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Accuracy of Digital Satellite Images for Producing Topographic Maps

By

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Abstract

Advanced technologies in all sciences, concerning topographic map production, are developed in methods and processing. Topographic maps were produced by using ground field instrumentations or by manipulating analytical stereo plotters devices with different kinds and techniques. Nowadays, topographic maps are produced from scanned aerial photographs or from satellite images depend on software and hardware operation systems.

In this research pair of spatial images from SPOT 3 satellite were used with aid of Leica Photogrammetric suite (LPS) digital software to produce topographic map of an area in upper Egypt with varied relief.

The topographic map which produced from satellite digital images was compared with the same once that covered the same study area at scale 1:50000, produced by stereo plotters in the Egyptian Military Survey Department. The proposed topographic map which produced from satellite digital images was of reasonable accuracy and can be used instead of maps of scale 1:50000.

Keyword: Leica Photogrammetric suite; topographic maps;

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1. Introduction

Topographic map has a significant role in military and civilian usage, for its importance in troops maneuvering, site occupation, route selection, construction, city planning,…etc. The production of topographic map depends on: the objective or usage of map, required accuracy, available time and available human resources to accomplish the job. Methods of producing topographic maps start by using traditional field instruments which gives high accuracy, then photogrammetric stereo plotters were used to cover large area and ended by digital photogrammetry which produces maps with different scales from either aerial photographs or satellite images.

In this research digital photogrammetry method has been applied by using stereo pair of satellite images captured from SPOT3 satellite. Each image has 60X60Km and about 95% overlap that cover an area located in upper Egypt. These images were processed by Leica Photogrammetry Suite (LPS) software. Well distributed tie and ground control points were chosen within the study area to get best triangulation results with a reasonable Root Mean Square error (RMSE) of the selected checkpoints. The produced topographic map or Digital Terrain Model (DTM) for the study area is compared with topographic maps that cover the same area at scale 1 : 50,000 and produced in Egyptian Military Survey Department.

2. Remote sensing applications for producing topographic map:

Topographic map is characterized by large - scale detail and quantitative representation of relief, usually using contour lines in modern mapping. This kind of maps is used to show both natural and man – made features (Harvey, 1980). Topographic surveys were prepared by the military to assist in planning for battle and for defensive emplacements. Topographic map series became a national resource in modern nations for planning infrastructure and resource exploitation (U.S Geological Survey, 2007).

Remote sensing technique is one of the promising tools for topographic map production that used digital work station with the aid of software.

Remote sensing exhibit a diversity and range of performance that sample nearly all available parts of the electromagnetic spectrum with dozens of spectral bands. Digital form has pixel sizes ranging from less than 1 m to 1000 m complemented by a number of airborne hyper spectral systems with hundreds of spectral bands, each on the order of 10 nm wide.

The satellite which had been launched recently for example: Quick Bird, Ikonos and Orbview-3 have 1 m and better resolution, continue their missions with quite success. Recent works show that geometry of Quick Bird or Ikonos imagery are accurate enough for mapping purpose up to scale 1 : 5000.

The increased utilization of high resolution satellite imagery has been due to recent strides of dramatically improved spatial resolution, wider coverage, higher frequency of revisit time, as well as considerably decreased satellite launch costs. When using high resolution satellite imagery for topographic mapping, as a resource for spatial information collection, the limitation such as expensive data acquisition fee, paucity of imaging regions and archived data is apparent (zhu et al. , 2008).

According to small overlapping for satellite images, the large coverage for 3D environmental monitoring is not possible (Chen, et al., 2008). The linear array satellite image such as SPOT, Ikonos, Quick Bird,….etc with their flexibility in acquiring stereo coverage over any part of the earth, has proven to be an excellent replacement for the other space- borne imaging such as digital frame cameras (Javan and Azizi, 2008).

There are two primary problems in the application of satellite remote sensing as an operational method of map compilation. The first problem is a lack of continuous stereo cover and relatively low resolution. The second problem is due to cloud coverage. By the end of the last decade, the development of the potential satellite imagery to produce thematic and topographic maps at small and medium scales were done.

3. Processing of SPOT images:

Digital photogrammetry became nowadays an optimistic approach for producing topographic maps. Digital photogrammetric workstation was used with the aid of Leica Photogrammetic Suite (LPS) software to process SPOT images that covered the study area.

LPS uses the most reliable geometric modeling called the colinearity equation based orthorectification. This process incorporates the sensor or camera orientation, relief displacement and earth’s curvature in its modeling process. Orthorectification in LPS produces planimetrically true ortho images where all geometric errors are removed. The ortho image has the geometric characteristics of map and the image qualities of a photograph.

3.1 Study Area:

The study area is located in the south of Arab Republic of Egypt, with 60 square km terrain, extended between min X = 426432, max X = 501954 and min Y = 2622647, max Y = 2686777 in UTM system coordinate. The study area is mountainous, in which minimum elevation is 85 m and maximum elevation is 452 m.

3.2 Used SPOT Images:

The used satellite images for the study area is a pair of SPOT images, which have a 60X60 km dimensions, with 95% overlap, 4.13^0. Instrument field of view, 10 m by 10 m ground sampling interval (Nadir Viewing), 6000 pixel per line, was collected by SPOT which has an orbit at distance 832 km in 1999, panchromatic mode.

4. characteristics of Leica Photogrammetry Suite

Leica Photogrammetry Suite (LPS) is a versatile software product for Digital Photogrammetric Workstations (DPW), providing accurate oriented photogrammetric tools for a broad range of geospatial imaging applications. It allows users to work with imagery from a wide variety of sources and formats including black and white, color or multispectral with up to 16 bits per band. LPS also generates the whole range of deliverables photogrammetrists demand, from triangulated imagery and Digital Terrain Models (DTM) to line-of-sight analyses.

These processes are facilitated by a wide choice of formats for imagery, ground control, orientation and Global Positioning System (GPS) data, vector data and processed imagery. Projects can be completed in any of hundreds of coordinate and map projections systems.

The productivity of LPS is a tight focus on workflow through the unique workflow toolbar. The toolbar guides are used through any project from the beginning to the end. Users can monitor the progress of their projects either step by step or with extensive use of LPS batch processing functionality.

LPS works with both stereo and monoscopic hardware configurations on Microsoft Windows XP and Microsoft windows 2000 platforms. Full 3D stereo imagery can be viewed using either passive polarized or active LCD stereoscopic viewing systems.

LPS is a modular product, the core module is feature rich and suitable for many standard applications. The modular architecture of LPS allows it to be scaled to accommodate a variety of photogrammetric and Geographic Information System (GIS) workflows.

Steps for producing topographic map of the study area were manipulated by Yarob 2009 and summarized as follows:

1- Project setup and Management.
2- Internal and external orientation.
   a- Select SPOT images that cover study area.
   b- Internal orientation for every image.
   c- Enter the coordinates of Ground Control Points (GCP) and checkpoints (see table 4-1) to do external orientation. The distribution of these points over the study area is given in Figure (4.1).
   d- Generate tie point automatically (select number of tie points, strategy and their distribution).
3- Triangulation.
   a- Select triangulation steps and then run it.
   b- If triangulation results are acceptable, according to the total image unit weight and Root Main Square Error (RMSE) for control and checkpoints the next steps will be carried out.

4.1 DTM extraction

Digital Terrain Model (DTM) report consists of the following steps:

- Used block file.
- Location of block file.
- Time of DTM correlation.

- Points per second.
- Time of DTM generation.
- Total time of processing.

4.2 Ortho Resampling

The next step is to create orthorectified images of the block file. Orthorectified Images have no relief displacement and geometric errors compared with the nonorthorectified image. The orthorectified images displays objects in their real coordinates X,Y and Z. Click ortho resampling on LPS toolbar and save the output on hard disk with a given name. Then, select DTM source, vertical units, DTM file name and output cell size in X and Y directions.

4.3 contour Display

Click process and interactive terrain editor on the main window of LPS and load image pairs, then click terrain file and display. This tab shows terrain files file name and terrain display. Click setting, the terrain display setting will appear in tab of contours which shows contour interval, index of contours and intermediate contours. Then contours will be displayed in the DTM as shown in Figure (4.2).

5. Results and Analysis

In order to obtain a topographic map, or corresponding DTM, for the study area, LPS software version 8.7 was used to establish contour lines from the pair of SPOT images with overlap about 95%. These contour lines were drawn with interval 20 meters to compare it with contour lines obtained from four topographic Maps of scale 1:50000 for the same study area. These four topographic maps were produced by Military Survey Department in Egypt from aerial photographs in 1990 using photogrammetric stereoplotters.

To compare the contour lines produced by LPS from SPOT satellite images, with the corresponding contour lines of the topographic base map, the format file from

DTM extraction was used to extract randomly selected points from Surfer Software Version 8. The contour map that can be produced by Surfer Software Version 8 is shown in Figure (5.1). In order to test the produced map, 32 points were selected randomly and converted by special software from UTM system coordinate (E, N) to geographic system coordinate (Φ , λ) as shown in Table (5.1) to compare them with corresponding points on topographic base maps. The selected points were plotted on the base maps in order to verify the positions (locations) of them with their corresponding points from the base maps of the Military Survey Department. Figures (5.2), (5.3) and (5.4) show positions of some selected points on the base maps. The differences between elevations (LPS & base maps) are tabulated in Table (5.2). The average value of these elevations is 2.75 and the standard deviation is determined and found to be 0.302m. These values can be considered permissible according to the scale of maps, the accuracy of satellite images, distributions of GCPs and their availability and the nature of the study area. In order to determine the linear misclosure of the selected points to the actual position of the corresponding points on the base map, the height of each point is plotted accurately and the difference in latitude and longitude for the selected and plotted points were tabulated in Tables (5.3) and (5.4).

The linear misclosure for the selected points and their correspondence are tabulated in Table (5.5).

To assess the precision of linear misclosures, the standard deviation, σ_L is determined and found to be 0.4927 sec. The mean value of misclosure set lies between +_σ_L, then the sample is normally distributed and contains only random variants. The mean value of linear misclosure was found to be 12.52 sec. and mean square error = 0.2428 sec. and RMSE= 0.4927 sec.

We can conclude that:

1- Producing topographic maps at scale 1:50000 and smaller from SPOT 3 images is possible with sufficient accuracy.
2- Distribution of ground control points and their accurate layout on SPOT 3 images plays a very important role in the final accuracy for producing topographic map.
3- Producing topographic maps from satellite images with acceptable accuracy, is easier and faster than the classic methods.

6- References

1- Chen, L.C.; T. Teo and C. Yuan Lo (2008)," Elevation-Controlled Block Adjustment for Weakly Convergent Satellite Images". The International Archives of the Photogrammetry, Remote Sensing and Spacial Information Sciences.Vol.XXXVII. Part B1.Beijing, China.

2- Harvey P.D.A., "The History of Topographical Maps : Symbols, Pictures and Surveys", Thames and Hudson, 1980,p.9.

3- Javan, F.D. and A. Azizi (2008)," The Affine Projection Model as a Tool for Rapid Geo-Coding of IRS-P5 Satellite Imagery". The International Archives of the Photogrammetry, Remote Sensing and Spacial Information Sciences.Vol.XXXVII. Part B4.Beijing, China.

4- " Organizing the U.S. Geological Survey". The united States Geological Survey : 1879-1989. U.S. Geological Survey, U.S. Department of the Interior (2000-04-10). Retrieved on 2007-06-19.

5-Zhu, L.; H. Umakawa; F. Guan; K. Tachibana and H. Shimamura (2008). ' Accuracy Investigation of Orthoimages Obtained from High Resolution Satellite Stereo Pairs". The International Archives of the Photogrammetry, Remote Sensing and Spacial Information Sciences.Vol.XXXVII. Part B1.Beijing, China.

Table (4-1) coordinates of Ground Control and checkpoints

Point ID	X	Y	Z	Point status	Point usage
151	484968.126	2653065.766	180	Full	Control
152	485565.893	2657432.219	140	Full	Control
153	493842.403	2657887.574	169	Full	Control
154	459808.403	2648747.093	208	Full	Control
155	469534.467	2650199.365	190	Full	Control
156	487353.943	2667025.846	161	Full	Check
157	482494.147	2663278.951	183	Full	Check
158	482618.650	2672751.186	182	Full	Check
160	486209.946	2651588.331	-	Horizontal	Control
161			171	Vertical	Control
162			172	Vertical	Check
163	471647.788	263634.634	207	Full	Check

Table (5-1) coordinates of points used for checking accuracy

Point ID	Lat (d, m ,s)	Long (d, m, s)	Z (m)
1	24 02 40.84	32 30 33.22	452
2	24 06 49.99	32 30 59.31	404
3	24 05 10.28	32 30 32.66	226
4	24 02 41.01	32 31 27.29	376
5	23 58 07.12	32 31 55.29	182
6	24 06 02.53	32 49 00.83	192
7	23 50 39.03	32 33 17.83	182
8	24 05 11.15	32 35 29.98	183
9	24 03 05.91	32 31 27.20	354
10	23 59 21.98	32 51 08.00	180
11	23 48 16.98	32 43 17.97	207
12	24 01 43.99	32 51 28.97	140
13	24 01 43.99	32 51 28.97	169
14	24 10 01.99	32 49 43.98	182
15	24 12 14.41	32 34 34.54	124
16	24 08 05.64	32 36 23.53	172
17	24 01 02.43	32 37 45.85	201
18	24 03 07.96	32 46 18.95	209
19	23 58 58.77	32 44 58.38	193
20	23 59 22.67	32 36 52.13	207
21	23 58 07.28	32 32 49.29	188
22	23 54 24.45	32 41 49.93	198
23	23 51 55.00	32 38 41.40	212
24	23 53 58.29	32 33 17.14	183

25	23 50 38.79	32 31 56.91	187
26	24 11 01.71	32 54 25.05	172
27	24 13 05.55	32 44 29.64	182
28	24 09 46.51	32 46 45.28	208
29	23 55 15.22	32 53 58.70	172
30	23 53 34.63	32 41 50.05	190
31	23 51 54.53	32 38 14.43	217
32	23 46 54.55	32 31 30.75	190

Table (5-2) The Different between Elevations

Point ID	Z in LPS (m)	Z in Base map (m)	Difference (m)
1	452	456	4
2	404	412	8
3	226	229	3
4	376	379	3
5	182	186	4
6	192	197	5
7	182	184	2
8	183	187	4
9	354	348	6
10	180	183	3
11	207	202	5
12	140	144	4
13	169	165	4
14	182	185	3
15	124	121	3
16	172	178	6
17	201	205	4
18	209	204	5
19	193	195	2
20	207	207	0
21	188	185	3
22	198	202	4

23	212	216	4
24	183	184	1
25	187	185	2
26	172	171	1
27	182	177	5
28	208	204	4
29	172	174	2
30	190	196	6
31	208	202	6
32	190	194	4

Table (5-3) Different in Latitude

Point ID	Lat (d, m ,s) in LPS	Lat (d, m, s) in base map	Difference (d, m, s)
1	24 02 40.84	24 02 43.84	00 00 03
2	24 06 49.99	24 06 42.99	00 00 07
3	24 05 10.28	24 05 20.28	00 00 10
4	24 02 41.01	24 02 49.01	00 00 08
5	23 58 07.12	23 58 11.12	00 00 04
6	24 06 02.53	24 06 10.53	00 00 08
7	23 50 39.03	23 50 51.03	00 00 12
8	24 05 11.15	24 05 21.15	00 00 10
9	24 03 05.91	24 03 08.91	00 00 03
10	23 59 21.98	23 59 11.98	00 00 10
11	23 48 16.98	24 01 32.99	00 00 02
12	24 01 43.99	24 01 32.99	00 00 11
13	24 01 43.99	24 02 04.98	00 00 06
14	24 10 01.99	24 09 53.99	00 00 08
15	24 12 14.41	24 12 10.41	00 00 04
16	24 08 05.64	24 08 20.64	00 00 15
17	24 01 02.43	24 01 00.43	00 00 02
18	24 03 07.96	24 03 01.96	00 00 06
19	23 58 58.77	23 58 50.77	00 00 08
20	23 59 22.67	23 59 22.67	00 00 00
21	23 58 07.28	23 58 03.28	00 00 04
22	23 54 24.45	23 54 20.45	00 00 04
23	23 51 55.00	23 51 42.00	00 00 13

24	23 53 58.29	23 53 54.29	00 00 04
25	23 50 38.79	23 50 44.79	00 00 06
26	24 11 01.71	24 11 00.71	00 00 01
27	24 13 05.55	24 13 15.55	00 00 10
28	24 09 46.51	24 09 56.51	00 00 10
29	23 55 15.22	23 55 11.22	00 00 04
30	23 53 34.63	23 53 34.63	00 00 00
31	23 51 54.53	23 52 00.53	00 00 06
32	23 46 54.55	23 46 52.55	00 00 08

Table (5-4) Different in Longitude

Point ID	Long (d, m, s) in LPS	Long(d, m, s) in base map	Difference (d, m, s)
1	32 30 33.22	32 30 30.22	00 00 03
2	32 30 59.31	32 31 01.31	00 00 02
3	32 30 32.66	32 30 24.66	00 00 08
4	32 31 27.29	32 31 22.29	00 00 05
5	32 31 55.29	32 31 53.29	00 00 02
6	32 49 00.83	32 49 08.83	00 00 08
7	32 33 17.83	32 33 40.83	00 00 23
8	32 35 29.98	32 35 39.98	00 00 10
9	32 31 27.20	32 31 12.20	00 00 15
10	32 51 08.00	32 51 00.00	00 00 08
11	32 43 17.97	32 43 20.97	00 00 03
12	32 51 16.97	32 51 16.97	00 00 12
13	32 56 21.99	32 56 11.99	00 00 11
14	32 49 43.98	32 49 50.98	00 00 07
15	32 34 34.54	32 34 45.54	00 00 11
16	32 36 23.53	32 36 43.53	00 00 20
17	32 37 45.85	32 37 30.85	00 00 15
18	32 46 18.95	32 46 20.95	00 00 02
19	32 44 58.38	32 44 50.38	00 00 08
20	32 36 52.13	32 36 52.13	00 00 00
21	32 32 49.29	32 32 37.29	00 00 12
22	32 41 49.93	32 41 51.93	00 00 02
23	32 38 41 40	32 38 32 40	00 00 09

24	32 33 17.14	32 33 25.14	00 00 08
25	32 31 56.91	32 31 46.91	00 00 10
26	32 54 25.05	32 54 31.05	00 00 06
27	32 44 29.64	32 44 07.44	00 00 22
28	32 46 45.28	32 46 55.28	00 00 10
29	32 53 58.70	32 53 42.70	00 00 16
30	32 41 50.05	32 42 00	00 00 10
31	32 38 14.43	32 38 20.43	00 00 06
32	32 31 30.75	32 31 38.75	00 00 08

Table (5-5) Linear misclosure

Point ID	Δ Lat (Δ φ)	Δ Long (Δλ)	Linear misclosure 1
1	3	3	04.24
2	7	2	07.28
3	10	8	21.81
4	8	5	09.43
5	4	2	04.47
6	8	8	11.31
7	12	23	25.94
8	10	10	14.14
9	3	15	15.30
10	10	8	12.81
11	2	3	03.61
12	11	12	16.28
13	6	11	12.53
14	8	7	10.63
15	4	11	11.70
16	15	20	25.00
17	2	15	15.13
18	6	2	06.32
19	8	8	11.31
20	0	0	00.00
21	4	12	12.64
22	4	2	04.47

23	13	9	15.81
24	4	8	08.94
25	6	10	11.66
26	1	6	06.08
27	10	22	24.17
28	10	10	14.14
29	4	16	16.49
30	0	10	10.00
31	6	6	08.49
32	8	8	11.31

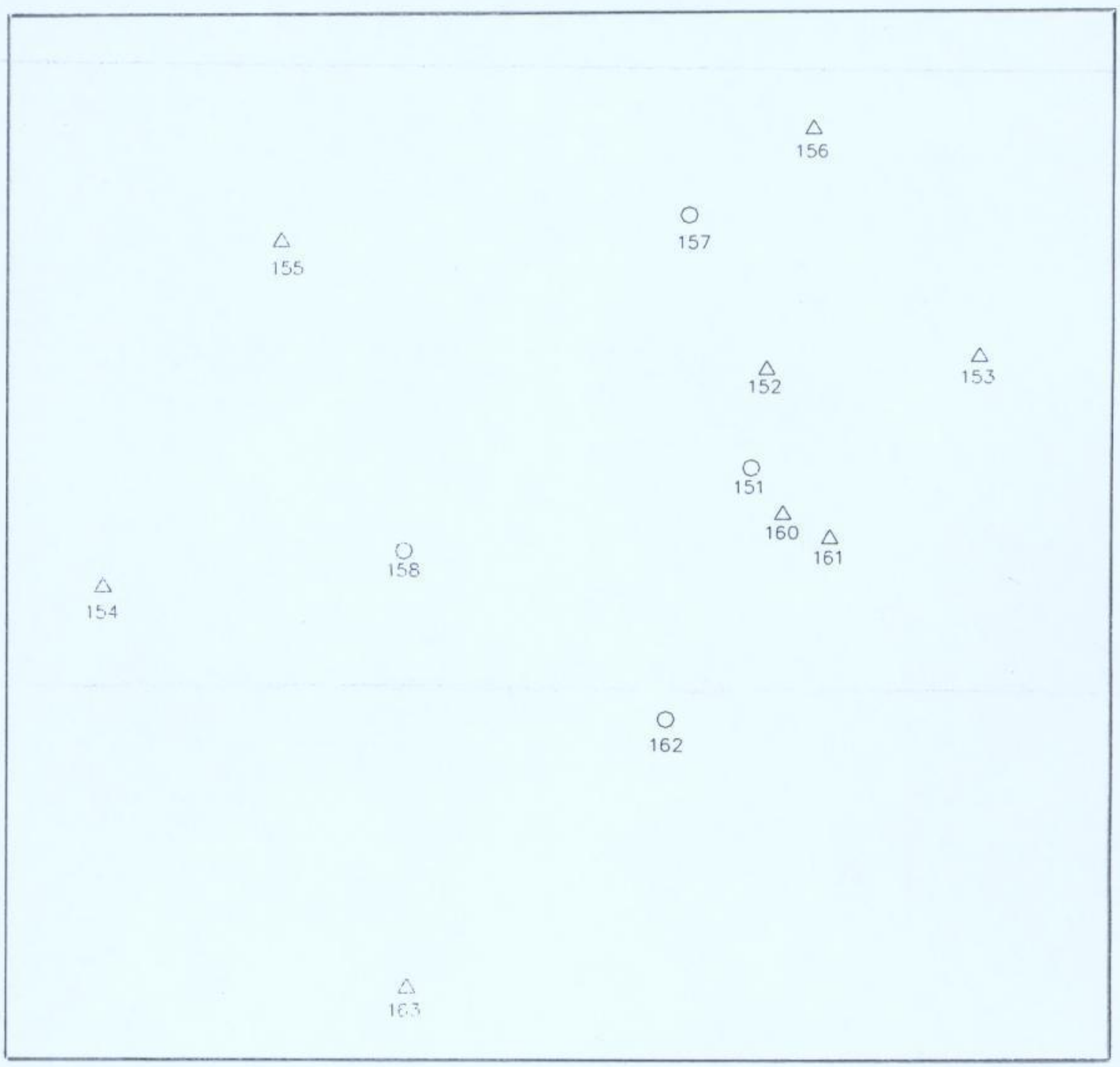

Fig (4.1) Distribution of Ground Control and Check Points

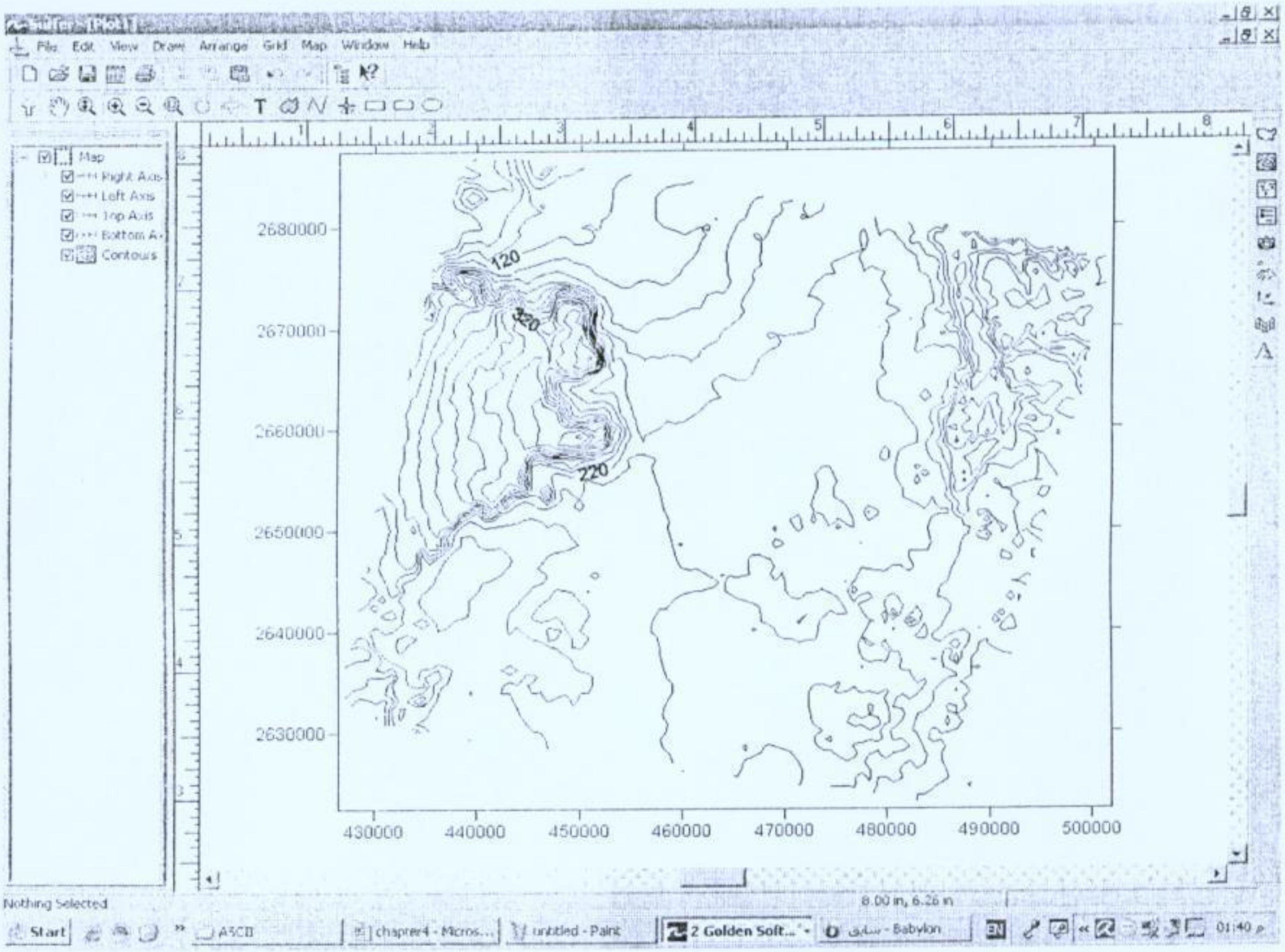

Fig (5.1) map contour lines in Surfer

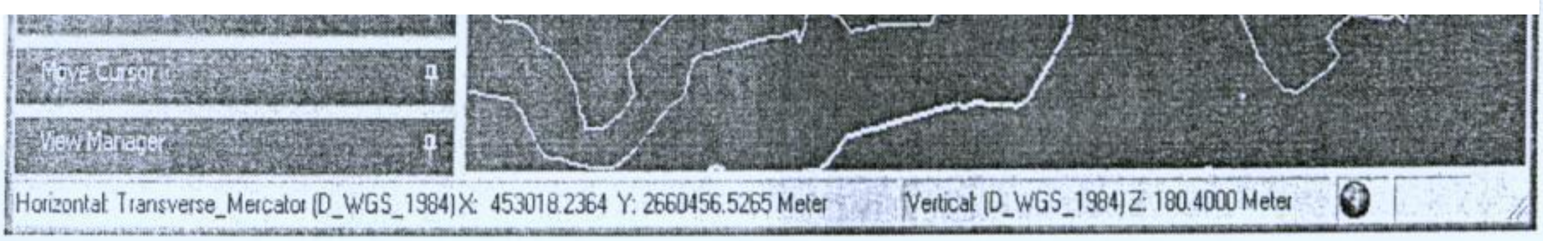

Fig (4.2) Contours Display

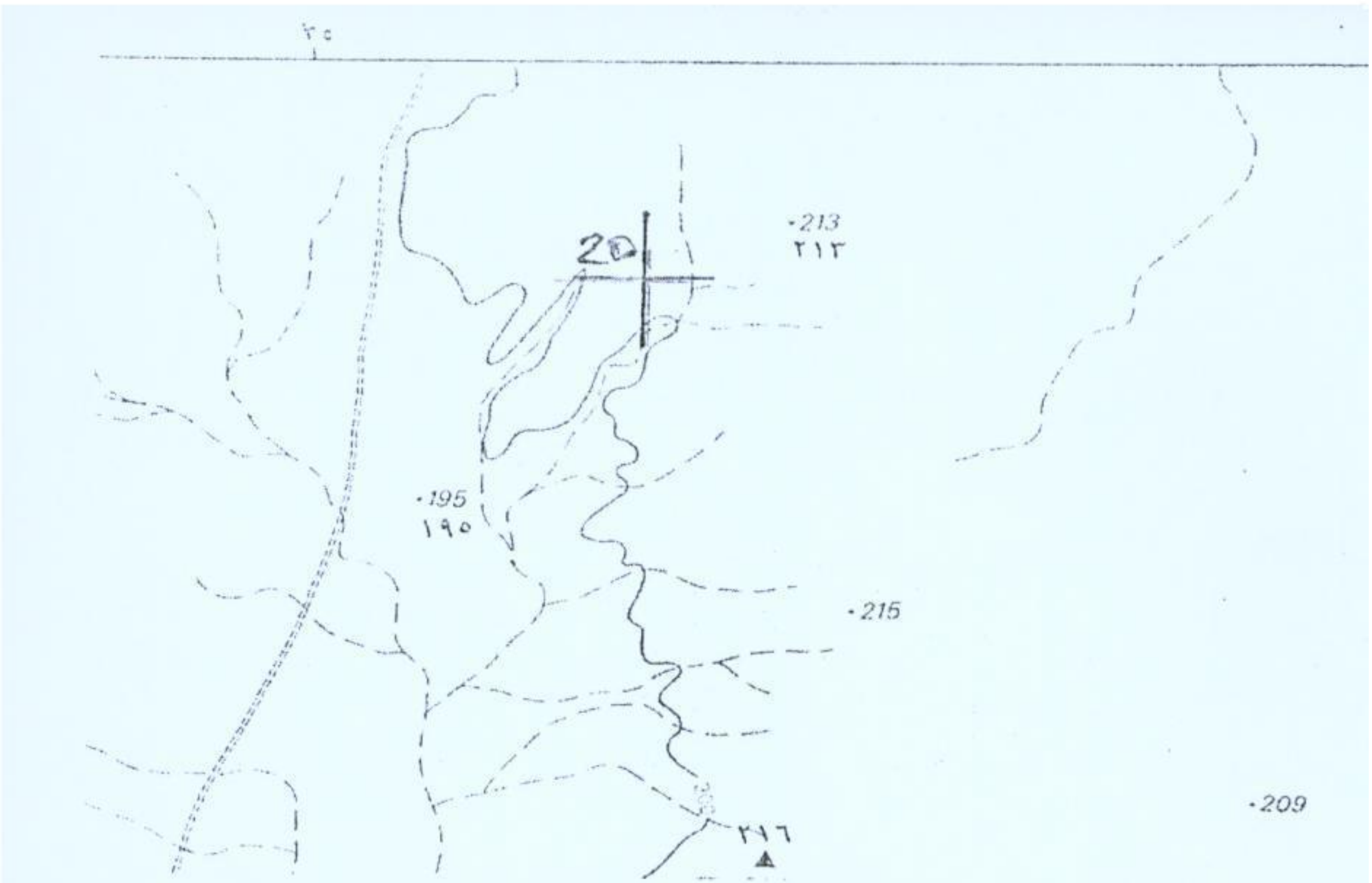

Fig (5.2) position of point 20 (of height 207m) in base map

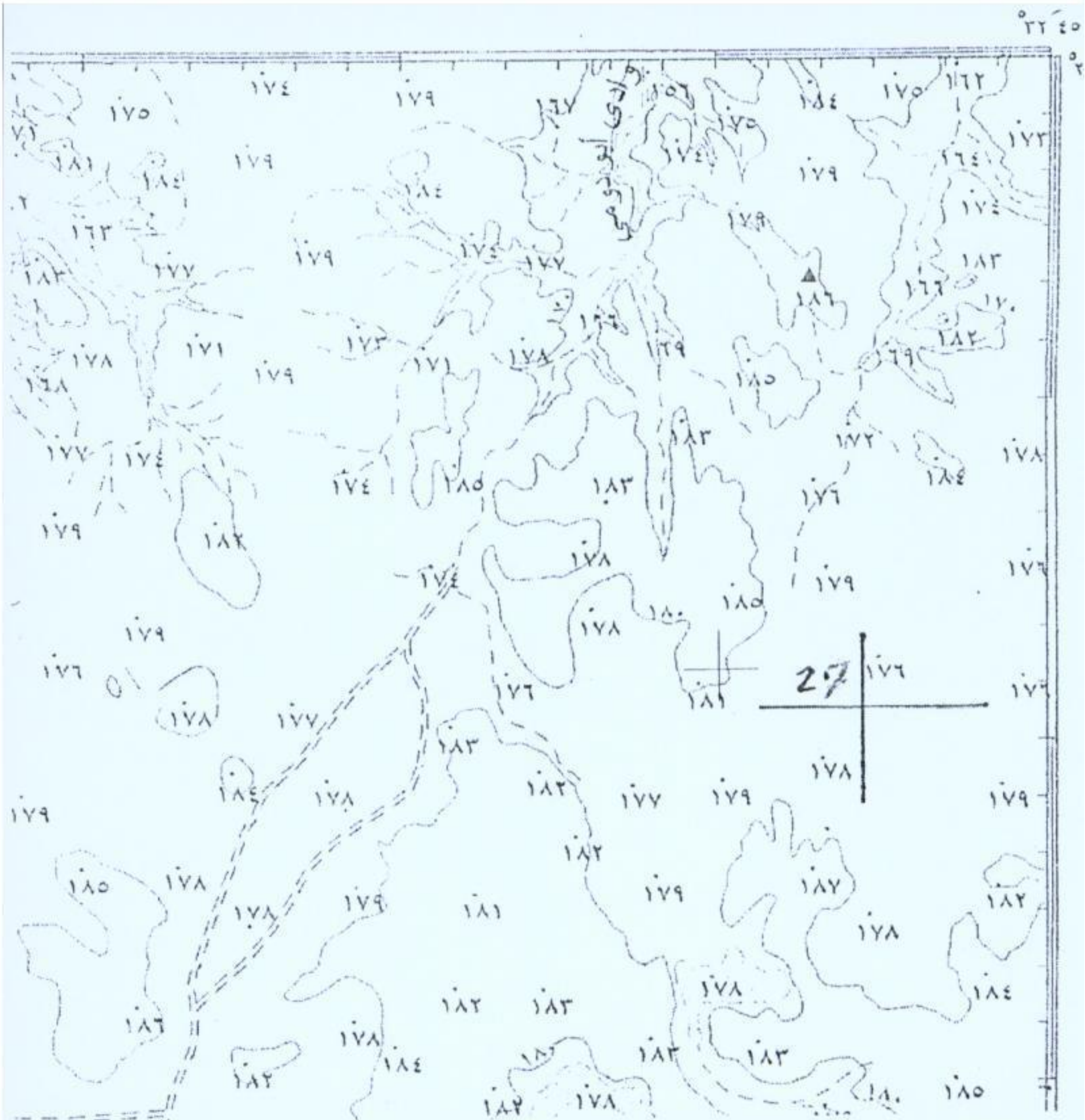

Fig (5.3) position of point 27 (of height 182m) in base map

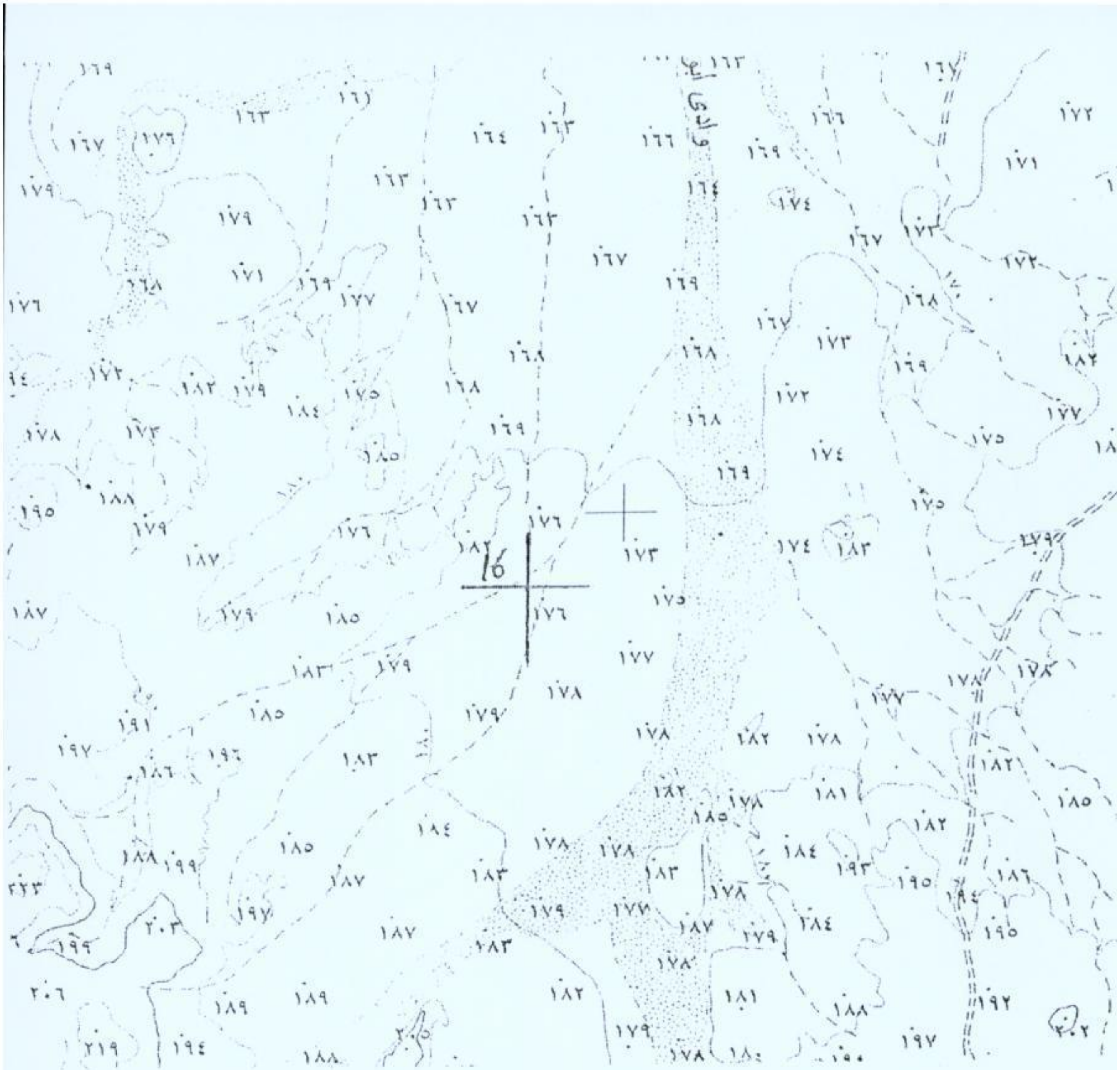

Fig (5.4) position of point 16 (of height 172m) in base map