MANUAL

OF

MENSURATION AND SURVEYING

FOR

MANDALS AND PATWARIS IN ASSAM.

SHILLONG:
PRINTED AT THE ASSAM SECRETARIAT PRINTING OFFICE.
1900.

PRICE—ONE RUPEE (or 1s. 4d.)

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PRINTING DEPARTMENT.

PREFACE.

THIS Manual of Mensuration and Surveying is chiefly intended for Mandals and Patwaris, and for use in Survey Schools and Primary Schools in Assam.

PART I, *Mensuration*, is the work of Babu Girish Chandra Datta, Deputy Inspector of Schools, Lower Assam Division, revised by Mr. F. J. Monahan, I.C.S., late Director of this Department, and now Secretary to the Chief Commissioner of Assam, with the kind assistance of Dr. Booth, M.A., SC.D., Director of Public Instruction, Assam.

PART II, *Surveying*, has been prepared by Mr. Monahan by whom the plan of the Manual was arranged in consultation with Mr. J. Willson, M.A., late Director of Public Instruction, Assam.

L. J. KERSHAW,

Offg. Director, Department of Land Records and Agriculture, Assam.

SHILLONG,
The 14th June 1899.

PART I.

MENSURATION.

PART I.

MENSURATION.

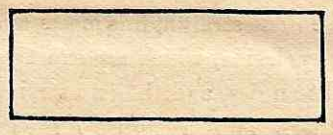
CHAPTER I.

DEFINITIONS.

1. *Mensuration.*—Mensuration is the art of measuring figures of every form, whether superficial or solid, regular or irregular.

2. *Superficies.*—A superficies or surface has length and breadth, but no thickness (see figure 1) :

Figure 1.

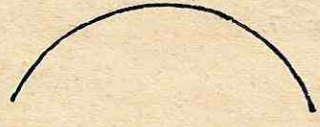


3. *Line.*—A line has length only, without breadth or thickness, and is the boundary of a superficies.

It may be straight (right) (*see* figure 2), or curved (see figure 3) :

Figure 2.

Figure 3.



4. *Point.*—The extremities of a line are points ; a point marks position, but has neither parts nor dimensions (see figures 4 and 5) :

Figure 4.

Figure 5.

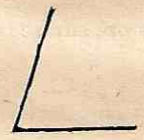
5. *Straight line.*—A straight line is the shortest distance between two points (*see* figure 2).

NOTE.—A line is said to be straight when the whole of it has the same direction, or points the same way.

6. *Plane surface.*—A plane surface (is a perfectly flat superficies) or even surface, and is such that if any two points in it be joined by a straight line, the whole of the straight line will be in the superficies (see figure 1).

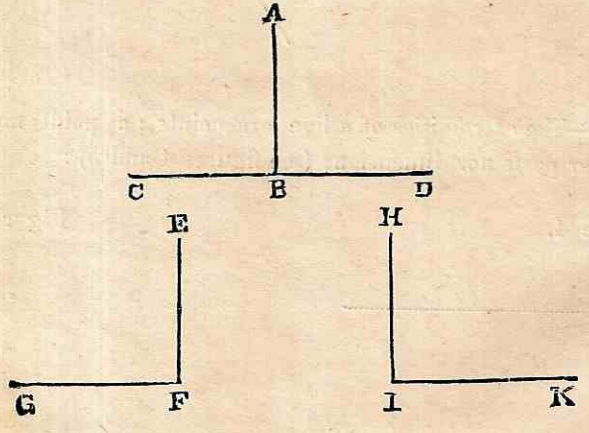
7. *Angle.*—An angle is formed by two lines, meeting one another. When the two lines are straight lines, the angle is called a *rectilinear* angle (see figure 6):

Figure 6.



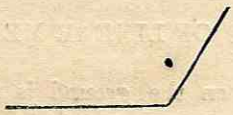
8. *Perpendicular.*—When one straight line meets another straight line so as to form two angles, one on each side, which are exactly equal one to the other, these angles are called right angles, and the two straight lines are said to be perpendicular one to the other. Thus, in figure 7, the angles A B C and A B D formed by the straight lines A B and C D on either side of the straight line A B, being exactly equal one to the other, are right angles, the straight line A B is perpendicular to the straight line C D, and the straight line C D is perpendicular to the straight line A B. Similarly, the angles E F G and H I K are right angles, the straight lines E F and F G are perpendicular to one another and the straight lines H I and I K are perpendicular to one another (figure 7).

Figure 7.



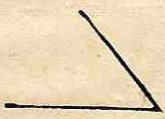
9. *Obtuse angle.*—An obtuse angle is an angle greater than a right angle (see figure 8):

Figure 8.



10. *Acute angle.*—An acute angle is an angle less than a right angle (see figure 9):

Figure 9.

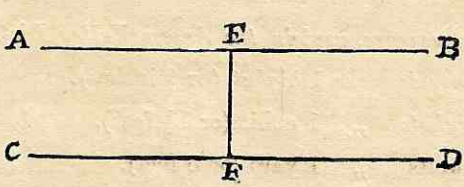


11. Two straight lines in the same plane which, being produced to the greatest distance in either direction, will never meet, are said to be parallel to one another. Thus, the two straight lines A B and C D, in the same plane which, though produced to the greatest distance, either in the direction A B, C D, or in the direction B A, D C, will never meet, are parallel to one another (see figure 10):

Figure 10.

12. Any two straight lines which are perpendicular to the same straight line, all these being in the same plane, will be parallel to one another. Thus, in figure 11 the two straight lines A B and C D, which are perpendicular to the straight line E F, are parallel to one another:

Figure 11.



CHAPTER II.

TABLES OF LINEAR MEASURE.

13. The length of a line on the ground is reckoned by the number of equal straight lines of a certain length which are contained in it or which, when added to one another, will give the same total length. Each of such equal lengths into which the total length to be measured is divided,—as an inch, a foot, a yard, a link, etc.,—is called an unit of linear measure.

14. Table of English linear measure—

12 inches make 1 foot.
3 feet „ 1 yard.
5½ yards „ 1 rod or pole.
40 poles „ 1 furlong.
8 furlongs „ 1 mile.

Hence we obtain the following results :

Mile	Furlongs	Poles	Yards	Feet	Inches
1	= 8	= 320	= 1760	= 5280	= 63360
	1	= 40	= 220	= 660	= 7920
		1	= 5½	= 16½	= 198
			1	= 3	= 36
				1	= 12

In measuring land a chain, called *Gunter's chain*, is used, which is 22 yards or 66 feet or 4 poles long and consists of 100 equal links. The length of an offset staff (*tár*) is 20 Gunter's links, or $\frac{1}{5}$th of a Gunter's chain. The staff is divided by marks into 20 equal parts, each of which is one Gunter's link in length.

15. Table of local linear measure—

(*a*) *Assam measure, used in the Assam Valley Districts.*

12 *angulis* make 1 *bighat* (or 9 inches).
2 *bighats* „ 1 cubit (or 1½ feet).
2 cubits „ 1 yard (or 3 feet).
4 yards „ 1 *mauzadari tár* (*nal*) (or 12 feet).

In measuring land by the mauzadari method a chain is used, called *mauzadari chain*, which is 30 feet or 20 cubits long, and consists of 40 equal links, each link of the mauzadari chain is therefore 9 inches or 1 *bighat* long. Thus, 22 links of the mauzadari chain make a pole, 22 mauzadari chains (or 880 links) make a furlong, 176 mauzadari chains (or 7,040 links) make a mile, and 16 links make a mauzadari *tár* (*nal*).

A mauzadari *tár* or *nal*, is a straight rod 12 feet long and divided by marks into 12 equal parts, each part measuring 1 foot. Like the 30 feet chain, it is used in measuring lands where the cadastral survey system has not been introduced.

(*b*) *Bengal measure, used in the Surma Valley Districts.*

6 *angulis* make 1 *chatak* (or 4½ inches).

2 *chataks* „ 1 *bighat* (or 9 inches).

4 „ „ 1 cubit (or 1½ feet).

4 cubits or 16 *chataks* make 1 *katha* (or 6 feet).

20 *kathas* or 80 cubits „ 1 *bigha* (or 120 feet).

16. EXAMPLES—

(1) Convert 23 yards 1 foot 6 inches into cubits :

Yards	Foot	Inches
23	1	6
3		
69		
1		
70 feet.		
12		
840		
6		
9) 846 inches.		
2) 94 *bighats.*		
47 cubits.		

∴ The number of cubits required is 47.

(2) Convert 2 furlongs 20 poles 4 yards into *táras*, etc.

Furlongs	Poles	Yards
2	20	4

40

80

20

100 poles.

$5\frac{1}{2}$

500

50

550

4

4)554 yards.

138-2 yards.

∴ The result is 138 *táras* 2 yards.

(3) Reduce 2 miles 2 chains 5 yards to cubits.

Miles	Chains	Yards
2	2	5

80

160

2

162 chains.

22

324

324

3564 yards.

5

3569

2

7138 cubits.

∴ The number of cubits required is 7138.

(6) Convert 7011 feet into linear *bighas*, etc.:

6) 7011

20) 1168 *kathas* 8 *chataks*.

58 *bighas* 8 *kathas*.

∴ The result is 58 *bighas* 8 *kathas* 8 *chataks*.

(7) Convert 58 *bighas* 8 *kathas* 8 *chataks* into feet.

Bighas	*Kathas*	*Chataks*
58	8	8
120	6	4½
6960 feet.	48 feet	36 inches or 3 feet.

48 „

3 „

7011 feet.

∴ The result is 7011 feet.

EXAMPLES.

(1) Convert 627 feet into cubits.

(2) „ 204 cubits into feet.

(3) Reduce 1 mile 20 cubits into feet.

(4) Convert 10260 inches into *társ*, etc.

(5) „ 501 *társ* respectively into cubits, yards, feet, and links.

(6) „ 52 chains (Gunter's) respectively into feet, yards, cubits, links.

(7) Convert 25 chains (30 feet) respectively into feet, yards, cubits, *bighats*.

(8) How many miles, etc., are there in 255904 cubits ?

(9) Convert the following into linear *bighas*, etc.:
4501 yards 4165 feet 6 inches.

(10) How many feet, etc., are there in 10 *bighas* 2 *kathas* 4 *chataks* ?

17. *The use of the chain.*—To measure a straight line on the ground with the chain the services of two men, called chainmen, are required. Two flags are first set up at the points, the distance between which is to be measured. One of the chainmen, called the 'rear chainman' stands at one of the flags, called the 'back flag,' and holds one end of the chain close to the

(4) Convert 5 *társ* 2 yards 1 cubit into feet :

Tars.	Yards.	Cubit.
5	2	1
4		
20		
2		
22 yards.		
2		
44		
1		
45 cubits.		
$1\frac{1}{2}$		
45		
$22\frac{1}{2}$		
$67\frac{1}{2}$ feet, or 67 feet 6 inches.		

∴ The result is 67 feet 6 inches.

(5) How many miles, yards, etc., are there in 960000 *angulis* ? :

12) 960000 *angulis.*
2) 80000 *bighats.*
2) 40000 cubits.
1760) 20000 yards (11 miles.
1760
2400
1760
22) 640 (29 chains.
44
200
198
2 yards.

∴ The result is 11 miles 29 chains 2 yards.

ground. The other chainman, called the 'front chainman' holds the other end of the chain, and, taking with him ten arrows, proceeds in the direction of the other flag, called the 'forward flag.' The rear chainman directs the front chainman in a straight line towards the forward flag, and, as soon as the chain is stretched to its full length between the two flags, the front chainman puts one arrow into the ground at his end of the chain. The rear chainman then comes up to the arrow with his end of the chain, which he holds there, the front chainman taking on the other end of the chain in a straight line towards the forward flag. The chain having been a second time stretched tight in a straight line between the two flags, the front chainman plants a second arrow in the ground at his end of the chain. The rear chainman then takes up the arrow first planted in the ground, and comes up to the second arrow, the front chainman proceeding in the direction of the forward flag as before. This process is repeated until a distance of 10 chains has been measured, when the front chainman will have no more arrows in his hands. The front chainman then stops at the end of the tenth chain, and the rear chainman, coming up to him, makes over to him the arrows which he holds. The front chainman then goes forward as before, and so on, until the forward flag is reached by the front chainman, when the number of chains and links measured is counted. The number of arrows held by the rear chainman at any time will show the number of chains which have been measured in addition to the last distance of ten chains counted. In proceeding between the flags, the rear chainman directs the front chainman by seeing that the front arrow is planted in a straight line with the rear arrow and the forward flag. The front chainman should also take care to plant each arrow in a straight line with the arrow at the rear end of the chain and the back flag. Any straight line thus measured on the ground between two points with the chain is called a *chain line*.

18. As the chain is liable to stretch in use, its length should be frequently tested.

For the purpose of testing the length of Gunter's chains a distance of 66 feet is measured on the ground by means of a standard bar of steel 6 feet in length, with feet and inches accurately marked on it. Two stout wooden pegs are permanently fixed in the ground at each end of this distance, which is divided into distances of ten links each by means of smaller pegs. To test the length of the chain it is stretched on the ground along the line marked by the pegs. If found longer than the required length of 66 feet, the chain is shortened by removing one or more of its rings or by closing the joints of the rings. If found the short, the chain can be lengthened by opening the joints of the rings.

19. The measuring tape is 66 feet long and has marked on one side feet and inches, and on the other side links. It may be used in the same way as the chain, but is not often used in measuring land, as it would not stand much wear and tear.

20. The offset staff (*tár*) is used in measuring distances not exceeding 150 links. It is used by one man, who judges with the eye the direction in which the measurement is to be taken and lays the staff on the ground with one end at one of the two points the distance between which is to be measured and the other directed towards the other point. Having thus measured a distance of one offset staff, he then raises the end of the staff at the point from which the measurement starts, keeping the forward end on the ground and turning the staff over, again lays it on the ground in the required direction, so as to measure a second distance of an offset staff in length. This process he repeats until the whole distance has been measured. Each time that he causes the staff to revolve he should call out the number of offset staves measured by him. It is important that each time the staff is turned over it should be laid flat on the ground before the rear end is taken up again.

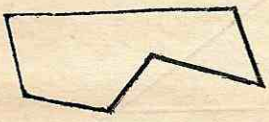
The mauzadari *tár* or *nal* is used in the same manner as the offset staff in making mauzadari measurements.

CHAPTER III.

RECTILINEAR FIGURES.

21. *Plane rectilinear figure.*—A plane rectilinear figure is a figure lying all in the same plane, which is bounded by straight lines. The boundaries of the figure are called sides (see figure 12) :

Figure 12.



22. *Triangle.*—A triangle is a plane rectilinear figure having three sides and consequently three angles (see figure 13); it is called right angled when one of the angles is a right angle (see figure 14) :

Figure 13.

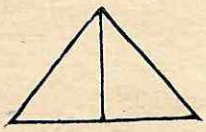
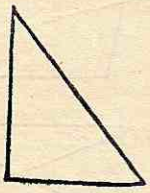


Figure 14.



23. Any side of a triangle may be called the base ; then the height of the triangle is the length of the perpendicular drawn from the opposite angular point on the base. Thus, in the three triangles in figure 15 the side A B being taken to be the base, the height is the length of the straight line C D

CHAPTER IV.

SQUARE MEASURE.

28. The area or the content of a plane figure is reckoned by the number of equal squares of a certain size which would be contained in it, or which, being added together, would cover the same total area. Each of such equal squares into which the whole area to be measured is divided is called an unit of square measure, and is described by the length of its sides. Thus, a square inch is an unit of square measure, being a square of which each side is one inch in length, a square foot is a square of which each side is a foot in length, etc.; so if the figure to be measured be the rectangle A B C D (figure 22); and the small square E, the side of which is one inch in length, be the unit of square measure proposed, then the area of the rectangle is said to be as many square inches as it contains squares, each of the same size as the square E, that is to say, 12 square inches:

Figure 22.

29. Table of English square measure--

Table of square measure.

144 square inches ... ... = 1 square foot.
9 „ feet ... ... = 1 „ yard.
$30\frac{1}{4}$ „ yards ... ... = 1 „ pole.
40 „ poles ... ... = 1 rood.
4 roods ... ... = 1 acre.
10000 square links ... ... = 1 square chain.
100 „ chains or 1000000 square links = 1 „ furlong.
6400 „ „ or 64000000 „ „ = 1 „ mile.
625 „ links ... ... = 1 „ pole.
25000 „ „ ... ... = 1 rood.
100000 „ „ or 10 square chains ... = 1 acre.
1 acre ... ... = $3\frac{1}{40}$ square *bighas*.

From the above table we may obtain the following results:

Square mile.	Square furlongs.	Acres.	Roods.	Square chains.	Square poles or rods.	Square yards.	Square feet.
1	2	3	4	5	6	7	8
1	64	640	2560	6400	102400	3097600	27878400
	1	10	40	100	1600	48400	435600
		1	4	10	160	4840	43560
			1	$2\frac{1}{9}$	40	1210	10890
				1	16	484	4356
					1	$30\frac{1}{4}$	$272\frac{1}{4}$
						1	9

30. Local measure (officially used) :

(*a*) *Assam measure, used in the Assam Valley districts.*

144 square *angulis* ... ... = 1 square *bighat.*
4 „ *bighats* ... ... = 1 „ cubit.
4 „ cubits ... ... = 1 „ yard (or *kani*).
4 square yards (or *kanis*) ... = 1 *powa.*
4 *powas* ... ... = 1 *lessa.*
20 *lessas* ... ... = 1 *katha.*
5 *kathas* ... ... = 1 *bigha.*
4 *bighas* ... ... = 1 *pura.**
1936 *bighas* ... ... = 1 square mile.
144 square feet ... ... = 1 *lessa.*

* *Note.*—The *pura* is not used officially.

Hence we obtain the following results :

Bigha.	*Kathas.*	*Lessas.*	*Powas.*	Square yards or *kanis.*	Square cubits.	Square *bighats* or square links (30 feet chain).
1	2	3	4	5	6	7
1	5	100	400	1600	6400	24600
	1	20	80	320	1280	5120
		1	4	16	64	256
			1	4	16	64
				1	4	16
					1	4

(*b*) *Bengal measure, used in the Surma Valley districts.*

1 square *bighat* ... ... = 1 *kara.*
4 *karas* or 1 square cubit ... ... = 1 *ganda.*
20 *gandas* or 20 square cubits or 5 square yards = 1 square *chatak.*
4 square *chataks* or 80 square cubits or 20 square yards. = 1 *powa.*
4 *powas* or 16 square *chataks* or 320 square cubits or 80 square yards. = 1 square *katha.*
20 square *kathas* or 6400 square cubits or 1600 square yards. = 1 square *bigha.*

Note —

81	square inches	...	...	... = 1 *kara.*
2¼	„ feet	...	...	... = 1 *ganda.*
45	„ „	...	...	... = 1 square *chatak.*
180	„ „	...	...	... = 1 *powa.*
720	„ „	...	...	... = 1 square *katha.*
14400	„ „	...	...	... = 1 „ *bigha.*
1936	„ *bighas*	...	...	... = 1 „ mile.

31. The following table shows the comparison between the English, the Bengal, and the Assam square measure :

English.	Bengal districts.	Assam districts.
1	2	3
1 square chain (30 feet)	1 *katha* 4 *chataks* ...	6¼ *lessas.*
1 „ „ (66 feet)	6 *kathas* 16 *gandas* or 1936 *gandas.*	30¼ *lessas.*
1 pole	6 *chataks* 1 *ganda* ...	30¼ *kanis.*
1 rood	15 *kathas*, 2 *chataks* ...	3 *kathas* 15 *lessas* 2 *powas* 2 *kanis.*
1 acre	3 *bighas* 8 *chataks* (or 242 *powas*).	3 *bighas* 2½ *lessas.*
1 square mile ..	1936 square *bighas* ...	1936 *bighas.*

32. Bengal land measure may be turned into Assam measure in the following way :

Rule.—Take down *bighas* as they are, then multiply the remaining by 5, take as many *lessas*, *kanis*, and *tils** respectively as there are *kathas*, *chataks*, and *gandas* in the product.

* 20 *tils* ... ... = 1 *kani* or 1 square yard.
5 „ ... ... = 1 square cubit.
1¼ „ ... ... = 1 „ *bighat.*

33. Examples—

Ex. 1.—Reduce 15 *bighas* 6 *kathas* 10 *chataks* to *bighas, kathas, lessas,* etc.:

Kathas	*Chataks*
6	10
	5
33 *lessas*	2 *kanis.*

∴ the Assam measure is 15 *bighas* 1 *katha* 13 *lessas* 2 *kanis.*

Ex. 2.—Reduce 107 *bighas* 3 *kathas* 5 *chataks* 17 *gandas* 3 *karas* to Assam *bighas, kathas,* etc. :

Kathas	*Chataks*	*Gandas*	*Karas*
3	5	17	3
			5
16	13	8	3

or 16 *lessas* 3 *powas* 1 *kani* 8¾ *tils.*

∴ the Assam measure is 107 *bighas* 16 *lessas* 3 *powas* 1 *kani* 1 square cubit 3 square *bighats.*

34. Assam land measure may be turned into Bengal measure in the following way :

Rule.—Take down *bighas* as they are, then divide the remaining by 5 ; take as many *kathas, powas, chataks* respectively as there are *lessas, powas, kanis* in the quotient, and for remainder, if any, take 4 times the number of *gandas.*

35. Examples :

Ex. 1.—Reduce 15 *bighas* 1 *katha* 13 *lessas* 3 *kanis* to *bighas, kathas, chataks,* etc. :

Katha	*Lessa*	*Powas*	*Kanis*
1	13	0	3
or 5)	33	0	3
	6	2	2-4 *gandas.*

∴ the Bengal measure is 15 *bighas* 6 *kathas* 10 *chataks* 4 *gandas.*

N.B.—In questions involving square cubits and square *bighats* take *gandas* for square cubits and *karas* for square *bighats.*

Ex. 2.—Reduce 107 *bighas* 16 *lessas* 3 *powas* 1 *kani* 1 square cubit 3 square *bighats* to Bengal measure :

Lessas	*Powas*	*Kani*			
5) 16	3	1			
3	1	1	16	*gandas.*	
			1	„	3 *karas.*
3	1	1	17	„	3 „

∴ the Bengal measure is 107 *bighas* 3 *kathas* 5 *chataks* 17 *gandas* 3 *karas.*

36. EXAMPLES—

Ex. 1.—Convert 48420 square feet into *bighas,* etc. :

144 { 9) 48420 square feet.
4) 5380 *kanis.*
4) 1345 *powas.*
3,36 1 *powa.*

∴ 3 *bighas* 1 *katha* 16 *lessas* 1 *powa* (Assam measure).

{ 9) 48420 square feet.
5) 5380 „ yards.
16) 1076 „ *chataks.*
20) 67 4 square *chataks.*
3 7 *kathas.*

∴ 3 *bighas* 7 *kathas* 4 *chataks* (Bengal measure).

Ex. 2.—Convert 200 square chains (Gunter's) into *bighas,* etc. :

200 square chains.
$30\frac{1}{4}$
60,50 *lessas.*

∴ 60 *bighas* 2 *kathas* 10 *lessas* (Assam measure).

200 square chains.
1936
20) 387200 *gandas.*
16) 19360 *chataks.*
20) 1210 *kathas.*
60 10 *kathas.*

∴ 60 *bighas* 10 *kathas* (Bengal measure).

Ex. 3.—Convert 30892842 square links into *bighas*, etc. (Gunter's chain):

30892842 square links.

$30\frac{1}{4}$

926785260
7723210
10000) 934508470
934,50 8470
4
3,3880
4
1,5520

∴ 934 *bighas* 2 *kathas* 10 *lessas* 3 *powas* 1 *kani* (Assam measure).

30892842 square links.

1936

185357052
92678526
278035578
30892842
10000) 59808542112
20) 5980854 *gandas*.
6) *chataks* 299042 14 *gandas*.
20) *kathas* 18690 2 *chataks*.
bighas 934 10 *kathas*.

∴ 934 *bighas* 10 *kathas* 2 *chataks*, 14 *gandas* (Bengal measure).

Ex. 4.—Reduce 2 square miles 16 square chains 360 square feet to *bighas*, etc. (Gunter's chain)—

Square miles	Square chains	Square feet
2	16	9)360
1936	$30\frac{1}{4}$	4)40 *kanis*.
		4)10 *powas*.
bighas 3872	*lessas* 4,84	*lessas* 2 2 „

∴

Bighas	*Kathas*	*Lessas*	*Powas*
3872	0	0	0
4	4	4	0
0	0	2	2
3876	4	6	2 (Assam measure).

Square miles	Square chains	Square feet
2	16	9) 360
1936	1936	5) 40 square yards.
3872	20) 30976 *gandas*.	8 *chataks*.
	1548 *chataks* 16 *gandas*.	
	8	
	16) 1556	
	20) 97 *kathas* 4 *chataks*.	
	Bighas 4 17 *kathas*.	
	3872	
	3876 17 *kathas* 4 *chataks* 16 *gandas*.	
	(Bengal measure).	

Ex. 5.—Convert 20 *bighas* 2 *kathas* 15 *lessas* 2 *powas* 2 *kanis*, respectively, into square yards, square feet, square cubits :

Bighas	*Kathas*	*Lessas*	*Powas*	*Kanis*
20	2	15	2	2

100

2055 *lessas*.
4

8222 *powas*.
4

32890 *kanis* or square yards.
4

131560 square cubits.

32890 square yards.
9

296010 square feet.

∴ 32890 square yards.
131560 „ cubits.
296010 „ feet.

Ex. 6.—Reduce 10 *bighas* 2 *kathas* 10 *chataks* 12 *gandas* respectively, into square cubits, square yards and square feet :

Bighas	*Kathas*	*Chataks*	*Gandas*
10	2	10	12

20

202 *kathas*.
16

3242 *chataks*.
20

4) 64852 *gandas*, or square cubits.
16213 square yards.
9

145917 square feet.

∴ 64852 square cubits.
16213 „ yards.

Ex. 7.—Convert 201 acres into *bighas*, etc. :

201 acres.
10

2010 square chains.
$30\frac{1}{4}$

60300
502 2 *powas.*

608,02 2 *powas.*

∴ 608 *bighas* 2 *lessas* 2 *powas* (Assam measure)

201 acres
bighas 3 8 *chataks.*

603 5 8 *chataks.*

608 *bighas* 8 *chataks.*

201 acres
8 *chataks.*

20) *kathas* 100 8 *chataks.*
bighas 5 8 *chataks.*

∴ 608 *bighas* 8 *chataks* (Bengal measure).

Ex. 8.—Convert 5 acres 2 roods 20 poles into *bighas*, etc.

Acres	Roods	Poles
5	2	20

4

22
40

900
$30\frac{1}{4}$

27000
225

4) 27225 square yards or *kanis.*
4) 6806 1 *kani.*
Lessas 17,01 2 *powas.*

∴ 17 *bighas* 1 *lessa* 2 *powas* 1 *kani* (Assam measure).

900 poles.
121
20) 108900 *gandas.*
16) 5445 *chataks.*
20) 340 5 *chataks.*
17 *bighas*

∴ 17 *bighas* 5 *chataks* (Bengal measure).

Ex. 9.—Reduce 623 square chains to acres, etc. :

10) 623 square chains

acres 62 3
4
rood 1 2
40
poles 8 0

∴ 62 acres 1 rood 8 poles.

Ex. 10.—Reduce 2537500 square links to acres, etc. :

100000) 2537500 square links.

acres 25 375
4
rood 1 5
40
poles 20 0

∴ 25 acres 1 rood 20 poles.

Ex. 11.—Convert 35 *bighas* into acres, * etc. :

35
40
121) 1400 (11 acres.
1331
69
4
121) 276 (2 roods.
242
34
40
121) 1360 (11 poles.
1331
29 square cubits.

∴ 11 acres 2 roods 11 poles and 29 square cubits.

* 1 acre = $3\frac{1}{40}$ ($\frac{121}{40}$ or 3·025) *bighas, i.e.,* 3 *bighas* and one fortieth of a *bigha* ∴ 1 *bigha* = $\frac{40}{121}$ acres. Therefore 4 0 times *bigha* divided by 121 gives acres.

40. In Bengal and the Surma Valley such examples are expressed and worked in a different way.

The length, 80 cubits, is represented by one linear *bigha*, 4 cubits by one linear *katha* and 1 cubit by 4 linear *chataks* [see article 15 (*b*)]. By this method, 464 cubits is represented by 5 *bighas* 16 *kathas* and example No. 2 is expressed in the following manner:

Find the area of a piece of ground 5 *bighas* 16 *kathas* long and 4 *bighas* 15 *kathas* broad. The rule by which the area is found is called the rule of *Suvanker*:

41. *Rule of Suvanker.*

Bigha into *bigha* makes *bigha*.

Katha into *bigha* makes *katha*.

Katha into *katha* makes *ganda*.

Twenty *gandas* make one *katha*.

Note.—If there be any remainder after raising *gandas* in the product to *katha* take sixteen times *gandas* in the area.

42. EXAMPLES—

Find the area of a piece of land 5 *bighas* 16 *kathas* long and 4 *bighas* 15 *kathas* broad:

Length	... ...	5 *bighas* 16 *kathas*.
Breadth	... ...	4 *bighas* 15 *kathas*.

5 *bighas* × 4 *bighas* = 20 *bighas*	20 *bighas*.
16 *kathas* × 4 *bighas* = 64 *kathas* = 3 *bighas* 4 *kathas*	3 „ 4 *kathas*.
15 *kathas* × 5 *bighas* = 75 *kathas* = 3 „ 15 „	3 „ 15 „
16 *kathas* × 15 *kathas* = 240 *gandas* = 12 „	12 „
∴ the area is 27 *bighas* 11 *kathas*	27 „ 11 „

Reasons for the above process—

5 *bighas* × 4 *bighas* = 20 square *bighas*.

16 *kathas* × 4 *bighas* = $\frac{16}{20}$ *bighas* × 4 *bighas* = $\frac{4}{5}$ square *bighas* = 3 *bighas* 4 *kathas*.

15 *kathas* × 5 *bighas* = $\frac{15}{20}$ *bighas* × 5 *bighas* = $\frac{3}{4}$ square *bighas* = 3 *bighas* 15 *kathas*.

15 *kathas* × 16 *kathas* = $\frac{15}{20}$ *bighas* × $\frac{16}{20}$ *bighas* = ($\frac{3}{4}$ × $\frac{4}{5}$) square *bighas* = $\frac{3}{5}$ square *bighas* = 12 square *kathas*.

43. But if there be *chataks* in length and breadth the area is calculated in the following way:

bighas into *chataks* make *chataks*.

kathas into *chataks* make *gandas*.

chataks into *chataks* make *kags*.

44. Examples.

Ex. 1. Find the area of a piece of land 7 *bighas* 8 *kathas* 6 *chataks* long and 5 *bighas* 12 *kathas* 9 *chataks* broad :

	B.	*k.*	*ch.*	*gan.*	*kags.*
Length	7	8	6	0	0
Breadth	5	12	9	0	0

	B.	*k.*				
7 *bighas* × 5 *bighas* = 35 *bighas*	35	0	0	0	0	
8 *kathas* × 5 *bighas* = 40 *kathas* =	2	0	...	2	0	0	0	0
12 *kathas* × 7 *bighas* = 84 *kathas* =	4	4	...	4	4	0	0	0
8 *kathas* × 12 *kathas* = 96 *gandas*								
= 4 *kathas* + 16 *gandas*								
= 4 *kathas* $\frac{16}{20}$ *kathas*								
= 4 *kathas* + ($\frac{4}{5}$ × 16) *ch.*								
= 4 *kathas* + 12 *chataks.*								
+ 16 *gandas* ...				0	4	12	16	0
7 *bighas* × 9 *chataks* = 63 *chataks*								
= 3 *kathas* 15 *chataks* ...				0	3	15	0	0
5 *bighas* × 6 *chataks* = 30 *chataks*								
= 1 *katha* 14 *chataks* ...				0	1	14	0	0
8 *kathas* × 9 *chataks* = 72 *gandas*								
= 3 *chataks* 12 *gandas* ...				0	0	3	12	0
12 *kathas* × 6 *chataks* = 72 *gandas*								
= 3 *chataks* 12 *gandas* ...				0	0	3	12	0
9 *chataks* × 6 *chataks* = 54 *kags*								
= 3 *gandas* 6 *kags* ...				0	0	0	3	6
				41	15	1	3	6

∴ the area is 41 *bighas* 15 *kathas* 1 *chatak* 3 *gandas* 6 *kags*.

Ex. 2.—Find the rent of land 4 *bighas* 10 *kathas* long and 3 *bighas* 5 *kathas* broad, at Re. 1-4 per *bigha* :

	B.	*k.*	*ch.*
Length	4	10	0
Breadth	3	5	0
	12	0	0
	1	10	0
	1	0	0
	0	2	8
	14	12	8

		Rs.	a.	p.
Rent of 1 *bigha*	=	1	4	0
				14
„ 14 *bighas*	=	17	8	0
„ 10 *kathas* or ½ of 1 *bigha*	=	0	10	0
„ 2 „ 8 *chataks* or ¼ of 10 *kathas*	=	0	2	6
		18	4	6

∴ the rent is Rs. 18-4-6.

ASSAM DISTRICTS.

45. In the Assam Valley such examples are expressed and worked in a different way.

The length, 8 cubits, is represented by 1 *tár* or *kahan*, 2 cubits by 1 *chowk* and half a cubit by one *pan*.

By this method 462 cubits are represented by 57 *kahans* and 3 *chowks* and example No. 3 (page 24) is represented in the following manner :

Find the area of a piece of ground 57 *kahans* 3 *chowks* long and 47 *kahans* 2 *chowks* broad :

46. Local method—

Tár into *tár* makes *lessa*.
Chowk into *tár* makes *powa*.
Chowk into *chowk* makes *káni*.
Pan into *tár* makes *káni*.
Pan into *chowk* makes 5 *tils*.
Pan into *pan* makes 1¼ *til*.

47. Examples.

Ex. 1.—Find the area of a piece of land 57 *társ* 3 *chowks* long, and 47 *társ* 2 *chowks* broad :

	Tars.	*chowks.*
Length	57	3
Breadth	47	2

57 *társ* × 41 *társ* = 2679 *lessás* ...	... 2679 *lessás.*	
3 *chowks* × 47 *társ* = 141 *powas* or 35 *lessas* 1 *powa*	35 „	1 *powa.*
2 *chowks* × 57 *tars* = 114 *powas* or 28 *lessas* 2 *powas*	28 „	2 „
3 *chowks* × 2 *chowks* = 6 *kanis* = 1 *powa* 2 *kanis*	0 „	2 *kanis.*
	27, 43 *lessas*	2 *kanis.*

∴ the area is 27 *bighas* 2 *kathas* 3 *lessas* 2 *kanis*.

Ex. 2.—Find the area of a piece of ground 5 *társ* 2 *chowks* 2 *pans* long and 2 *társ* 2 *chowks* 2 *pans* broad:

	Társ.	*chowks.*	*pans.*
Length	5	2	2
Breadth	2	2	2

5 *társ* × 2 *társ* = 10 *lessas* — 10 *lessas*

2 *chowks* × 2 „ = 4 *powas* = 1 *lessa*	1 „
2 „ × 5 „ = 10 „ = 2 „ 2 *powas*	2 „ 2 *powas.*
2 „ × 2 *chowks* = 4 *kanis* = 1 *powa*	0 „ 1 *powa.*
5 *társ* × 2 *pans* = 10 *kanis* = 2 *powas* 2 *kanis*	0 „ 2 *powas* 2 *kanis.*
2 „ × 2 „ = 4 „ = 1 *powa*	0 „ 1 „ 0 „
2 *chowks* × 2 *pans* = (4 × 5) *tils* = 20 *tils* = 1 *kani*	0 „ 0 „ 1 „
2 „ × 2 „ = (4 × 5) „ = 20 *tils* = 1 *kani*	0 „ 0 „ 1 „
2 *pans* × 2 „ = (4 × 1¼) „ = 5 *tils*	0 „ 0 „ 0 „ 5 *tils.*
	14 „ 3 „ 0 „ 5 „

∴ the area is 14 *lessas* 3 *powas* 5 *tils.*

Ex. 3.—Find the rent of a piece of land 25 *társ* long and 23 *társ* broad at Re. 1-6 per *bigha*:

Length	25 *társ.*
Breadth	23 „
	5, 75 *lessas.*

∵ the area is 5 *bighas* 3 *kathas* 15 *lessas.*

	Rs.	a.	p.
Rent of a *bigha* is	1	6	0
			5
„ 5 *bighas*	6	14	0
„ 2 *kathas* 10 *lessas* = ½ of 1 *bigha*	0	11	0
„ 1 *katha* 5 *lessas* = ½ of 2 *kathas* 10 *lessas*	0	5	6
	7	14	6

∴ the rent required is Rs. 7-14-6.

48. If we know the area of a rectangle, and also its length, we can find the breadth by dividing the number which expresses the area, by the number which expresses the length; and, similarly, if we know the area and the breadth, we can find the length.

49. EXAMPLES.

Ex. 1.—The area of a rectangle is 27 *bighas* 11 *kathas*, and its length is 464 cubits, find its breadth :

Bighas *Kathas*
27 11
20

551
320

11020
1653
---
464)176320 square cubits (380 cubits.
1392

3712
3712

∴ the breadth is 380 cubits.

Ex. 2.—The area of a rectangle is 27 *bighas* 2 *kathas* 3 *lessas* 2 *kanis*, and its breadth is 380 cubits, find the length :

Bighas *Kathas* *Lessas* *Powas* *Kanis*
27 2 3 0 2
or 2743 *lessas* 2 *kanis*.
4

10972 *powas*.
4

43890 *kanis* or square yards.
4
---
380) 175560 square cubits (462 cubits.
1520

2356
2280

760
760

∴ the length is 462 cubits.

Ex. 3.—The area of a rectangle is 5 acres 2 roods and its length is 1100 links ; find the breadth :

Acres roods.
5 2
4
22 roods.
25000
1100) 550000 square links.
500 links.
or 5 chains.

∴ the breadth is 5 chains.

Ex. 4.—Find the cost of whitewashing the walls of a room 16 cubits long 12 cubits broad and 8 cubits high at 6 annas per square yard.

Rule.—The area of the inner-side of the four walls may be obtained at once by taking twice the product of the sum of the length and breadth into the height :

Length 16 cubits.
Breadth 12 ,,
28 ,,
Height 8 ,,
224 square cubits.
2
4)448 ,, ,,
112 square yards.
6
672 annas, or Rs. 42.

∴ the cost of whitewashing the room is Rs. 42.

Ex. 5.—A room is 4 yards long 3 yards broad ; find the length of the carpet 3 cubits broad, which will be required to cover the floor :

Length 4 yards.
Breadth 3 ,,
12 square yards carpet.
4
3) 48 square cubits carpet.
16 cubits.

∴ The length of the carpet is 16 cubits.

Area of Squares.

50. A square is a rectangle having its length and breadth equal; hence to find the area of a square we multiply the number which denotes the length of a side of the square by itself.

Note.—When a number is multiplied by itself the product is called its square.

Thus, as $4 \times 4 = 16$, so 16 is called the square of 4, and 4 is called the square-root of 16.

51. Examples.

Find the area of a square each side of which is 260 feet:

260
260
15,600
52
67,600 square feet.

9) 67600 square feet.

4) 7511 *kanis* 1 square foot.

4) 1877 *powas* 3 *kanis*.

4,69 *lessas* 1 *powa*.

∴ the area is 4 *bighas* 3 *kathas* 9 *lessas* 1 *powa* 3 *kanis* (Assamese).

9) 67600 square feet.

5) 7511 square yards 1 square foot.

16) 1502 *chataks* 4 *gandas*.

20) 93 *kathas* 14 *chataks*.

4 *bighas* 13 *kathas*.

∴ the area is 4 *bighas*, 13 *kathas*, 14 *chataks*, 4 *gandas* (Bengali).

Area of Right-angled Triangles.

52. We have found in paragraph 26 that the diagonal of a rectangle divides it into two equal right-angled triangles; the area of each of these triangles is therefore equal to half the area of the rectangle, or half the product of its length and breadth (paragraph 37). The area of any right-angled triangle is therefore equal to half the product of the two sides which are

perpendicular to one another. If one of these sides be taken to be the base, the area of the triangle will be half the product of the height and the base.

53. Examples.

Ex. 1.—Find the area in *bighas, kathas,* etc., of a right-angled triangle whose base is 120 yards and height 60 yards :

120 yards.
60 ,,
2) 7,200 square yards.
3,600 ,,

Assamese.

4) 3600 square yards.
4) 900 *powas.*
2,25 *lessas.*

∴ the area is 2 *bighas* 1 *katha* 5 *lessas.*

Bengali.

5) 3600 square yards.
16) 720 *chataks.*
20) 45 *kathas.*
2 *bighas* 5 *kathas.*

∴ the area is 2 *bighas* 5 *kathas.*

Ex. 2.—Find the area of a right-angled triangle of which the base is 9 chains and the height 4 chains, in acres, etc. :

9 chains.
4 ,,
2) 36 square chains.
10) 18 ,,
acre 1 8 ,,
4
roods 3 2
40
poles 8 0

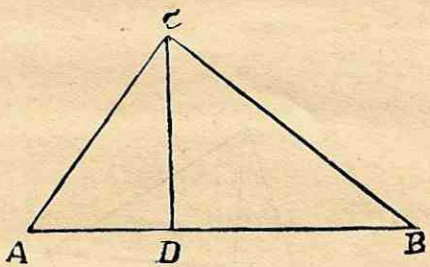
∴ the area is 1 acre 3 roods and 8 poles.

Area of any Triangle.

54. The area of any triangle, whether right-angled or not, is equal to half the product of the base and the height.

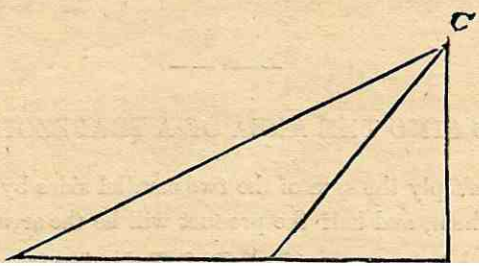
For the area of the triangle A B C in figure 24, of which A B is the base and C D the height, is equal to the area of the triangle A C D added to the area of the triangle B C D. But the area of the triangle A C D is equal to half the product of C D and A D, and the area of the triangle B C D is equal to half the product of C D and B D. Therefore, the area of the triangle A B C is equal to half of C D × (A D + D B) or half the product of C D and A B:

Figure 24.



Again, the area of the triangle A B C in fig. 25, of which A B is the base, and C D the height, is equal to the area of a triangle A C D less the area of the triangle B C D, that is to say, to half of C D × (A D—B D) or to half of C D × A B:

Figure 25.



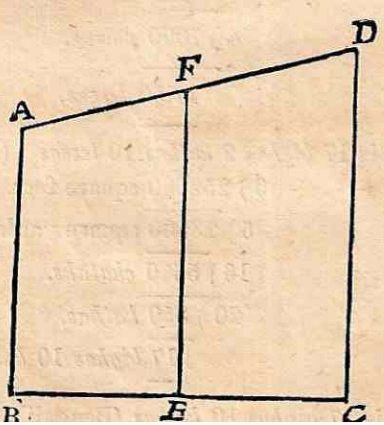
Ex. 2.—The parallel sides of a trapezoid are 12 chains 50 links and 10 chains 30 links, and the perpendicular distance between them is 8 chains, find the area :

12 chains, 50 links = 1250 links.
10 „ 30 „ = 1030 „
2280 „
8 „ ... = 800 „
2) 1824000 square links.
100000) 912000 „
acres 9,12
4
,48
40
poles 19,20
$30\frac{1}{4}$
6,05

∴ the area is 9 acres 19 poles 6 square yards.

58. The area of a trapezoid of which the two parallel sides are perpendicular to one of the other sides is equal to the product of that side and of a line drawn from its middle point, perpendicular to it, to intersect the opposite side :

Figure 28.



Thus, if A B C D be a trapezoid, having the two parallel sides A B and C D perpendicular to the side B C, and a line E F be drawn from E, the middle point of the side B C, perpendicular to that side, to intersect the opposite side A D at F, then E F will be equal to half the sum of A B and C D and the area of the trapezoid will be equal to the product of E F and B C.

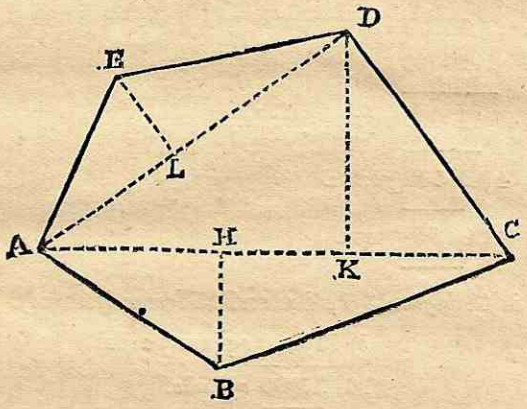
Area of a Polygon.

59. Divide the figure into any convenient number of triangles. Find the area of every triangle and the sum will be the area of the polygon (figure 29.

60. Examples.

A B C D E is a five-sided figure ; B H and D K are perpendiculars on A C ; E L is perpendicular on A D; the following lengths are in yards :

Figure 29.



A C = 500.
A D = 400.
B H = 120.
D K = 240.
E L = 100.

The area of the triangle A B C—

500 yards.
120 „

2) 60000 square yards.

30000 „

The area of the triangle A C D—

500 yards.
240 „

2) 120000

60000

The area of the triangle A E D—

400 yards.
100 „

2) 40000

20000 square yards.

A B C = 30000
A C D = 60000
A E D = 20000

4) 110000 square yards.

4) 27500 *powas*.

68,75 *lessas*.

∴ the area is 68 *bighas* 3 *kathas* and 15 *lessas* (Assam).

5) 110000 square yards.

16) 22000 *chataks*.

20) 1375 *kathas*.

68 15 *kathas*.

∴ the area is 68 *bighas* 15 *kathas* (Bengal).

61. EXAMPLES.

Ex. A.—Find the area in *bighas*, *kathas*, etc., of rectangles having the following dimensions :

(1) 25 *nals* by 10 *nals*.
(2) 20 chains by 15 chains (30 feet chain).
(3) 15 chains by 5 chains (Gunter's).
(4) 20 *nals* 2 yards by 10 *nals* 3 yards.
(5) 630 feet by 108 feet.
(6) 430 links by 2 chains (Gunter's).

Find the area in *bighas, kathas, chataks,* etc., of rectangles having the following dimensions :

(7) 7 *bighas* by 5 *bighas.*

(8) 6 *bighas* 12 *kathas* by 3 *bighas* 9 *kathas.*

(9) 5 *bighas* 11 *kathas* 7 *chataks* by 3 *bighas* 7 *kathas* 10 *chataks.*

Find the area in *bighas, kathas, lessas* of rectangles having the following dimensions :

(10) 8 *társ* 2 *powas* by 5 *társ* 3 *powas.*

(11) 31 *társ* 3 *powas* by 16 *társ* 1 *powa.*

(12) Find the breadth of a rectangle whose area is 1 acre and length 110 yards.

(13) Find the length of a rectangle whose area is 220 *bighas* 2 *kathas* 15 *lessas,* or 220 *bighas* 11 *kathas* and breadth 32 *háths.*

Find the area in acres, roods and poles of rectangles having the following dimensions :

(14) 15 chains by 5 chains (Gunter's).

(15) 10 chains 80 links by 12 chains 40 links (Gunter's).

(16) 4235 yards by 280 yards.

(17) 6600 feet by 44 yards.

(18) Find the cost of painting the inner side of the four walls of a room 30 feet long 17 feet broad and 15 feet high at 4 annas per square yard.

(19) The cost of matting the floor of a room is Rs. 10-8 at 3 annas per square yard. Find the length of the room, the breadth being 16 feet.

(20) A room is 30 feet long 20 feet broad and 10 feet high. Find the area of the four walls, and the cost of covering the four walls at 4 annas 9 pies per square foot, and also find the length of cloth required, 1 yard broad.

(21) Find the number of bricks 5 inches long and 3 inches broad that can be contained in 1 *bigha* of land.

Ex. B.—Find the area in *bighas, kathas,* etc., of squares having sides of the following lengths :

(1) 86 yards 2 feet.

(2) 120 chains (30 feet chain) 2 *társ.*

(3) 25 chains (Gunter's) 50 links.

Find the area in acres, roods, and poles of squares having sides of the following lengths :

(4) 5 chains (Gunter's) 20 links.

(5) 2,640 feet.

Ex. C.—Find the area of the triangles having the following dimensions :

(1) Base 25 *táns*, height 10 *táns*.

(2) Base 8 chains, height 4 chains (30 feet chain).

(3) Base 5,760 feet, height 240 feet.

(4) Base 25 chains 40 links, height 12 chains (Gunter's).

(5) Base 20 chains 50 links, height 5 chains 40 links (Gunter's).

(6) Find the height of a triangle whose area is 33 *bighas* 3 *kathas* 7 *lessas* or 33 *bighas* 13 *kathas* 6 *chataks* 8 *gandas*, and the base 8658 feet.

(7) Find the base of a triangle whose area is 66 acres, and the height 11 chains (Gunter's).

Ex. D.—Find the area of the trapezoids which have the following dimensions :

(1) Parallel sides 20 and 10 *táns*, perpendicular distance 5 *táns*.

(2) Parallel sides 8 and 4 chains (30 feet chain), perpendicular distance 3 chains (30 feet chain).

(3) Parallel sides 6 chains 25 links and 7 chains 75 links, perpendicular distance 5 chains (Gunter's).

(4) Parallel sides 325 and 275 feet, perpendicular distance 400 feet.

(5) Parallel sides 100 and 120 yards, perpendicular distance 240 yards.

(6) Parallel sides 125 chains 20 links and 115 chains 30 links, perpendicular distance 10 chains (Gunter's).

(7) The area of a trapezoid is 256 *bighas* 2 *kathas* 10 *lessas*, or 256 *bighas* 18 *kathas*, the sum of the two parallel sides is 2880 feet, find the perpendicular distance between them.

(8) The area of a trapezoid is 8 acres 2 roods 17 poles, the perpendicular distance is 2 chains 50 links, find the sum of the two parallel sides.

Ex. E.—Find the areas of the quadrilaterals having the following dimensions :

(1) Diagonal = 25 chains.
Perpendiculars = 7 and 5 chains (Gunter's).

(2) Diagonal = 375 yards.
Perpendiculars = 128 and 352 yards.

(3) Diagonal = 17 chains 25 links.
Perpendiculars = 10 chains 52 links, and 7 chains 28 links (Gunter's).

Ex. F.—(1) A B C D E is a five-sided figure, B H and D K are perpendiculars on A C, and E L is a perpendicular on A D. The following lengths are in links. A C = 1040, B H = 480, E L = 320, A D = 870, and D K = 650. Find the area.

(2) A B C D E F is a six-sided figure, B H and D K are perpendiculars on F C, E L is a perpendicular on F D, and A P is a perpendicular on B F. The following lengths are in feet :

F C = 1,250, B H = 350, D K = 400, F D = 650, E L = 200, B F = 750, and A P = 250. Find the area.

(3) A B C D E F G is a seven-sided figure. B N and G M are perpendiculars on A C, G O and E P on F D, and D Q on G C. The following lengths are in chains :

A C = 55, F D = 52, G C = 44, G M = 13, B N = 18, G O = 12, E P = 8, and D Q = 23. Find the area.

Ex. G.—Mauzadari and zamindari methods.

Find the areas of the triangles having the following dimensions :

(1) Sides 144 feet and 120 feet, base 240 feet.

(2) Sides 6 *bighas* 12 *kathas* and 7 *bighas* 4 *kathas*, base 8 *bighas* 4 *kathas*.

CHAPTER VI.

LOCAL MEASURES NOT OFFICIALLY USED—SURMA VALLEY.

62. In the Surma Valley districts lands are commonly measured with a *nal* 14 cubits long (one cubit being taken as equal to 18 inches). The length of the *nal*, however, varies in different places. A *nal* is divided into 16 equal parts, every part is called a *pan*, and the entire *nal* a *káhan*.

63. With a *nal* of 14 cubits, the following tables of linear and square measure are used:

Table of Linear Measure.

21 *angulis* make 1 *pan*.

$3\frac{1}{2}$ cubits „ 1 *chowk*.

14 „ „ 1 *nal* or *káhan*.

Table of Square Measure.

20 *tils* or $12\frac{1}{4}$ square cubits make 1 *kág*.

4 *kágs* or 49 „ „ 1 *kara*.

4 *karas* make 1 *ganda*.

20 *gandas* „ 1 *pan*.

4 *kágs* or 49 square cubits or 4 *pans* make 1 *rek*.

4 *reks* or 196 square cubits make 1 *jaista*.

7 *jaistas* or 1372 square cubits make 1 *powa*.

4 *powas* or 28 *jaistas* or 5488 square cubits make 1 *keyár*.

3 *keyárs* or 16464 square cubits make 1 *chowk*.

4 *chowks* or 12 *keyárs* or 65856 square cubits make 1 *hál*.

1 *keyár* = $\frac{343}{400}$ *bighas* (or 17 *kathas* 2 *chataks* 8 *gandas*).

1 *hál* = 10 $\frac{29}{100}$ *bighas* (or 10 *bighas* 5 *kathas* 12 *chataks* 16 *gandas*) = 3 $\frac{243}{605}$ acres (or 3 acres 1 rood 24 square poles 8 square yards).

Nal into *nal* makes *jaista*.

„ „ *chowk* makes *rek*.

„ „ *pan* makes *kág* or *pan*.

Chowk into *chowk* makes *kág* or *pan*.

„ „ *pan* makes *buri*.

Pan into *pan* makes $1\frac{1}{4}$ *gandas* or 5 *karas*.

The above measures are not now used in any Government or official surveys.

PART II.

SURVEYING.

PART II.
SURVEYING.

CHAPTER I.
DEFINITIONS.

1. *Boundaries.*—The *boundaries* of any land are the lines surrounding it on all sides : thus, the boundaries of a field are the lines separating it from adjoining fields ; the boundaries of a village are the lines separating it from adjoining villages.

2. *Surveying.*—The process of measuring any land and preparing a map of it is called *surveying.*

3. *Plotting.*—The process of drawing on the paper the lines composing the map, after the necessary measurements have been taken on the ground, is called *plotting.* To make a *map* of any land is to draw on paper lines which shall correctly represent all the boundaries of the land and of each part of it.

4. *The scale.*—The scale of a map is the proportion which the length of each line on the map bears to the distance represented by that line on the ground. Thus, in a map on the scale of 16 inches to the mile, a line measuring 16 inches in length on the paper will represent a distance of one mile on the ground ; one inch on the paper will represent $\frac{1}{16}$th of a mile, or 5 chains, on the ground ; a distance of one chain on the ground will be represented by a line $\frac{1}{5}$th of an inch long on the paper.

5. *Cadastral maps.*—Cadastral maps in Assam are drawn on the scale of 16 inches to a mile. For each village there is a separate map. The map of a small village is contained in one sheet. The map of a large village consists of two or more sheets, each of which represents a part of the village. The name of the village is printed on each sheet.

Every plot of land which is all of the same class and is contained in one *patta* is called a field (*dág*). Each plot of Government waste is also called a field (*dág*). On a cadastral map the boundaries of the village and the boundaries of each field are shown by lines. Each field has a number, which is shown on the map.

6. *The dág chitha.*—The *dág chitha* of a village is a list of the fields in the village with their numbers.

7. *The jamabandi.*—The *jamabandi* of a village is a list of the *pattas* in the village showing the names of the settlement-holders (*pattadars*), and the fields contained in each *patta.**

* This chapter should be illustrated by showing the class the cadastral map of a village, with its *dág chitha* and *jamabandi.*

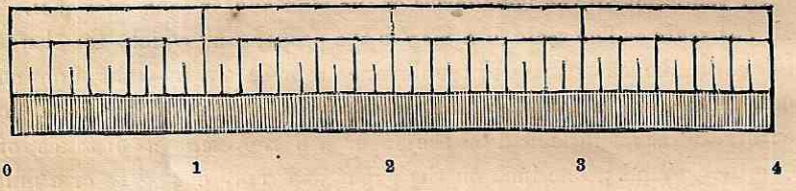
CHAPTER II.

SCALES.

8. *Scales.*—In preparing maps, certain instruments are used, with the help of which lines on the paper can be measured off so as to represent correctly distances on the ground on the scale of the map. These instruments are used also in measuring the distance on the ground represented by any line shown on a map. They are called *scales.*

9. *Simply divided scales.*—A simply divided scale is a piece of metal or cardboard, having on its edge a number of equal distances marked, each of which represents a known distance on the ground.

Figure 1 below represents a simply divided scale for measuring chains and distances of $\frac{1}{10}$th of a chain (10 links) on the scale of 16 inches to a mile : Figure 1.



The whole length of the figure is 4 inches, which represents 20 chains on the scale of 16 inches to a mile. Each of the larger divisions within the inch spaces is $\frac{1}{5}$th of an inch in length, and represents one chain. Each of these larger divisions is divided into 10 equal parts, each of which is $\frac{1}{50}$th of an inch in length, and represents $\frac{1}{10}$th of a chain or 10 links.

In drawing straight lines of any required length with the help of a scale the *compass* and the *ruler* are used.

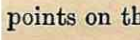
10. *The compass.*—The compass consists of two legs moveable about a point. The legs are made of steel and have fine points, and the upper portion is made of brass. In order to mark off any distance, the legs of the compass are opened so that the points fit on two divisions of the scale which measure that distance. The compass is then taken up carefully without altering the distance of its points from one another, and the points are placed on the paper on which the distance is to be marked off.

11. *The ruler.*—A ruler is a piece of wood with a straight edge. In order to draw a straight line between any two points marked on the paper, the ruler is placed with its edge close to both points, and the point of a pencil is drawn along the edge of the ruler from one point to another.

12. Thus, in order to draw a straight line representing 150 links on the scale of 16 inches to a mile,—place one point of the compass on the end of the line marked 0 on the extreme left of the scale in figure 1 and open the other leg to the right, so that its point may touch the line marking the fifteenth of the smaller divisions from the left of the scale. Then take the compass up, keeping the points at the same distance from one another, and place the points on the paper. Now place the ruler with its edge against the points marked on the paper with the compass, and draw the point of the pencil from one of those points to the other, along the edge of the ruler.

13. Again, to find the distance represented by a straight line A B on the scale of 16 inches to the mile (figure 2). Open the compass and place the points on the paper, so that one may touch the point A, and the other the point B. Then take the compass up, keeping the points at the same distance from one another, and place the points on the edge of the scale in figure 1, so that one may touch the end of the line marked 0 on the extreme left of the scale. It will be found that the other point touches the end of the line marking the 22nd of the smaller divisions from the left of the figure. The line A B therefore represents a distance of 220 links, or 2 chains and 20 links, on the scale of 16 inches to a mile.

Fig. 2.



14. EXAMPLES.

Ex. 1.—Draw straight lines of the following lengths :

(1) $1\frac{1}{2}$ inches.
(2) $\frac{1}{10}$ inch.
(3) $2\frac{1}{5}$ inches.

Ex. 2.—Draw straight lines representing the following distances on the scale of 16 inches to a mile :

(1) 80 links.
(2) 3 chains 30 links.
(3) $2\frac{1}{2}$ chains.
(4) 1 chain 70 links.

Ex. 3.—Give the length of each of the straight lines shown below, and state what distance each of them represents on the scale of 16 inches to a mile :

(1) C———D.

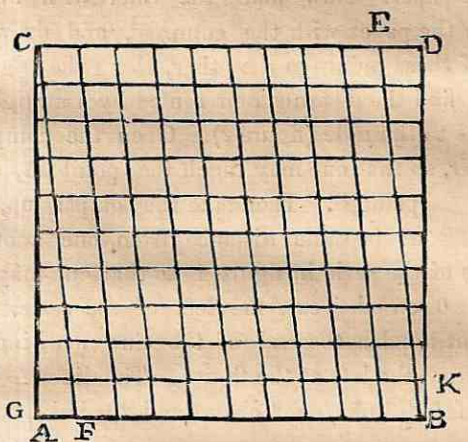
(2) E———F.

(3) G———K.

(4) L———M.

15. *Diagonal scale.*—With a simply divided scale such as that given in figure 1, distances of not less than 10 links can be accurately measured on a map. In order to measure and plot distances with greater accuracy, the diagonal scale is used. A diagonal scale of 16 inches to a mile is constructed as follows (figure 3) :

Figure 3.



A B, a straight line two inches long, is divided into ten equal parts, each representing a chain, as for a simply divided scale. Two straight lines of equal length, A C and B D, are drawn at right angles to A B from A and B, and a straight line is drawn from C to D, thus forming a rectangle C A B D. The line C D, which is equal to the line A B, is divided into ten equal parts, each of them representing a chain. The line A C is then divided into ten equal parts and lines parallel to A B are drawn through each point of division of the line A C so as to intersect the line B D. These lines will divide the line B D also into ten equal parts. A straight line is then drawn from B to the point E marking the first division on the line D C, to the left of D, another straight line from the first division of the line B A to the second division of the line D C, a third from the second division of the line B A to the third division of the line D C, and so on, the last straight line joining the point F at the ninth division of the line B A with C. Then the length on each line drawn parallel to A B and C D which is intersected between the straight lines B D and B E will bear the same proportion to D E as the distance from A B of the line on which it is intersected bears to the whole length of the line B D. Thus, as D E represents one chain, the length intercepted between B D and B E on the line drawn parallel to C D, which intersects the line B D at distance of $\frac{9}{10}$ths of its length from B, will be $\frac{9}{10}$ths of a chain or 90

links. Similarly, the lengths intercepted between the lines A C and F C on lines drawn parallel to A B and C D will be proportionate to their distances from C D. The length intercepted on each parallel line between B E and the line drawn from the first division of the line B A to the left of B to the second division of the line D C to the left of D will be equal to D E and will represent a chain. Similarly, the lengths intercepted on the parallel lines between C F and the line joining the 9th division of the line D C to the left of D with the 8th division of the line B A to the left of B and those intercepted on the parallel lines between each other pair of lines joining the divisions in the lines A B and C D will represent chains.

By means of this scale very short distances can be accurately measured and plotted. Thus, the length intercepted between B D and B E on the line parallel to A B, which intersects B D at a distance of one-tenth of its length from B will represent $\frac{1}{10}$th of a chain or 10 links. If a line G K be drawn parallel to A B cutting B D at the point K, which is at a distance of $\frac{1}{20}$th of its length from B, that is at a distance of half the length of the first division on B D from B, the portion of this line intercepted between B D and B E will represent $\frac{1}{20}$th of a chain, or 5 links. If one point of the compass be placed at K and the other point extended to the second division of the line G K made by its intersection with the line joining the first division of B A with the second division of D C, the distance between the points of the compass will represent a length of 1 chain and 5 links or 105 links.

16. EXAMPLES.

Ex. 1.—Draw from the diagonal scale straight lines of the following lengths :

(1) $\frac{3}{10}$ths of an inch.

(2) $\frac{14}{25}$ths of an inch.

(3) $1\frac{9}{50}$ths of an inch.

Ex. 2.—Draw straight lines representing the following distances on the scale of 16 inches to a mile :

(1) 170 links.

(2) 254 links.

(3) 4 chains 20 links.

(4) 6 chains 7 links.

Ex. 3.—Find from the diagonal scale, the length of each of the straight lines shown below, and state what distance each of them represents on the scale of 16 inches to a mile :

(1) A——————B.

(2) C——————D.

(3) E——————F.

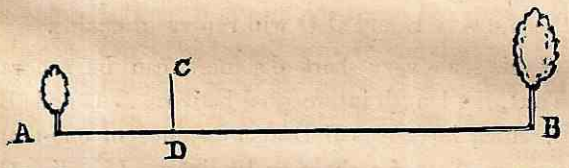
(4) G——————H.

CHAPTER III.

OFFSETS.

17. If A and B be points on a map representing points on the ground the positions of which are known, and C be a third point on the ground the position of C can be correctly shown on the map, as soon as we know the distance from B or from A of the point D, where a line drawn perpendicular to the straight line A B from C, meets the straight line A B :

Figure 4.



Thus, if A and B represent two trees, the position of which is shown on the map, and C be the corner of a field the position of which is not shown on the map (figure 4), then in order to show the point C on the map, the first thing to be done is to find out the point where a line drawn from C perpendicular to the straight line joining the trees at A and B, meets that straight line. This is done in chaining between the points A and B (as described in Part I, Mensuration, Chapter II, paragraph 17) with the help of the *cross-staff*.

18. *Cross-staff.*—The cross-staff (figure 5) consists of a square slab of wood about 8 inches broad, fixed, like the top of a small table, on a staff, the other end of which is pointed. Across the slab, two grooves exactly perpendicular to one another are cut with a saw :

Figure 5.

19. To find the position of the point D, where a perpendicular from C meets the straight line A B (figure 4), it is necessary to chain from A

towards B, or from B towards A. A flag is set up at C, or a man stands there holding a staff, and the position of the point D is guessed as nearly as possible with the eye. The cross-staff is then set up at the point guessed, and by looking along one of the grooves cut in the top of it, is adjusted so that that groove may be exactly in the line A B. This will be the case when the trees at A and B are visible by looking along the groove from either end. The cross-staff having been so adjusted, a man looks along the other groove, and if the flag or man at the point C be visible along it, it is known that the exact point at which the cross-staff has been set up is the point D. If not, the cross-staff is moved up and down the line A B, until the flag or man at the point C is visible through one groove, the other groove at right angles to it being exactly in the line A B, when the point D will have been found. The distances C D and B D are then measured, when the point C can be correctly shown on the map.

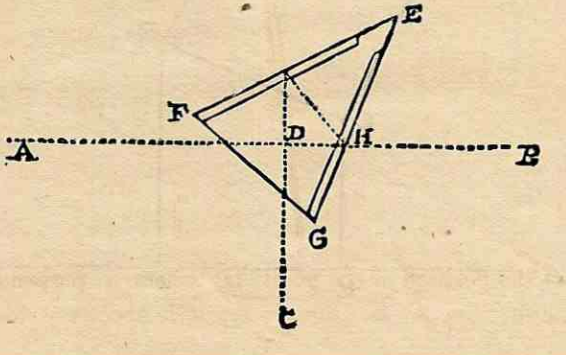
Thus, if the distance A D is measured as 3 chains and the distance C D is measured as 1½ chains, and the scale of the map is 16 inches to a mile, to find the point C, plot a length of 3 chains on the line A B and mark the point D at the end of that length. Then plot a straight line from D at right angles to the straight line A B, representing a length of 1½ chains. The point C will be at the end of this straight line.

20. A B is called the *chain line.* C D is called an *offset.*

The process of finding the position of the points C and D on the ground and measuring the distance C D is called *taking an offset.*

21. The *optical square* (figure 6) is an instrument with the help of which offsets can be taken more easily and quickly and with greater accuracy than with the cross-staff. It is made of brass, and contains two pieces of looking-glass which are fixed at an angle of 45° to one another. Above these there is an aperture on each side of the instrument which is held with a handle. A weight is usually attached to the handle by a string. If A B be the chain line (figure 6), and C the point to

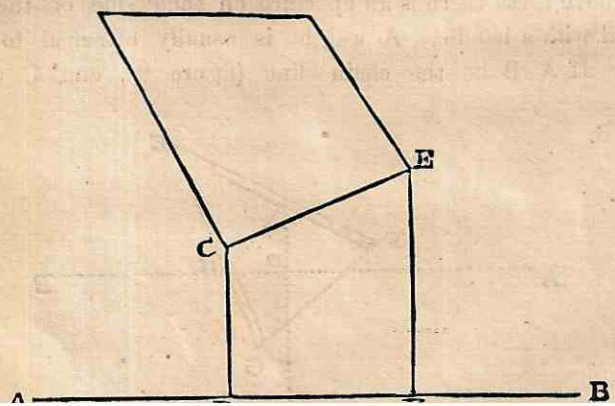
Figure 6.



which it is desired to take an offset, then, after placing flags at B and C, stand on the chain line facing towards B, raise the optical square to the level of the eye with the open part F G towards C, and the angle E pointing in the opposite direction. Then, keeping the eye near the edge of the instrument F, look through the aperture H in the side E G at the flag at B. The flag at C will then be reflected in the looking-glass E F, which is turned towards it, and from that looking-glass, in the looking-glass E G, in which the reflection will be visible at the same time that the flag at B is seen through the aperture H above the looking-glass E G. When the reflection of the flag at C, seen in the looking-glass E G, is exactly in a line with the flag at B seen along the line A B through the aperture, it is known that the point where the optical square is held is the point where a straight line drawn from the point C perpendicular to the straight line A B meets the straight line A B, that is the point D. If the reflection of the flag at C in the looking-glass E G is not at first seen exactly in a line with the flag at B, but a little to one side or the other, the person holding the optical square should move a little up or down the chain line A B until the reflection and the flag seen through the aperture come exactly into one line. The weight attached to the instrument, being then allowed to hang down, will be directly over the point D.

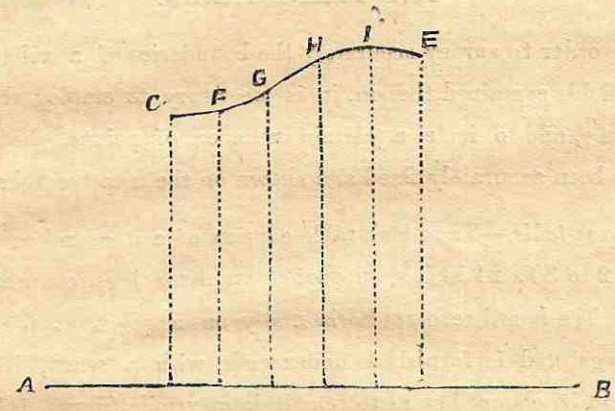
22. If A B represent on the map a chain line run between two points the positions of which are known, and C and E be two corners of a field near the chain line the field boundary between which is a straight line, the positions of the points C and E can be found by taking the offsets C D and E F to them from the line A B. The field boundary C E can then be correctly shown on the map by first plotting the points C and E and then joining them with a straight line (figure 7) :

Figure 7.



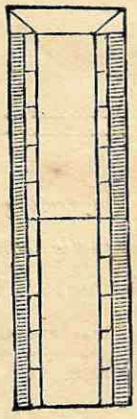
If the boundary be a curved one it can be surveyed approximately by taking offsets to a number of intermediate points F, G, H, I close to one another (figure 8). The most accurate way of surveying all field boundaries is by taking offsets from chain lines measured between points the position of which is known :

Figure 8.



23. *The offset scale.*—In plotting offsets, the offset scale is used, this is a small piece of ivory, about two inches long, across the middle of which a straight line is marked at right angles to the direction of its length. On either side of this line, lines are ruled, parallel to it, which divide it into lengths representing, on the scale of the survey, distances of a chain each, and the spaces between these lines are further subdivided by other lines into lengths representing distances of $\frac{1}{5}$th of a chain (20 links) or $\frac{1}{10}$th of a chain (10 links) each. By placing the offset scale on the map, so that the centre line of the scale may lie exactly over the chain line, distances perpendicular to the chain line can be marked off with the compass (figure 9) :

Figure 9.



CHAPTER IV.

THE PLANE-TABLE.

24. In order to survey accurately the boundaries of a village or estate and of the fields contained therein, it is necessary to employ the plane-table and sight rule, and to have a certain number of points, the positions of which have been accurately fixed and shown on the map beforehand.

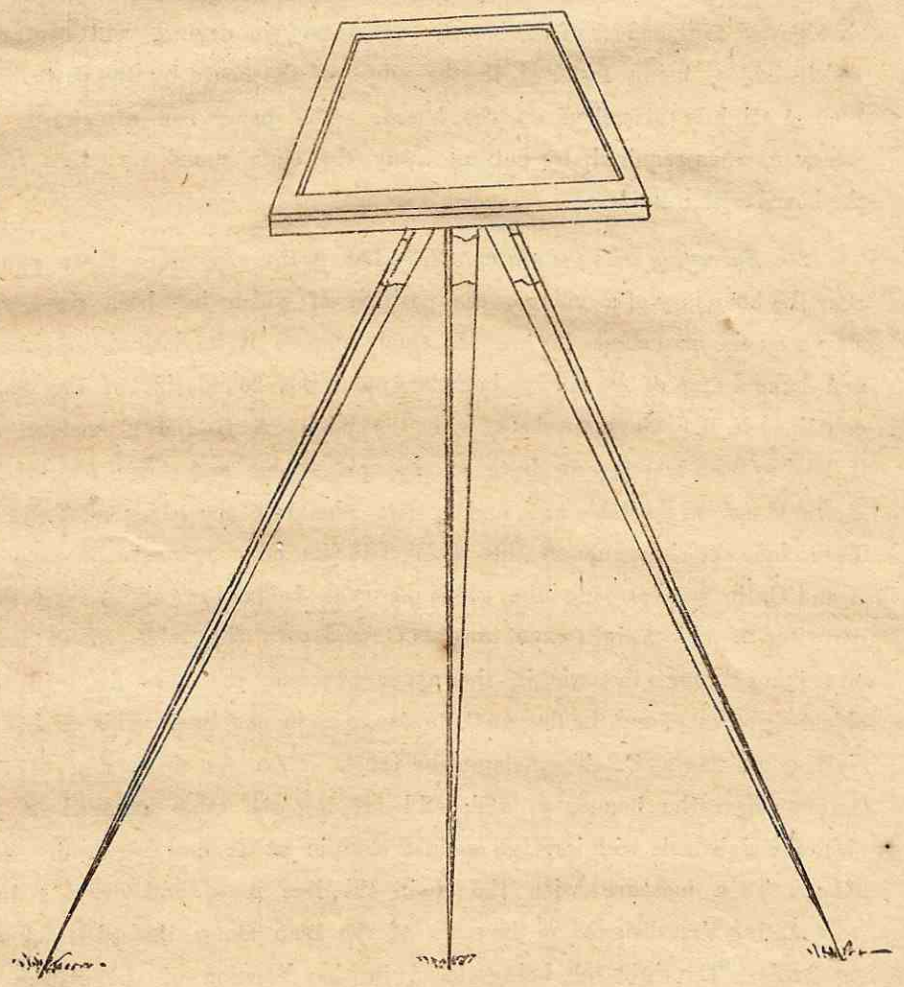
The plane-table.—The plane-table consists of a wooden board measuring from 15×12 to 30×24 inches, supported on three legs connected together at the top. The board revolves horizontally on a pivot at the junction of the three legs and is furnished underneath with a screw, by tightening which it can be clamped so as to remain immoveable (figure 10) on opposite page.

The sight rule.—The *sight rule* or index is a ruler with two pieces of brass, called *sight vanes*, fixed on to each end of it, so as to stand up at right angles to it, when the ruler is placed flat on the table. One of the sight vanes, called the eyesight vane, is divided lengthwise by a fine slit, the other by a cut from a quarter to half an inch wide in the middle of which a fine straight wire is fixed lengthwise (figure 11) :

Figure 11.

The rectangular compass.—The *rectangular compass* is a small rectangular wooden box containing a *magnetic compass*, that is, a revolving needle which points always towards the north. It is either fixed to one side of the plane-table or is kept detached and placed on the table when it is desired to find the direction of the north line.

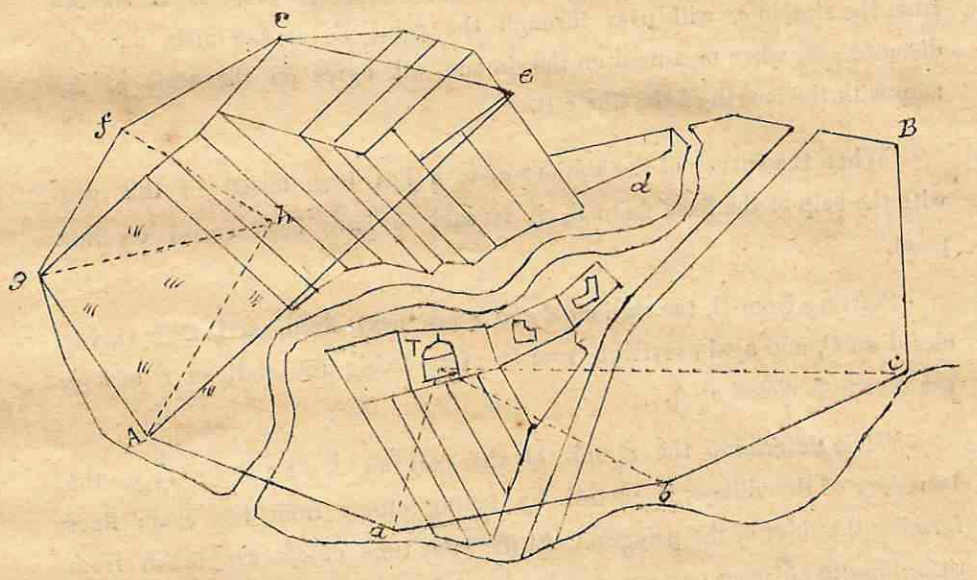
Figure 10.



25. *Mounting the paper.*—For the purpose of surveying with the plane-table, the sheet of paper on which the map is to be made is fastened tightly down on the board. In order to stretch the paper and fasten it tightly, it is cut a little larger than the surface of the board, and a thin strip of cloth is pasted round its edges on the under-side. The paper is then damped and placed on the board, and its edges are folded tightly over the edges of the board. The cloth round the under-side of the edges of the paper is then pasted to the edges of the board. The paper, in drying, will contract, and its edges, being fastened to the edges of the board by the paste, will become tightly stretched on the board. The paper can afterwards be removed, when required, by cutting away the cloth round its edges from the board with a knife.

26. *Surveying with the plane-table.*—Let A B C represent three points near the boundary of a village, the position of which has been fixed, and shown on the map sheet (figure 12), and suppose it is desired to survey and make a map of the village boundary and the boundaries of the fields contained in it. The map sheet, with the points A B and C marked on it, having been fastened as above on the plane-table and flags planted at B and C, set up the table at A and fix two pins into the paper at A and C. Then place the sight rule on the table with its edge against the pins at A and C, the end carrying the eye-sight vane being towards A, and that carrying the object sight vane, towards C, and turn the table round until on looking through the slit in the eye-sight vane, the wire fixed in the object-sight vane, and the flag at C, appear to be in one line. This is called *sighting* the flag at C. Then clamp the table. Then set up a flag at the station *a* near the boundary, and, still keeping the table clamped at A, place the sight rule with its edge against the pin at A and sight the flag at *a*. Then measure with the chain the line A *a*, and draw a line representing that distance on the scale of the map along the edge of the sight rule. The sight rule being placed in the direction of the station *a*, the end of the line so drawn will represent that station on the map. After marking the station *a* on the map at that point, the plane-table is unclamped and removed to the station *a* on the ground. A pin is then stuck in the

Figure 12.



map at *a*, the edge of the sight rule placed against the pins at A and *a*, and the table turned until the flag at A is sighted from *a*. The table is then again clamped, a flag is put up at the station *b* and that station is fixed and shown on the map in the same manner as the station *a*. The station C is next fixed in the same manner and shown on the map. In fixing the stations *a*, *b*, and *c* some error may perhaps occur in taking sights and measuring distances, and if many stations were fixed one after the other in this way, the error would gradually become larger. In order to see whether any error has occurred, and to prevent further error, the station *b* and the point B, the position of which has been already fixed and shown on the map, are next sighted from *c*, and if the survey has been correct, the line drawn along the sight rule from *c*, when the point B is sighted from the station *c*, will pass through the point B on the map, and the distance *c* B, when measured on the ground, will agree on the scale of the map with the length of the line *c* B.

When the survey of the stations *a*, *b*, *c* has been tested in this way with the help of the fixed point B, it is said to have been closed on that point.

Starting from B, the stations *d* and *e* are next fixed, and their survey closed on C, and again starting from C, after fixing the stations *f* and *g*, the survey is closed at A.

While describing the circuit of the polygon A *a b c* B *d e* C *f g*, the boundary of the village is plotted by taking offsets from the chain lines forming the sides of the polygon. At the same time offsets are taken from these lines to adjacent corners and bends of field boundaries, roads, streams, and other objects which it is desired to survey, and the places where the chain lines cut the boundaries of fields and edges of roads and streams are marked on the map. In order to complete the survey of the interior details, other lines are then run through the interior of the polygon by fixing stations in the same manner as in the survey of its outer sides, closing as often as possible either on points fixed beforehand or on stations fixed in the plane-table survey. Offsets are taken from these line to the corners of

fields and other details, and their intersections with field boundaries and edges of roads and streams (*katans*) are plotted on the map. The field boundaries, the roads, the courses of streams, and other details required can then be plotted without difficulty.

If the stations B and C be not visible from A, the station *a* can still be fixed with the help of the rectangular compass. Erect the plane-table with the paper mounted on it at A, and the rectangular compass being placed on the table with one of its longer sides parallel to one of the edges of the table, turn the table about until the north point of the needle is at the zero mark of the compass box, then clamp the table, which is now in position. The position of station A will be fixed by setting up and sighting a flag at that station, and then plotting the chain line A *a* with the help of the sight rule.

Suppose that we are somewhere within the polygon at *h*, and wish to find our position with reference to stations on the boundary, the plan of which has been mounted on the plane-table. The rectangular compass having been placed on the table with its length in the direction of the north line as shown on the plan, unclamp the table and turn it about until the zero mark of the compass box coincides with the north point of the needle. Then clamp the table, and plant flags at three or four of the nearest or most convenient stations, say A *g f*. Fix a pin at one of the corresponding stations A on the plan, place the fiducial edge of the index against the pin, turn it in the direction of the flag at A, until on looking through the slit in the eye-sight vane, the wire fixed in the object-sight vane, and the flag at A appear to be in one line, and draw a fine pencil line along the edge of the index. Our position must be at some point in this line. Repeat the observation from a pin fixed in the plan at the station F to the flag planted at that station, and draw a fine line along the index edge as before. Our position must also be somewhere in this line, and must, therefore, be at the point of intersection of the two lines. As a further check, sight a flag at station *g* with the fiducial edge of the index against a pin fixed at the point *g* on the plan, and draw another line from that point along the index. This line should pass through the former point of intersection, if the successive observations have been accurately made.

27. In surveying with the plane-table, the positions of distant conspicuous objects can be fixed by sighting them from two or more stations. Thus, if T be a temple within the polygon referred to above (figure 12), while the plane-table is at the station *a*, sight the flag at A and clamp the plane-table. Then place the sight rule on the table in such a position as to sight the temple T

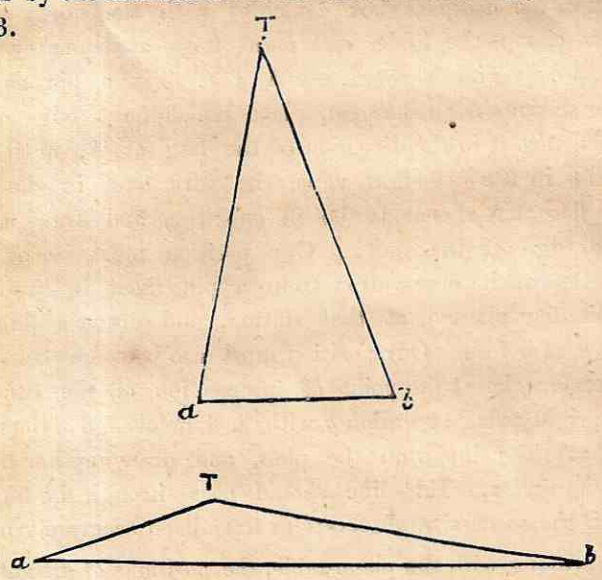
from *a* and rule a line from *a* along the edge of the sight rule. Similarly, at the station *b*, after sighting the flag at *a*, clamp the table and place the sight rule in such a position as to sight the temple from *b*, and rule a line from *b* along its edge. The point where these two lines intersect will give the position of the temple T, if the survey has been correct. To test its correctness, at the station *c*, after sighting the flag at *b*, clamp the table, sight the temple T with the sight rule, and rule a line in the direction given. If the survey has been correct, this line also will pass through the point where the two lines previously drawn intersect.

As a further check, therefore, on the accuracy of any plane-table survey, wherever possible, conspicuous objects should be sighted from the different stations.

Rays.—The lines drawn from different stations intersecting conspicuous objects which have been sighted with the plane-table are called *rays*.

28. The points *a* and *b* from which a distant object T is sighted should be chosen, so that the angle *a* T *b* formed by the lines drawn from *a* and *b* to T may be as nearly as possible a right angle. If the angle be much greater or much smaller than a right angle as in figure 13, then any small error made in sighting the object will cause a great error in its position on the map as shown by the intersection of the lines *a* T and *b* T:

Figure 13.



29. As the paper mounted on the plane-table expands or contracts slightly according to the state of the atmosphere, the working scale of the map is drawn on the paper on which the map is prepared, and the map plotted from that scale, so that the measurements may always remain true.

30. *Cadastral survey of villages.*—Cadastral maps are prepared with the plane-table by the help of stations, the positions of which have been accurately fixed and plotted by means of the theodolite. Polygons having their sides close to the village boundaries are first surveyed with the theodolite, and, to farther help in the plane-table survey, other lines within the polygons are also surveyed with the same instrument. The theodolite survey of the village polygons is called the traverse survey, and the lines surveyed with the theodolite within the polygons are called sub-traverse lines. The stations of the theodolite survey at the angles of the polygons, and on the sub-traverse lines are called theodolite stations. These stations are permanently marked. In surveying the boundaries of fields, and the roads, streams and other details within the village, supplementary lines are run, and supplementary stations fixed with the plane-table, as in the example given at the beginning of this chapter.

31. *Survey of new fields.*—When a new field is formed after the first survey of a village, through Government waste land being taken up under settlement by a raiyat the $\frac{mandal}{patwari}$ surveys it by running a line between fixed points through the field or close to it, and taking offsets to the corners of the field. If possible, the line is run between two theodolite stations. If a line cannot be run close to the field from one theodolite station to another, a convenient point is first fixed by measurement from one theodolite station to another and a line is run from this point through the field or close to it to a theodolite station or to another point similarly fixed. Thus, if A B C be theodolite stations marked on the ground, and shown on the map, a new field is formed in such a position that neither of the lines A B, A C, or B C passes close enough to the field for it to be surveyed by taking offsets from any of those lines, the $\frac{mandal}{patwari}$ having set up flags at B and C, first chains the lines A C and fixes the position of the point D on the map by its distance on that line from A. He then chains the line A B and fixes the position of the point E by its distance from A on that line. He then chains the line D E, which passes through the field to be surveyed (figure 14), or close to it (figure 15), and takes offsets from that line to the corners of the field. Before plotting the points D and E on the map it is necessary for the $\frac{mandal}{patwari}$ to survey the whole of each of the lines A B and A C, and compare the distances measured by him with those shown on the map, in order to test his measurements and detect any errors that may have occurred. When the number of theodolite stations shown on the map and demarcated on the ground is not enough to enable the $\frac{mandal}{patwari}$ to survey accurately all the new fields which may be formed in the village, the *kanungo* is required to erect additional marks (*dhips*) at points the positions of which have been fixed by him with the plane-table in the manner explained at the beginning of this chapter.

Figures 14 and 15.

Figure 14.

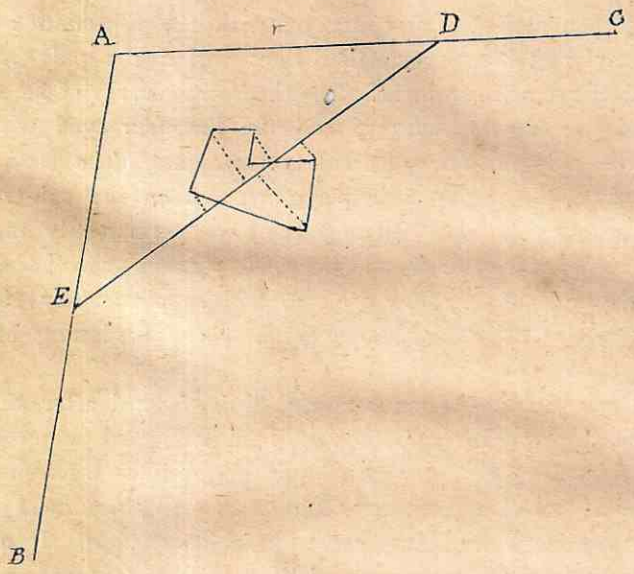
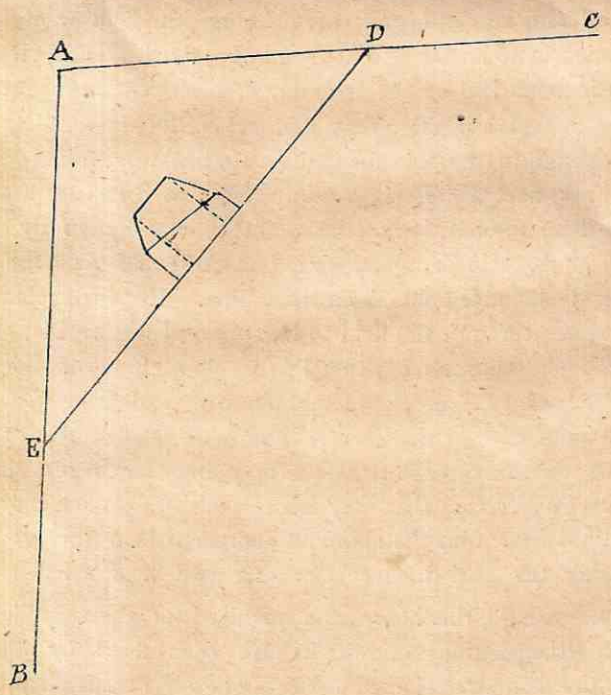


Figure 15.



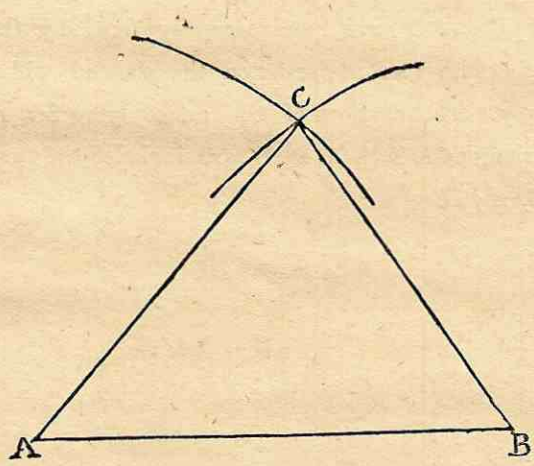
CHAPTER V.

CHAIN SURVEY.

32. In the preceding chapter, the method of surveying with the plane-table, when the positions of a certain number of points have been fixed beforehand and shown on the plan, has been described. When no points have been fixed beforehand by theodolite traverse or otherwise, an estate or village may be surveyed with the chain only, by the method described below.

33. If A B be a measured straight line between two points (figure 16) the position of any third point C with reference to the straight line A B can be determined if the distances A C and B C are known. This can conveniently be done by first opening the points of the compass to the distance A C, placing one of the points at A, and describing a circle on the paper; then opening the points to the distance B C, placing one of them at B, and describing a circle. The point where the two circles intersect one another will be the point C (figure 16). This method of finding the position of a point by measuring its distance from the extremities of a given base is called triangulation:

Figure 16.

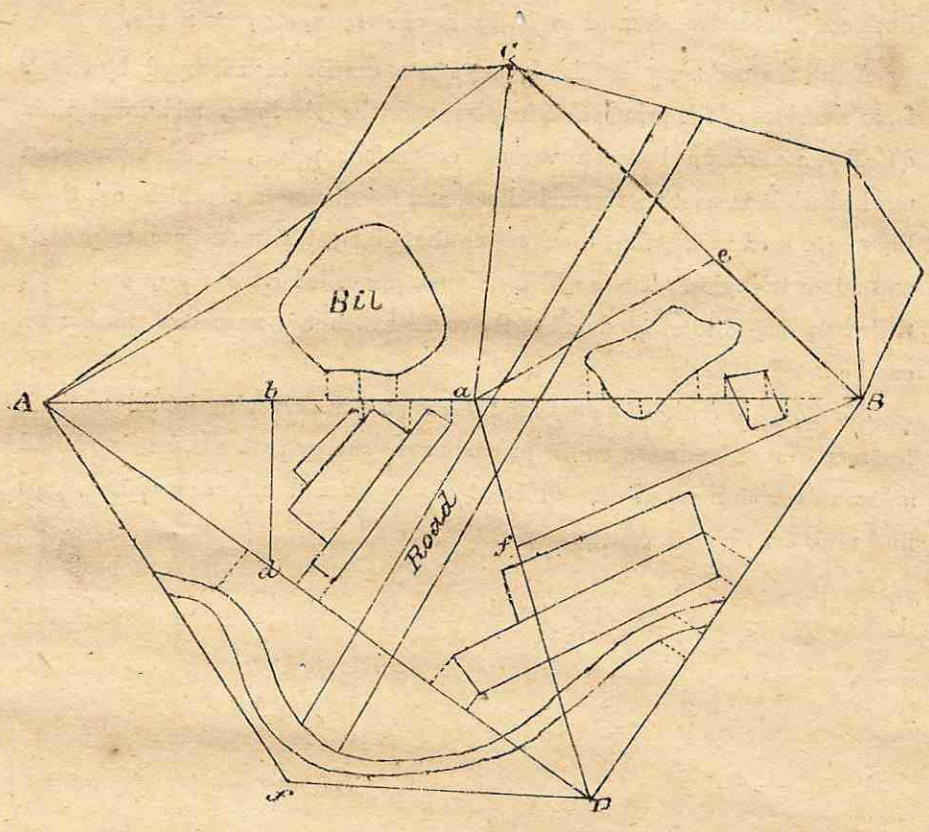


34. In order, then, to survey a village or estate with the chain only, it is necessary first to go over the ground and make a rough eye-sketch of the

boundary, as well as of roads, streams, buildings, and other conspicuous objects within it. A base line should then be selected, which should be the longest straight line which can be obtained within the boundary, passing over ground as even and free from obstacles as possible. Next, the positions of two convenient points near the boundary are found by triangulation from this base, and, if necessary, other points are fixed by building up subsidiary triangles on the sides of the two main triangles thus formed. Roads, streams, field boundaries, and other features to be surveyed are plotted by offsets from the sides of the triangles, and from other straight lines, called tie lines and cross lines, run between points fixed in the triangulation.

35. Thus, in surveying with the chain only the estate shown in figure 17 the base A B is first selected after making an eye-sketch of the estate, and measured on the ground. The points C and D are then fixed by forming the triangles A C B, and A D B. To test the correctness of the positions of the points C and D as ascertained by the survey, straight lines C a and D a are measured from C and D to a, a point on the base line A B, which has been marked with a peg, and the distance of which from A, or from B has been noted in measuring that line. The lines C a and D a are called *tie lines*, and if the points C and D have been correctly fixed by the triangulation, the lengths of these lines as measured on the ground will agree with the plot of the survey. The portions of the estate lying far from the sides of the two main triangles A C B, A D B are included in the two subsidiary triangles C i B, A j D.

Figure 17.



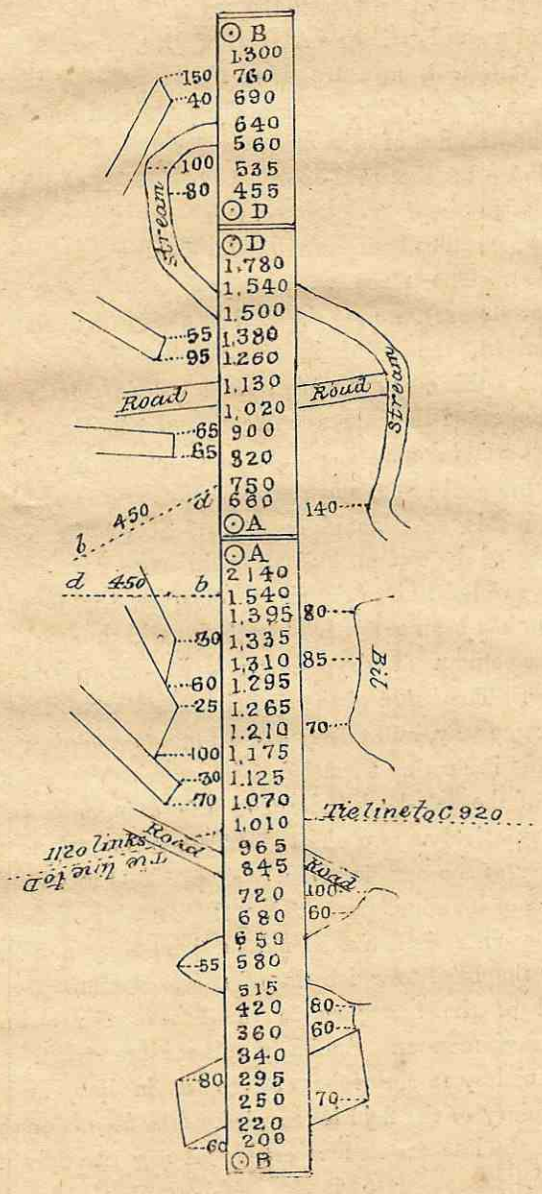
While chaining along the base, the sides of the principal triangles, and the tie lines, offsets are taken to all adjacent details which it is required to survey, such as bends and angles of village and field boundaries, tanks, buildings, etc., right and left of the chain line, and the distances at which the lines cut boundaries, sides of roads, banks of streams, etc., are noted.

As all the necessary details of the estate cannot be surveyed by offsets from the sides of the principal triangles and the tie lines, additional lines *b d*, B *f*, *a e* are run between various convenient points, which have been marked while measuring the main lines, and the distances of which on those lines have been noted, thus breaking up the principal triangles into trapezoids and minor triangles. These additional lines are called *cross lines*, and with their help offsets to every detail of the estate which it is necessary to survey can be noted.

36. *The field-book.*—As no plane-table is used in surveying by this method, the map cannot be drawn on the ground as the survey proceeds, but is plotted afterwards from notes of the different distances and offsets measured kept in a register, which is called the *field-book*.

The lengths are in links.

Fig: 18.



The field-book (figure 18) consists of a number of pages down the middle of each of which are ruled two parallel lines between which the chain measurements are recorded, the offsets being entered right and left in the margin. The column between the two parallel lines thus represents the chain line, and the measurements are recorded from the bottom to the top of the page.

The following example will illustrate the use of the field-book in recording the measurements of a single triangle A D B of the diagram in figure 17. Commencing from station B, measure from B towards A along the base line B A, and take an offset to the corner of the first field met with on the left of the line. The distance of this offset on the line is recorded between the two parallel lines of the field-book as 2 chains, and the length of the offset as 60 inks to the left of the column. Next note in the column the distance at which the boundary of the field crosses the chain line (2 chains 20 links). The place where a field boundary or other detail (*e.g.*, edge of road or stream), crosses the chain line is called the *katan*. The boundary being straight, the point in the parallel line to the left of the column opposite where this entry is made should be joined by a straight line with the point to the left of the column indicating the corner of the field to which the first offset was taken. Then take an offset to the corner of the field to the right of the chain line, and record it in the same way, the length of the offset being in this case noted on the right of the column. Join the point to the right of the column indicating this corner by a straight line with a point on the parallel line to the right, opposite the place where the distance of the *katan* has been entered. The *katan* will thus be indicated by two lines cutting the column of the field-book at two points immediately opposite one another. The *katan* of the opposite boundary of this field should be recorded in the same way, and offsets taken to the remaining two corners of the field, the points indicating them being joined with the points on either side of the column of the field-book indicating the corners to which offsets were first taken respectively. An offset should then be taken to the first bend of the boundary of the next irregularly shaped field met with, and the distance of the *katan* of its boundary noted. The boundary being curved, the place where the latter entry is made should be joined by a curved line to the point indicating the bend to which the offset was taken. Next an offset is taken to the bend of the boundary to the left of the chain line, and recorded in the same manner. Similarly offsets are taken to the next two bends of the boundary to the right of the chain line, and the *katan* of the opposite boundary of the field is recorded. The *katans* of the two edges of the road crossing the line are then recorded. A peg is driven into the ground at *a*, and that point is noted in the field-book and its distance on the

chain line recorded for the tie lines C *a* and D *a*. Offsets are taken to the corners of the fields, to the left of the chain line, and to the bends of the edge of the *bil* to the right. The point *b* is marked, and its distance recorded for the cross line *b d*. Finally, the whole distance up to A is measured, and recorded in conspicuous figures.

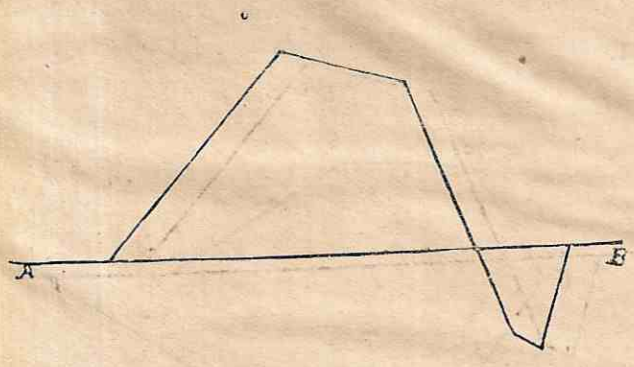
Measure now from A to D, and from D to B, in the same way, taking offsets right and left to the bends and corners of all adjacent details, noting where boundaries, edges of roads, streams, etc., cross the chain lines, leaving marks on the ground for cross lines, and noting the distances and corresponding letters in the field-book for reference. The two remaining sides A C and B C of the triangle A C B, and the different tie lines and cross lines are afterwards measured and recorded in the same way, and a record is thus obtained in the field book of every detail which it is necessary to survey. When surveying with the plane-table, the scale of the survey is settled beforehand, and a map on that scale is prepared on the spot. When the survey has been recorded in a field-book, it can be plotted afterwards on any scale.

37. *Plotting.*—In mapping a chain survey the large triangles are plotted first, second the tie lines, third the cross lines, then the offsets to the boundary of village or estate, and lastly the interior details.

A convenient point on the paper is selected which may represent either end of the base line and from it a straight line is drawn representing the measured length of that line on the scale of the map. Next the lengths of the sides A C and B C are set off on the same scale, the position of the point C being determined by their intersection, and the sides A D and B D are set off in the same way. Now, mark the point *a*, where the tie line D *a* cuts the base line, and from B lay off on that line the distance B *a*, which should fall exactly on the last intersection, if the work has been correct. The tie line C *a*, and distance A *a* should likewise intersect in the same point. The cross lines, being also laid off, will be a further check on the measurements, which, if correctly made on the ground, should all fit into each other when plotted. The skeleton plot having thus been completed, the offsets to the boundary of the village or estate and its interior details, are laid off from the sides of the different triangles and trapezoids and joined up with one another and with the *katans* as shown in the field book.

In order to show in the map the position of the area surveyed, and of the details comprised in it with reference to the magnetic meridian or north and south line, the angle between that line and the base line, which is called the *bearing* of the base line, must be observed on the ground by means of the *prismatic compass*, and afterwards laid off on the map with the *protractor*. These instruments are not described in this manual, as they are

Ex. 4.



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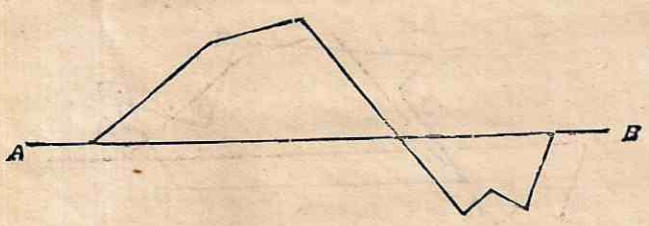

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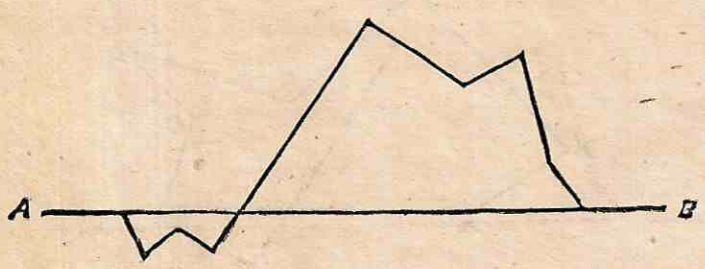

CHAPTER VII.

CHECK LINES.

44. The correctness of any map may be partially tested by running a chain line between any two points the position of which is shown on the map and comparing the length of the line, as measured with the distance represented, on the scale of the map by a straight line drawn on the map from one of the points to the other. If the two lengths do not agree, it is evident that that portion of the map is inaccurate.

The correctness of a field survey is tested by running a chain line between two points, the position of which has been fixed and shown on the map, and noting the distances on the line of the points at which it intersects the boundaries of fields and natural features, such as roads and streams (*katans*), as well as the lengths of offsets taken to the corners of fields near the line, and comparing the distances and lengths with those shown by a straight line drawn between the two points on the map.

The *katans* and the offsets taken from the check line are noted in a field book (paragraph 36). Thus, the correctness of the portion of a field map shown in figure 12 may be tested by running a check line from the station A to the station *c*. To test the correctness of the cadastral map of a whole village numerous check lines have to be run in different directions, and, in order to do this, supplementary points have to be fixed by measuring distances on lines run between theodolite stations in the manner explained in paragraph 30.

In order to compare the check line with the map, it is usual to plot the check line with the *katans* and offsets taken in running it, on the scale of the map, on a strip of thin transparent paper. The strip is then placed on the map so that the points between which the check line has been run, as plotted on the strip may lie exactly over the same points shown on the map, when it is at once seen whether the *katans* and offsets plotted from the check line agree with the map, and, if not, what the amount of disagreement is.

ASSAM SECRETARIAT PRINTING OFFICE (AGRI.) No. 33—300—19-2-1900.