banāt . .	‘ daughters ’ ; *al-banāt al-na‘sh*, Ursa major.
baṭiyya .	‘ small cask ’ ; *qā‘idat al-baṭīh*, α Crateris.
baṭn .	‘ interior ’ ; *baṭn al-hūt*, κ Piscium.
dabarān .	‘ the 4th manzil (α, θ, γ, δ, ε Tauri) ; α Tauri or Aldebaran.
dajājah .	‘ fowl ’ ; Cygnus ; *minqar al-dajājah*, ? η Cygni ; *zanab al-dajājah*, ω Cygni.
dalwa .	‘ jar ’ ; *al-dalw*, the sign Aquarius.
dubb .	‘ bear ’ ; *yad al-dubb*, ι Ursæ Majoris.
durā‘at .	‘ cuirass ’ ; *al-durā‘ī*, ? γ Cephei.
fakkah .	‘ bowl ’ ; *al-fakkah*, α Coronæ Bor. or Alphecca.
fam .	‘ mouth ’ ; *fam al-faras*, ε Pegasi ; *fam al-ḥūt*, α Pisc. aust. or Fomalhaut *fam al-Qiṭus*, γ Ceti.
farqad .	‘ calf ’ ; du. *farqadan*, β and γ Ursæ min. ; *anwar al-farqadīn*, β Ursæ min.
faras .	‘ horse ’ ; *fam al-faras*, ε Pegasi ; *janāḥ al-faras*, γ Pegasi : *sarat al-faras*, α Andromedæ ; the wedge that fastens the parts of an astrolabe together.
fard .	‘ alone ’ ; *fard al-shujā‘*, α Hydræ or Alphard.
ghūl .	‘ demon ’ ; *rās al-ghūl*, β Persei or Algol.
ghumaṣiā .	Procyon or α Canis minoris.
ghurāb .	‘ crow ’ ; *janāḥ al-ghurāb*, γ Corvi or Alghorab ; *minqār al-ghurāb*, α Corvi.
ḥaiyat .	‘ serpent ’ ; *‘unq al-ḥaiyah*, β Serpentis.
ḥamal .	‘ ram ’ ; *al-ḥamal*, the sign Aries.
haq‘at .	three stars in the head of Orion ; here λ Orionis.
ḥawwa .	‘ snake charmer ’ : *ras al ḥawwa*, α Ophiuchi.

ḥut . . ‘fish’ : *al-ḥūt* the sign Pisces : *fam al-ḥūt* Fomalhaut or α Pisc. aust. *zanab al-ḥūt*, κ Pisc. Aust.

‘idādah . ‘post’ : alhidade, sighter.

īsrī . . ‘left side’ ; see ρ and γ Orionis.

jadī . . ‘goat’ : *al-jadī*, the sign Capricornus ; also α Ursæ minoris ; *zanab al-jadī*. γ Capricorni.

janāḥ . . ‘wing’ : *janāḥ al-faras* γ Pegasi : *janāḥ al-ghurāb*, γ Corvi or Alghorab.

janūbī . . ‘south.’

jāthī . . Hercules (as the kneeling one) : *rās al-jāthī*. α Herculis.

al-Jauzā . the sign Gemini ; the constellation Orion ; *mankib al-jauzā*. α and γ Orionis ; *rijl al-jauzā*. β and κ Orionis.

ka‘b . . ‘ankle bone’ : *ka‘b al-faras*, ? κ Pegasi.

kaff . . ‘hand’ ; *kaff al-khaḍīb*. ρ Cassiopeiæ.

khaḍīb . ‘died red’, ‘bloody’ : *kaff al-khaḍīb* β Cassiopeiæ.

al-maghrib . ‘the west.’

mā . . ‘water’ ; *sāq sākib al-mā*. δ Aquarii.

ma‘laf . . ‘manger’ : ε Cancri or Præsepe.

mankib . ‘shoulder’ : *mankib al-faras*. β Pegasi : *mankib al-jauzā* α Orionis ; *mankib al-‘annāz*. β Aurigæ.

manzil . ‘station of the moon’ : pl. *manāzil*.

al-mashriq . ‘the east.’

matn . . ‘back’ ; *matn qīṭus*, ? ζ Ceti.

mijmarah . ‘censer’ ; Ara ; *rās al-mijmarah*. ζ Aræ.

minqār . ‘a beak’ : *minqār al-ghurāb*. α Corvi ; *minqār al-dajājah*, ?

mirfaq . ‘elbow’ ; *mirfaq al-thuraiya*. α Persei.

mizān . . ‘balance’ : *al-mizān*. the sign Libra ; *mīzān fakkah*. α Cor. Bor.

mufrad . ‘alone’ : *mufrad al-rāmiḥ*. η Bootis.

muqaddam . ‘preceding’ : *muqaddam al-sharatīn*, γ Arietis : *rās tawām al-muqaddam* α Geminorum.

muqanṭar . ‘resting on arches’ ; *muqanṭarāt* ‘bridges’ ; circles of altitude.

muri . . index.

al-nahar . ‘the stream’ ; Eridanus : *ākhr al-nahar* (Ultima fluvii). θ Eridani ; *masā al-nahar*.?

na‘sh . . ‘bier’ : *al-banāt al-na‘shin*. Ursa major.

nasr . . ‘eagle’ : *nasr al-ṭāir*. α Aquilæ : *nasr al-wāqi‘*, α Lyræ.

qadam . ‘foot’ : *qadam al-jauzā*, β Orionis.

qā‘idat . ‘foundation’ ; *qā‘idat al-baṭīh*. α Crateris (Quæ in basi Crateris est).

qalb . . ‘heart’ : *qalb al-‘aqrab*. α Scorpii or Antares ; *qalb al-asad*. α Leonis or Regulus.

Qantaurus . Κένταυρος

qaus . . ‘bow’ ; *al-qaus*. the sign Sagittarius.

Qīṭus . . Κῆτος : *fam al-qīṭus*. γ Ceti : *adr al-qīṭus*, π Ceti : *zanab al-qīṭus*, β Ceti.

quṭb . . ‘pole’ : *quṭb janūbī*, south pole : *quṭb shamālī*, north pole.

rāmī . . ‘archer’ : *‘aīn al-rāmī*, ν Sagittarii (Quæ in oculo est) ; *rakbat al-rāmī*, α Sagittarii.

rāmiḥ . . 'lance bearer'; *simāk al-rāmiḥ*. α Bootis or Arcturus; *mufrid al-rāmiḥ*. η Bootis.

rās . . 'head': *rās al-asad*. μ Leonis: *rās al-'awā*. ? δ Bootis. *rās al-ghūl*. β Persei or Algol: *rās al-jāthī*. α Herculis: *rās al-sabu'*. α Lupi; *rās tawām al-muqaddam*. α Geminorum: *rās al-ḥawwa* α Ophiuchi.

rijl . . 'foot': *rijl al-jauzā*. β or κ Orionis: *rijl qanṭūrus* α Centauri: on astrolabe A *rijl*=ι Ursæ maj.

rukbat . 'knee'; *rukbat al-rāmī*. α Sagittarii.

sā'āt . . 'hours.'

sabu' . . 'beast of prey': Lupus: *rās al-sabu'*. α Lupi.

ṣadr . . 'breast'; *ṣadr al-qīṭus*, ? π Ceti.

ṣafā 'iḥ . 'plates': (sing. *ṣafīḥa*) tablets of an astrolabe: saphiæ.

safīnah . 'ship': *ṭarafat al-safīnah*. ε Argus.

saḥābī . . 'cloudy': nebulous; *al-thuraiya*. *saḥābī*. χ Persei: *'ain al-rāmī saḥābī*, ν Sagittarii; *haq'ah saḥābī*. λ Orionis: *ma'laf saḥābī* ε Cancri or Præsepe.

sa'id . . 'wrist'; *sa'id al-asad*. 15 Com. Ber.

sākib . . 'one who pours out': *al-sākib*, the sign Aquarius. See *sāq*.

sāq . . 'leg': *sāq sākib al-māh*. δ Aquarii.

ṣarf . . ?'red': *ṣarfah*. β Leonis.

saraṭān . 'crab'; *al-saraṭān*, the sign Cancer.

shām . . 'Syria': *shi'ra shāmīh* α Can. min. or Procyon.

shamāl . 'north.'

sharaṭīn . the 1st manzil (β, γ Arietis); *muqaddam al-sharaṭīn*. γ Arietis.

shaulah . 'sting of a scorpion'; λ Scorpii.

shaẓiyya . 'small splinter': pl. *shaẓāya*, star pointers on *'ankabūt*.

shi'ra . Sirius: *shi'ra shāmīh*. Procyon: *shi'ra yamānīh*. Sirius.

shubakah . 'net': the star disc of an astrolabe: rete.

shujā' . . 'courageous': Hydra: *fard al-shujā'*. α Hydræ: *'unq al-shujā'*, ύ Hydræ.

simāk . . 'above': *simāk al-'azal*. α Virginis or Spica; *simāk al-rāmiḥ*. α Bootis or Arcturus.

suhail . . Canopus.

al-sunbulah . the sign Virgo.

surrah . 'navel': *surrah al-faras*. δ Pegasi or α And.

al-ṭāir . . 'the flier': α Aquilæ or Altair.

tālī . . 'following': applied to β Arietis and γ Eridani.

ṭaraf . . 'side': *ṭarafat al-safīnah*. ε Argus.

tawām . 'a twin': *rās tawām al-muqaddam*. α Geminorum.

thaur . . 'bull': *al-thaur*, the sign Taurus: *'ain al-thaur*. α Tauri or Aldebaran.

al-thuraiyā . the Pleiades: *al-thuraiyā*. χ Persei: *mirfaq al-thuraiyā*. α Persei.

tinnīn . . 'dragon': *rās tinnīn*, ? ι Herculis.

umm . . 'mother': the body of an astrolabe: mater.

'unq . . 'neck': *'unq al-shujā'*. ύ Hydræ: *'unq al-ḥaiya*. λ Serpentis.

usṭurlāb . 'astrolabe.'

wāqi' . . 'falling'; *nasr al-wāqi'*. α Lyra or Vega.

yad . . 'hand'; *yad al*-dubb, ι Ursæ maj.; *yad al-jauzā*, α Orionis.

yamānı . 'of Yemen'; *Shi'ri yamānīh*, Sirius.

yumnī . . 'right hand'; see α and κ Orionis.

zabānā . 'sting of an insect'; the 16th manzil; α Cancri.

zanab . . 'tail'; *zanab al-dajājah*, α Cygni; *zanab al-jadī*, γ Capricorni; *zanab qīṭus*, ? β Ceti.

ẕahr . . 'back'; *ẕahr al-asad*, δ Leonis.

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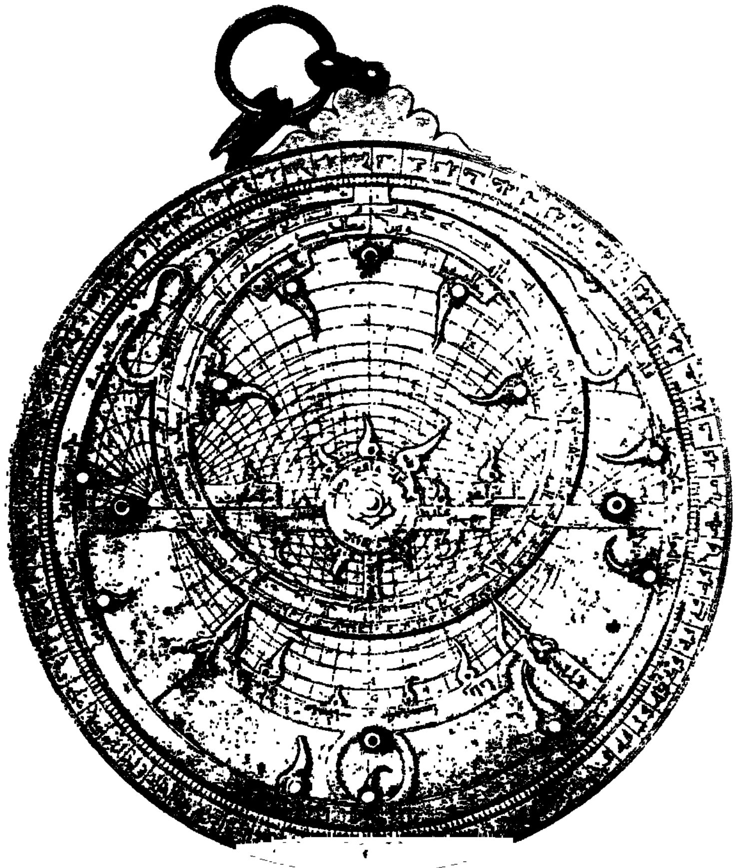

Fig. 1. Astrolabe A—Obverse.

Fig. 2. Astrolabe A—Reverse.

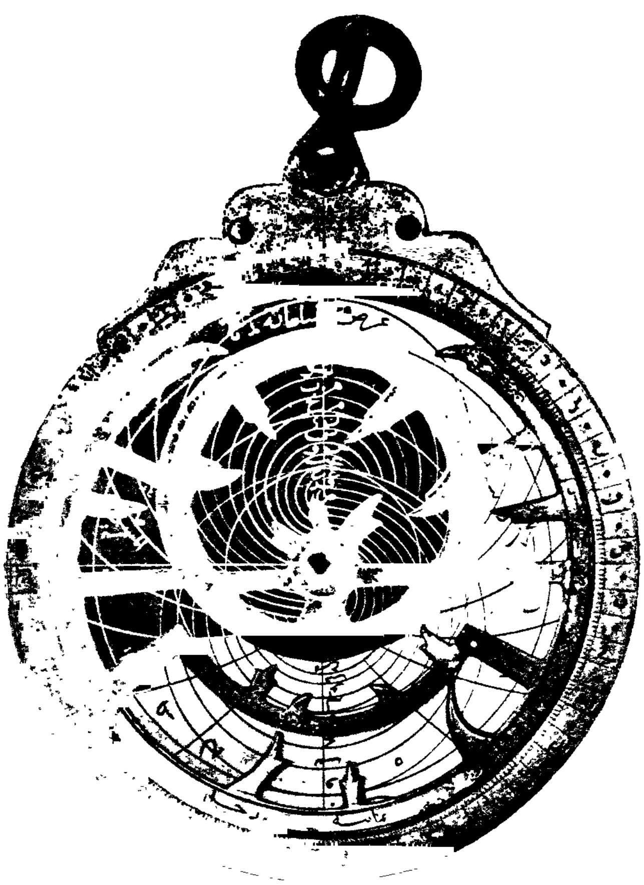

Fig. 3. Astrolabe B—Obverse.

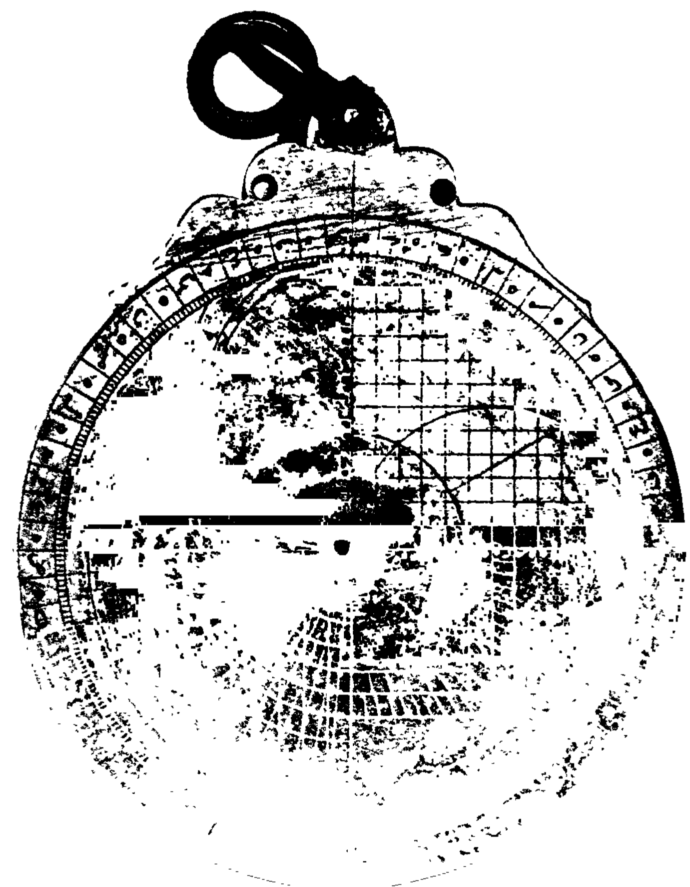

Fig. 4. Astrolabe B—Reverse.

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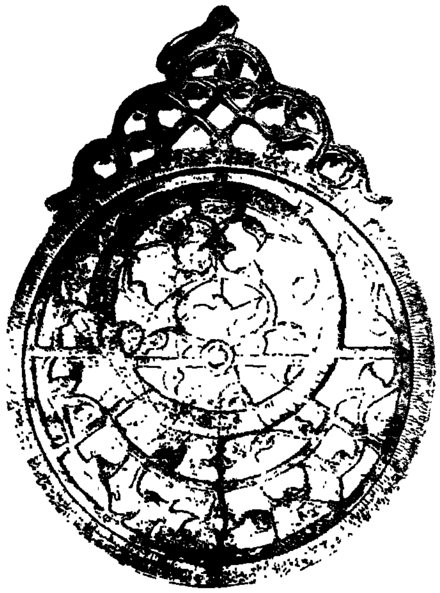

Fig. 5. Astrolabe C—Obverse.

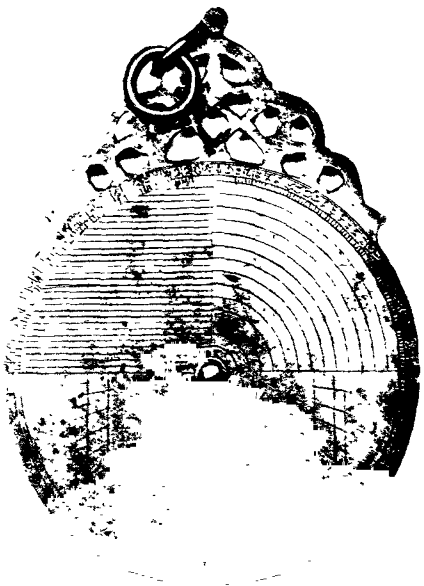

Fig. 6. Astrolabe C—Reverse.

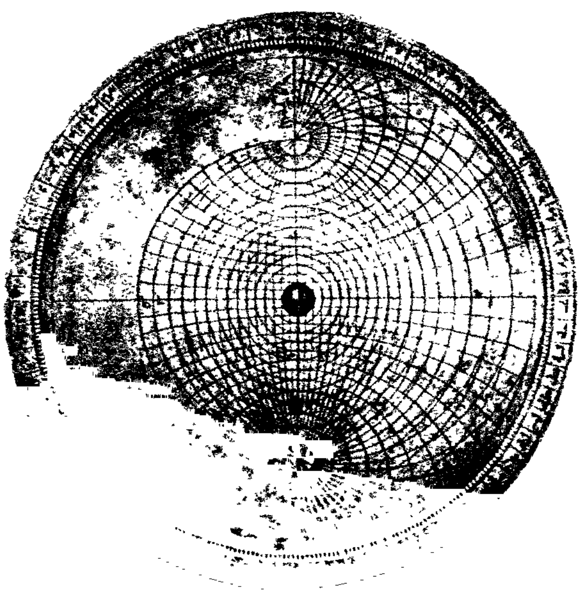

Fig. 7. Obverse of A. without 'Ankabūt

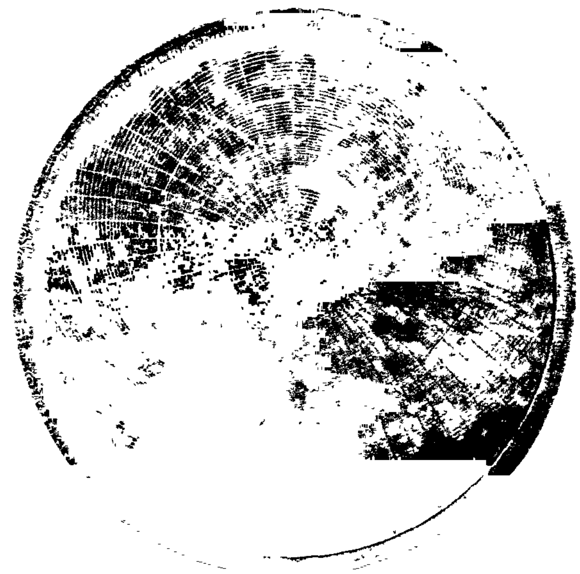

Fig. 8. Tablet of 'Ankabūt Co-ordinates.

Fig. 9. Celestial sphere made in A.D. 1676.

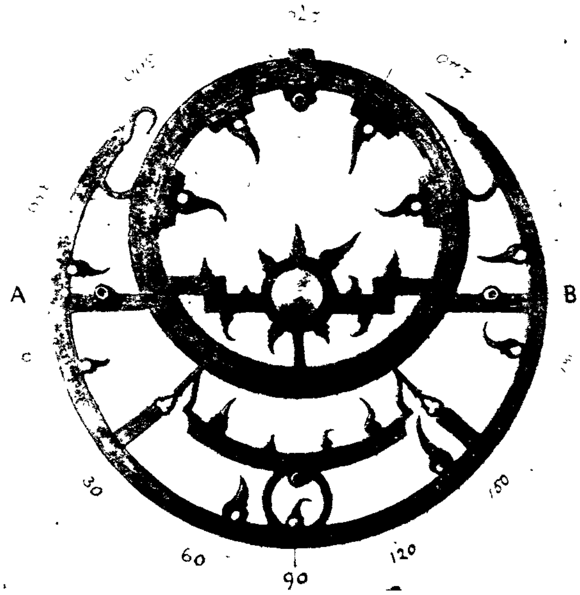

Fig. 10. 'Ankabūt with scale of longitudes.

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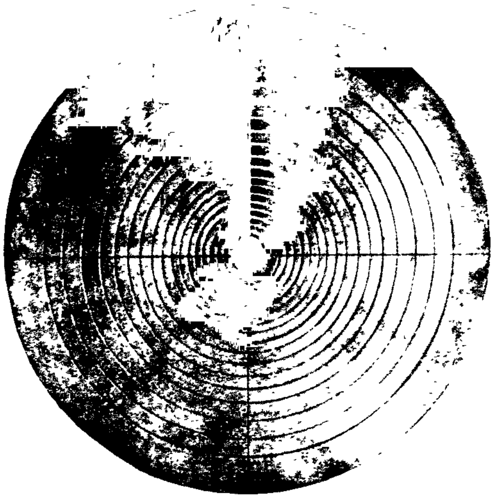

Fig. 11. I^a Declinations.

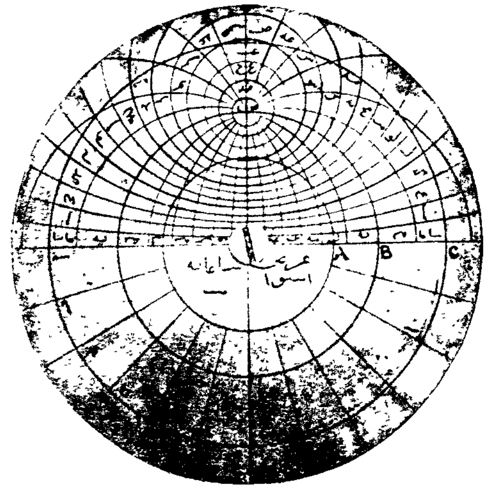

Fig. 12. I^b Latitude 0°.

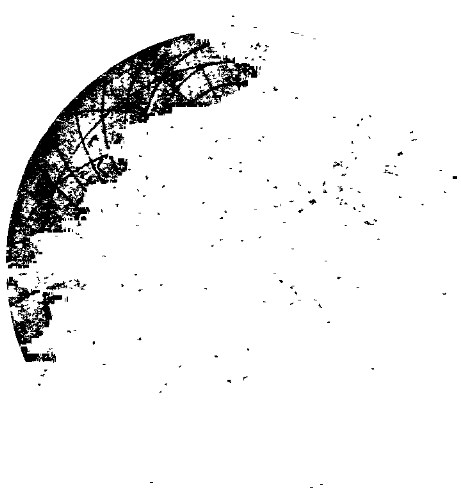

Fig. 13. II^a Latitude 18°.

Fig. 14. II^b Latitude 20°.

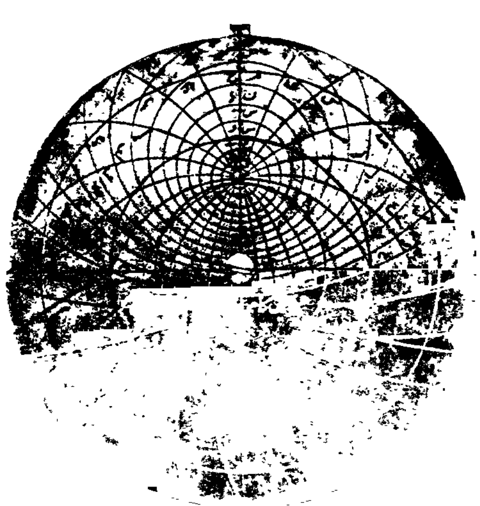

Fig. 15. III^a Latitude 21° 40′ (Mecca).

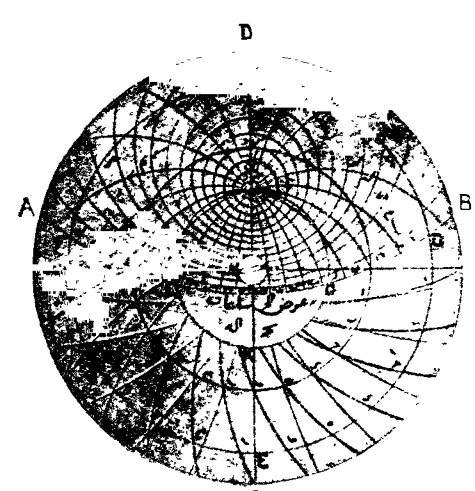

Fig. 16. III^b Latitude 23°.

Tablets of astrolabe B.

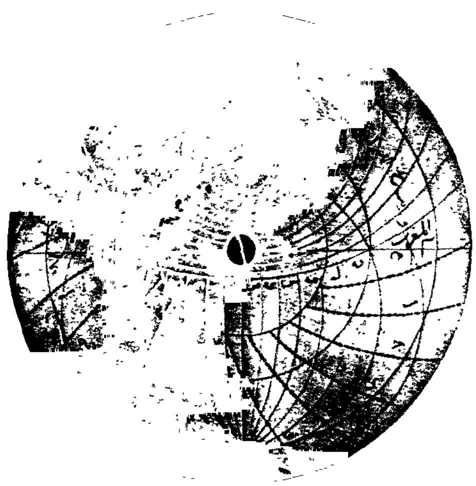

Fig. 17. IVᵃ LATITUDE 25°.

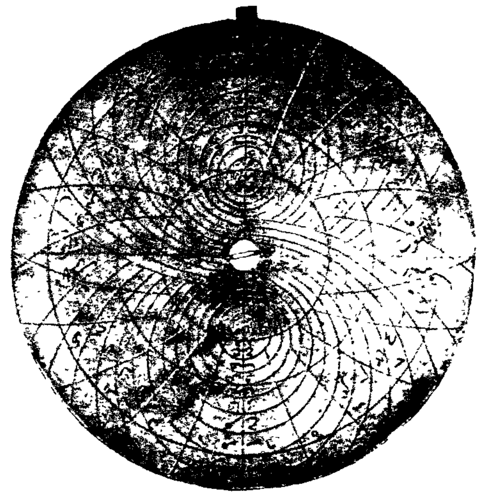

Fig. 18. IVᵇ LATITUDES 28° & 30°.

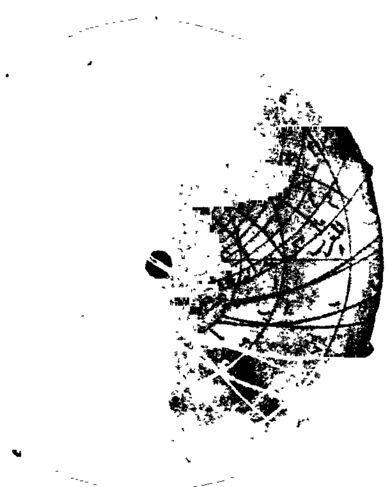

Fig. 19. Vᵃ LATITUDE 32°.

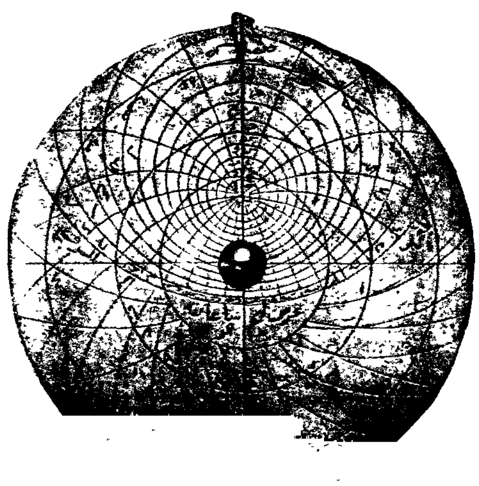

Fig. 20. Vᵇ LATITUDE 36°.

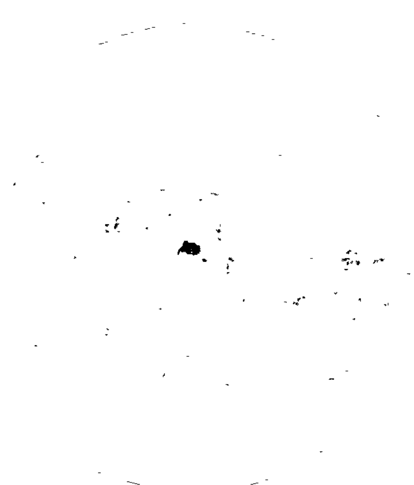

Fig. 21. VIᵃ LATITUDES 40° & 66° 30′.

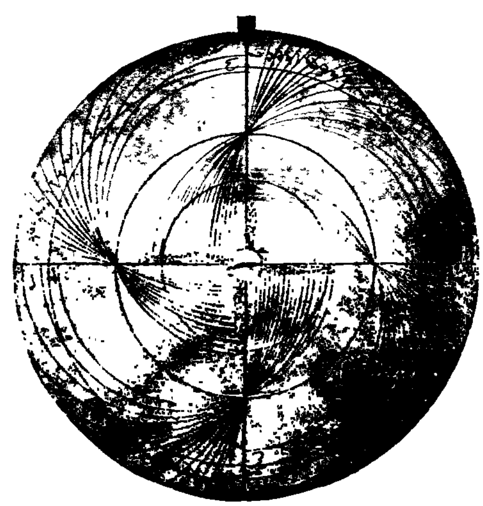

Fig. 22. VIᵇ HORIZONS.

TABLETS OF ASTROLABE B.

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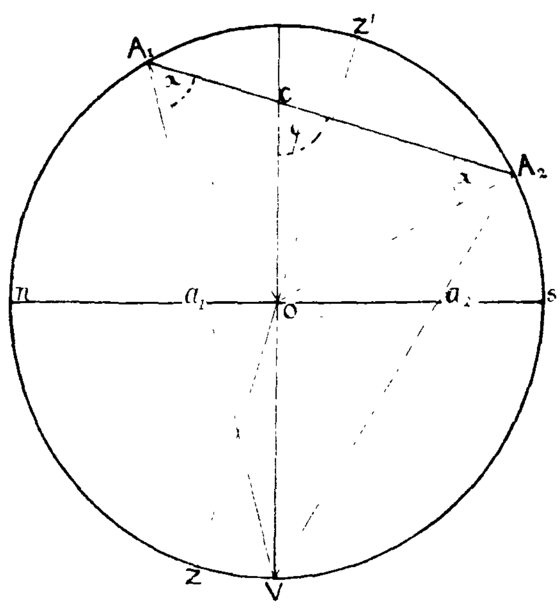

FIG. 23.

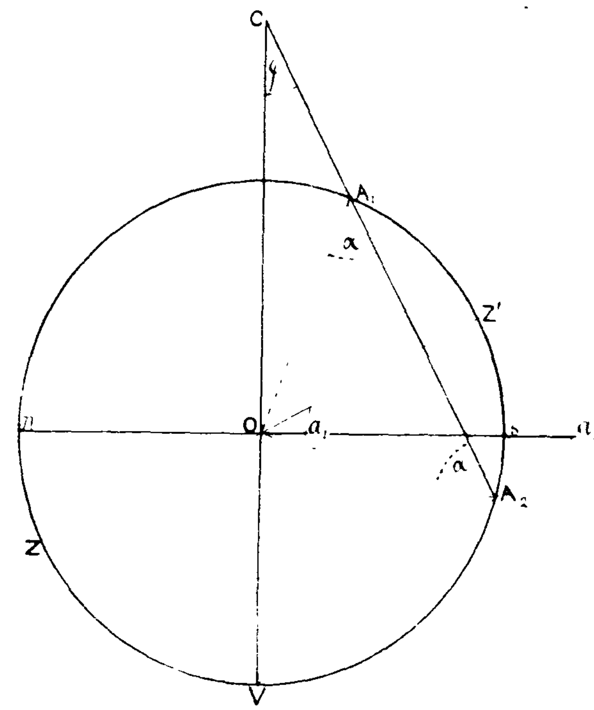

FIG. 24

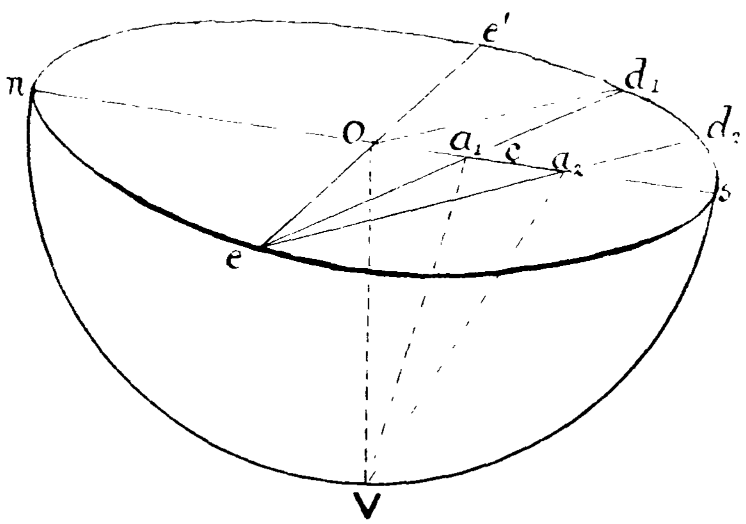

FIG. 25.

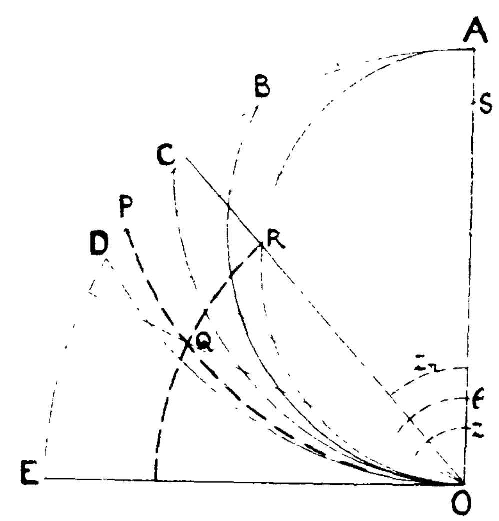

FIG. 26

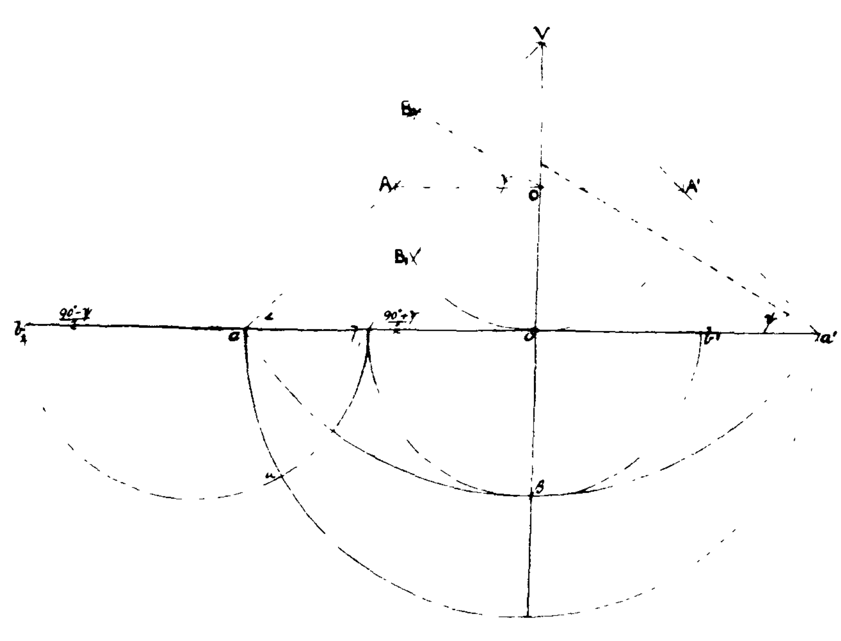

FIG. 27

Abjad Notation-Kūfic.

a=1 ا	b=2 ب	j=3 ج	d=4 د	h=5 ه	w=6 و	z=7 (ز)	ḥ=8 ح	ṭ=9 (ط)
ī=10 ي	k=20 ك	l=30 ل	m=40 م	n=50 ن	s=60 س	ʿ=70 ع	f=80 ف	ṣ=90 ص
q=100 ق	r=200 ر	sh=300 ش						

Abjad Notation-Naskhī.

a=1 ا	b=2 ب	j=3 ج	d=4 د	h=5 ه	w=6 و	z=7 ز	ḥ=8 ح	ṭ=9 ط
ī=10 ي	k=20 ك	l=30 ل	m=40 م	n=50 ن	s=60 س	ʿ=70 ع	f=80 ف	ṣ=90 ص
q=100 ق	r=200 ر	sh=300 ش	t=400 ت	th=500 ث	kh=600 خ	dh=700 ذ	ḍ=800 ض	ẓ=900 ظ
gh=1000 غ								

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