LIMITS OF ERROR IN LATITUDES AND LONGITUDES OF PLACES OBTAINED DURING THE RECON-NAISSANCES MADE IN PALESTINE.

By LIEUT.-COL. WARREN, R.E.

THE recent publication of the Trigonometrical Survey of Palestine affords an opportunity, which but rarely occurs, of rigidly testing the accuracy of a Reconnaissance of a district, previously made; and as the limit of error over extended areas, attainable under such circumstances, is a matter of general interest to persons interested in the mapping of the country around Palestine, I give a few notes I have made on the subject.

Previous to 1865 the maps of Palestine presented but a very inadequate idea of either the absolute or relative positions of places, and though several additions had been made from time to time very little apparent improvement was made in the maps until after that date.

In 1865-6 Major (then Lieutenant) Anderson, with a base, obtained astronomically, made a Reconnaissance of the watershed of Western Palestine and the district about the Sea of Galilee, giving a table of latitudes and longitudes of about 50 astronomical stations.

In 1867, I made a Reconnaissance of the plain of Philistia, valley of the Jordan and land of Gilead, giving a table of latitudes and longitudes of about 200 places in the plain of Philistia, of which about 20 were astronomical stations. In prosecuting this work, however, I came to the conclusion that a Reconnaissance, even of the most accurate description, would be insufficient for the wants of the biblical student, and I strongly urged the commencement of a trigonometrical survey—a work which has now been so successfully carried out and completed by Lieutenants Conder and Kitchener.

These tables of latitudes and longitudes as obtained by Lieutenant Anderson and myself (see P. E. F. Quarterlies, 1869, p. 74, 1871, p. 162) I have tested with those obtained from the Trigonometrical Survey sheets, but before giving the results it is necessary to point out that while I have assumed my longitude east of Greenwich from the same point as the Trigonometrical Survey, viz.:—point at Jaffa on Admiralty chart, Lieutenant Anderson takes his from the Dome of the Rock at Jerusalem, as obtained by Commander Maunsell from the said Admiralty point at Jaffa.

An analysis will therefore be useless unless it is ascertained whether there is any discrepancy between the longitude assumed by Lieutenant Anderson of the Dome of the Rock and that which I obtained myself from Jaffa.

The following comparison will show that there is a discrepancy between the longitudes of the Dome of the Rock as obtained by Commander Maunsell and myself (from the same point at Jaffa) and that while I only exceed the longitude given on the Trigonometrical Survey by 11 seconds, his observation exceeds it by 55 seconds.

COMPARISON OF RESULTS.

		Latitude N.			Error.		Longitude E.			Error.	
		°	′	″	′	″	°	′	″	′	″
Admiralty—1855..	..	31	46	38	− 0	6	35	18	57	+ 5	10
Doergens ..	..	31	46	56	+ 0	12	35	18	30	+ 4	43
Collier's Map	..	31	47	43	+ 0	59	35	15	47	+ 2	0
Van de Velde	..	31	46	50	+ 0	6	35	14	42	+ 0	55
Maunsell—1862 ..	..	31	46	39	− 0	5	35	14	42	+ 0	55
Anderson—1865 ..	..	31	46	47	+ 0	3	35	14	37	+ 0	50
Berghaus—1838 ..	..	31	46	45	+ 0	1	35	14	8	+ 0	21
Warren—1867	..	31	46	41	− 0	3	35	13	58	+ 0	11
Trig, Survey	..	31	46	44	..		35	13	47	..	
Captain Corry	..	31	46	49	+ 0	5	35	13	18	− 0	29

I assume that the Trigonometrical Survey sheets must be rigidly correct to at least 2″ of longitude, and therefore it appears that Maunsell's longitude is in excess by 55 seconds, and consequently Lieutenant Anderson's work about Galilee must be corrected to this extent throughout ; when this is done I find a general agreement in the comparative accuracy of all the Reconnaissance sheets, the errors averaging closely the same in each, it will therefore suffice if I describe that of Philistia alone as an example.

This work extended from Jaffa on the north to Gaza on the south, about 38 miles ; from Gaza on the west to Jerusalem on the east, about 45 miles.

I was occupied from 1st to 26th June, 1867 ; and in addition to the topographical details and observations for latitude and longitude, had to arrange for the taking of about 30 photographs of ancient sites, to examine the architectural remains, measure the ruins, and search out biblical sites.

My instruments consisted of an 8-inch sextant and artificial horizon, 5-inch theodolite, 3 pocket chronometers, pocket compass and aneroid barometers.

The system was briefly as follows, in principle :—To ascertain latitude at each camp by observation of the stars, and to obtain a true azimuthal angle from camp to camp. This would fix each camp on the earth's surface, and the distance from camp to camp was used as a base line from which points on each side would be obtained.

In practice the work was not quite so simple, for the camp could never be placed on the positions from whence azimuth angles would be taken with the theodolite, and neither of the observations would be taken very close to the villages.

The extreme limit of error in latitude as obtained by the 8-inch sextant I consider to be 10 seconds of arc, and in longitude as obtained by azimuth angles with 5-inch theodolite about 10 seconds in 60 miles : but though the positions from whence observations on hill tops could be taken should be thus close I do not think that the villages themselves, which are often 10 seconds in extent, could be fixed within 20 seconds of this correct position.

I have therefore taken 20 seconds of arc both of latitude and longitude to be the limit of error within which the *principal* towns should be fixed, and in order to facilitate a comparison I have classified the results and find that out of 134 stations and conspicuous points, of which I have given the latitudes and longitudes (obtained from about 20 astronomical observations),

60 (containing all the principal points except four) are within the limits of 20 seconds latitude and longitude.

29 are within 35 seconds.

45 minor points are beyond this.

Now on looking at these minor points I find that they are for the most part small villages lying in hollows in the plains, which cannot be recognised or seen from the surrounding hills, and could only be fixed by a series of compass observations, on the other hand I find that all the principal points are well placed, as will be seen by the accompanying list marked A.

COMPARISON. (A)

	Latitudes.						Error.		Longitudes.						Error.	
	°	′	″	°	′	″	′	″	°	′	″	°	′	″	′	″
El Muntâr ..	31	29	25	31	29	17	−0	8	34	28	5	34	28	19	+0	14
Gaza (highest minaret) ..	31	30	15	31	30	18	+0	3	34	27	37	34	27	51	+0	**14**
Sheikh Ali ..		32	10		32	33	+0	23		52	50		53	20	+0	**30**
Tel ed Dewar..		33	53		33	56	+0	3		50	40		50	25	−0	15
Kubeibeh ..		34	20		34	18	−0	2		51	0		50	52	−0	8
Mar Hanneh ..		35	33		35	48	+0	5		53	35		53	50	+0	15
Arak Menshiyeh		36	45		36	59	+0	15		46	50		47	32	+0	42
Beit Jibrîn ..		36	25		36	44	+0	19		53	35		54	15	+0	40
Tel Bulnard ..		37	50		38	3	+0	13		52	27		52	28	+0	1
Askulan ..		39	50		39	53	+0	3		32	20		32	38	+0	18
Berkusia ..		40	33		40	49	+0	16		49	12		49	40	+0	28
D. Dubban ..		40	25		40	34	+0	9		53	15		53	35	+0	20
Shuwaikeh ..		40	50		41	3	+0	13		58	23		58	5	−0	18
Beit Netîf ..		41	46		41	40	−0	6		59	25		59	40	+0	15
Tibneh.. ..		44	38		44	34	−0	4		55	50		55	30	−0	20
Deir Aban ..		44	36		44	32	+0	4	35	0	22	35	0	28	+0	6
Beit Atab ..		44	0		44	4	+0	4		2	55		3	4	+0	9
Esdûd ..		45	20		45	18	+0	2	34	39	20	34	39	41	+0	21
Deir el Howa..		45	6		45	10	+0	4		1	55	35	2	7	+0	12
Dome of Rock		46	44		46	41	−0	3	35	13	47		13	58	+0	11
Surah		46	34		46	36	+0	2	34	58	44	34	59	3	+0	19
Beshît.. ..		49	20		49	25		..		44	45		44	20	−0	25
Kutreh ..		49	20		44	32	+0	12		46	20		46	38	−0	18
Saidan.. ..		50	35		50	30	−0	5		54	0		54	12	+0	12
Musa Thalia ..		50	33		50	28	+0	5		55	33		55	45	+0	12
Akir		51	33		51	27	−0	6		48	56		49	18	+0	22
Abu Shusheh ..		51	28		51	35	+0	7		54	40		55	2	+0	22
Yebneh ..		52	0		52	14	+0	14		44	30		44	32	+0	2
Nianeh ..		52	10		52	12	+0	2		52	15		52	23	+0	8
Zernuka ..		52	49		53	11	+0	22		47	0		46	55	−0	5
Yebneh port ..		55	15		54	45	−0	3		41	50		41	32	−0	18
Ramleh ..		55	35		55	21	+0	14		52	0		52	1	+0	1
Nely Samwil ..		50	3		49	50	−0	13	35	10	28	35	10	45	+0	17
Tuliel el Ful ..		49	27		49	15	−0	12		13	30		13	50	−0	20

I am doubtful whether the great accuracy and rapidity of this class of work has yet been recognised by any section of thinking men. The best features of the work are that it cannot get out to any great extent, so that it may be carried for hundreds of miles with the same limit of error. For example, the extreme points in this Reconnaissance are Jerusalem and Gaza. In each of these cases the limit of error in latitude is 3 seconds, and in longitude respectively 11 and 13 seconds. I am not aware that there is any record of so large a number of points being accurately fixed over so extended a tract in so short a time ; the average day's work included the surveying from 50 to 70 square miles, and fixing the latitude and longitude of eight places.

The accuracy of this Reconnaissance was so little comprehended ten years ago that when I brought it forward it was distrusted because it was so unlike all the work that had been done before. At that time I asserted positively that Maunsell's longitude of the Dome of the Rock was nearly a minute too far to the west, and published my longitude in the P.E.F. Quarterly, 1871, p. 162, but finding that the former longitude was preferred to mine, I said I should be content to wait for the Trigonometrical Survey to decide between us, which it has now done in my favour.

THE SULPHUR OF THE VALLEY OF THE JORDAN.

(From the Zeitschrift of the German Palestine Association.)

By Dr. Oscar Fraas.

Some time ago I received an account from Herr Charles Paulus, sen., of the sulphur found in the Jordan Valley, which confirmed the result of observations previously made. Herr Paulus writes that some young men of the Temple Colony in Jerusalem made an excursion to the Dead Sea in the spring, and brought back with them " some specimens of a mineral substance they had found there. These specimens consist of a fine grey clay containing sulphur. The clay itself is good pottery clay, such as is found, not only in the neighbourhood of the Dead Sea, but which also exists in great quantities all over the chalk mountains of Palestine. . . .

" This sulphur consists for the most part of roundish lumps varying from the size of a pea to that of a walnut ; it is of a whitey yellow colour, earthy, very brittle and apt to lose its colour. Each of these sulphur balls is enclosed in a larger kidney-shaped lump of clay that forms as it were the shell containing the sulphur kernel. The clay in which small crystals are to be found, dissolves in water. Sulphur was also discovered in the cracks in the larger crystals (calcareous spar ?).

" The sulphur ground lies from 1 to 2 km. distant from the right bank of the Jordan, and a short German mile from the Dead Sea ; its surface is in some places flat and in others hilly. Several of these heights rise 100 feet above the level of the plain. The sulphur ground stretches out towards