Geomorphological and Sedimentological evidence of alpine glaciers in the Zagros Mountains, Dinevar, Iran

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Abstract

The altitude to which the past glaciers had been extended during the last glacial period in Dinevar Basin, western Iran, can be estimated based on glacier-geomorpic evidence such as cirques, U-shaped valleys, and the moraines in lowlands. This study estimates the elevation of snowline during this period for the basin as the objective of the research. Topographic and geologic maps, Landsat images and ASTER elevation data, climatic statistics and the sediment samples gathered by field survey were used as the material of this study. According to Wright method, the difference between the elevation of the highest and the lowest cirques and the altitude where have 60% of cirques have been obtained. The snowline altitude has produced the isotherm map of the basin during the last cold period. The results of the research have indicated that the permanent snowline during the last glacial period was 2820 meters above sea level (a.s.l.) and that the average temperature in the basin had been 5.8 degrees less than the present. The poor sorting of the samples with considerable angularity suggests that the sediments in low lands of the basin have been deposited by peri-glacial flooding. It can be concluded that the performance of glaciers in the basin is confirmed.

Keywords: Glacial Period, Snowline, Dinevar Basin, Climatic Changes.

1- Introduction

Approximately all the areas above 2500 m a.s.l. in mountainous highlands in western Iran experienced geomorphic changes due to alpine glaciation during Pleistocene. These changes have undergone partly the same climatic fluctuations throughout the world. These glaciers had more spatial extents and covered more area during the last glacial period, about 11000 years ago, than those occurring currently. As a result, glacier evidence has been left behind such evidences as cirques, wide valleys, abrasions on hard rocks and moraines in lowlands. As the boundaries of dominant climatic processes are taken as elevation surfaces, predicted elevation values can be indicative of some specific glacier limits and the dominance of different erosional processes. Therefore, in order to examine geomorphological evolution of mountain areas, we attempt to determine the permanent snowline altitudes during glacier and inter-glacier periods. Hence, the morphologies of former glacial cirques as evidence help recognize the elevation of snowlines

(Mahmudi, 1989). De Morgan (1980) studied the former glacial cirques in Oshtorankuh, 3800 m a.s.l., and Ghalyankuh, both in Iran, 2440 m a.s.l. and determined that lakes and mountain glaciers had existed in Iran during the Quaternary Period (Jedari, 2004). Bobek (1959, 1963) investigated the glaciers in Alborz and Kurdistan highlands of Iran and Dezive in 1934 surveyed the glaciation in Zardkuh-e-Bakhtiari, Iran. Additionally, work was conducted by Wright (1962) for reconnaissance of glacial activity and their evidence in Iran. According to Wright (1962) the Halgord Region of Kurdistan in Iraq, near the Iranian border, had been under the influence of mountain glaciation during Pleistocene. He also claimed the snowline elevation as1800 m a.s.l. and interpreted glacial cirques in north-facing aspects in Oshtorankuh, at 3000 m a.s.l. and moraines in small valleys at 2600 m a.s.l.. Based on glacier geomorphic maps of Pedrami (1982), the snowline during the Wurm glacial period was located at the elevation of 1600 m a.s.l. from Ghandil to Halgord and in the north to Kurdistan in Iraq over an area from Sardasht to Orumyeh. He suggested the extension of glaciers and moraines down to 400 m in Masuleh Valley in west of Rasht and also believed that moraines of Wurm period best can be observed around Banneh. Based on the evidence (Ghahroudi and Hassani, 2012) there are three summits in Ghandil Mountain in 3400 m a.s.l. that represent the snowline altitude in 1650 m a.s.l. for that area.

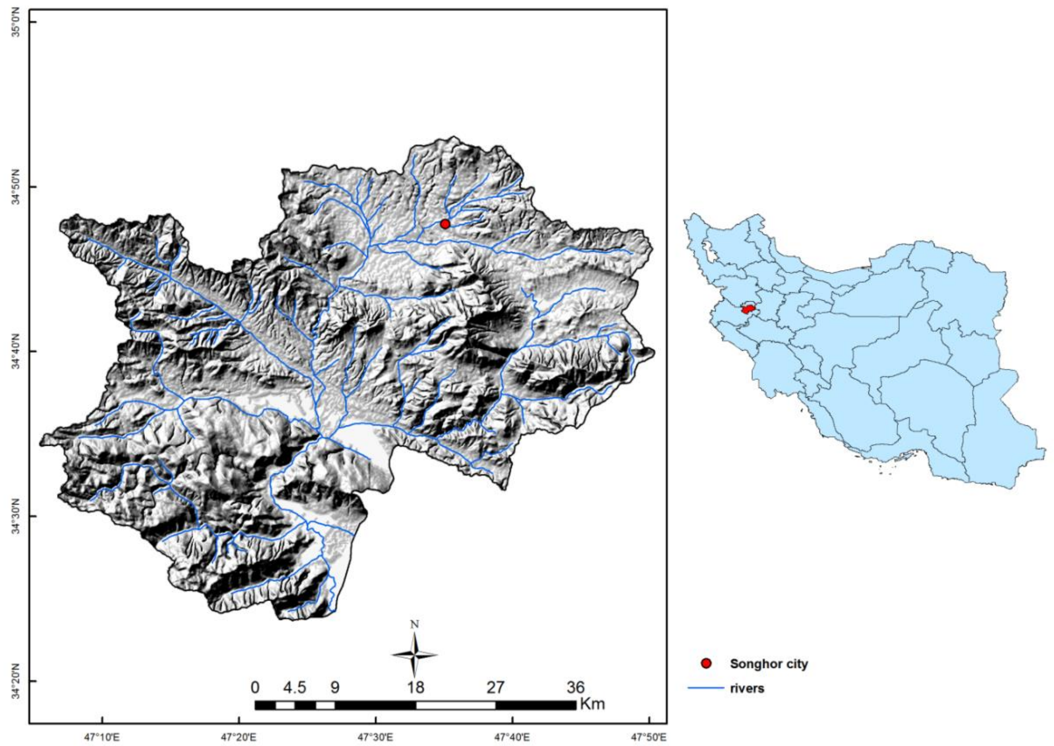

Figure 1) Location of Dinevar Basin in Zagros Mountain Range.

Ramsht (1992), relying on the geomorphic evidence and erosional remnants, predicted glaciers at 1600 m a.s.l. in different areas of Iran including Zafreh Shirkuh and also emphasized that the terminus of some glaciers had reached to the surrounding lowlands. Yamani (2007) investigated the geomorphic forms of glaciers and their surface extent in Zardkuh. Ghahroudi (2011) found the extent of snowline in the last cold period in Haraz Basin at 1750 m a.s.l. The purpose of the present study is to declare snowline altitude in the last cold period over Dinevar Basin in the north east of Kermanshah. The counties of Songhor, Sahneh, Harsin and Bisetun are included within the basin (Fig. 1). The lowest elevation of the basin, with an area of 214,577 hectares, is 1100 m a.s.l. and the highest 3350 m a.s.l.

2- Materials and Methods

Data were collected using topographic maps, at 1:25000 and 1:50000 scales, climatic data during 1980-2007, Landsat ETM+ Images, ASTER elevation data, and the sediment samples collected by field surveys with granulometric and microscopic analyses. The research was conducted in order as following stages:

2.1- Field survey

The evidence of glaciation in Dinevar Basin including cirques, U-shape valleys, and the signatures of ice movement in the moraines was surveyed in a field campaign (Fig. 2).

2.2- Data preparation

The data for the frequency of the cirques in elevation classes were gathered using the topographic maps and ASTER elevation data (Allan, 1998). 14 cirques of small and large sizes were recognized between the elevations from 3140 m to 2340 m (Table 1). These cirques are more concentrated in the elevations from 2800 m to 2600 m so that about 50% were found in this elevation class (Fig. 2).

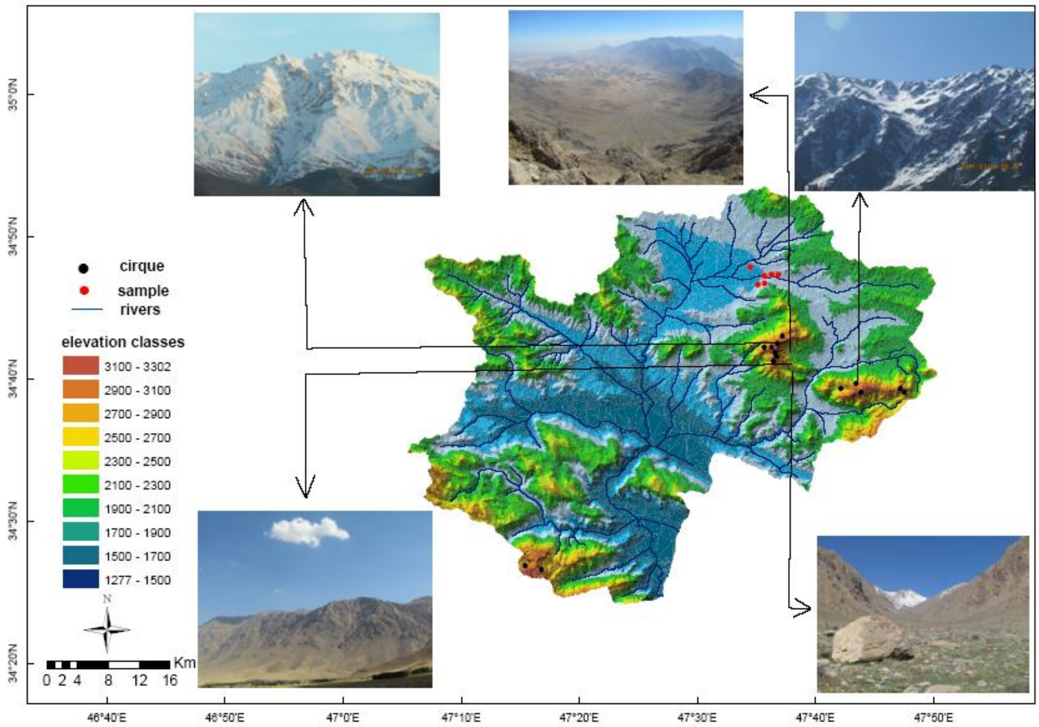

Figure 2) The elevation map, glacial landforms and the samples in Dinevar Basin.

Table 1) The frequency distribution of cirques elevations in Dinevar Basin.

No	Elevation classes	Frequency	Percentage	Cumulative percentage
1	2300 - 2400	1	7.14	7.14
2	2400 - 2500	0	0	7.14
3	2500 - 2600	1	7.14	14.28
4	2600 - 2700	2	14.28	28.56
5	2700 - 2800	5	35.71	64.27
6	2800 - 2900	1	7.14	71.41
7	2900 - 3000	1	7.14	78.55
8	3000 - 3100	1	7.14	85.69
9	>3100	2	14.28	100

2.3- Snowline altitude determination

According to the Wright method the elevation of 60% of cirques was specified to determine the snowline elevation of the past in the area. Achieving the elevation difference and the altitude of 60% of cirques, we determined the permanent snowline altitude for the area (equation 1) (Porter, 2001).

$$X = \frac{MaxElev.Cirque - MinElev.Cirque}{100} \times 60 \quad \text{(Eq.1)}$$

It means that above this elevation the mountain surfaces are permanently covered by snow throughout the year. This elevation is the 0-degree isotherm (Figu. 3).

Linear regression (equation 2) between temperature and elevation was calculated based on the climatic data from 13 meteorological stations (Table 2). Past temperatures were estimated using the permanent snowline elevation obtained from the Wright method (equation 1) and by the calculated regression (equation 2). According to dry lapse rate values, the monthly temperature decrease 6°C with 1000 m increase in elevation. It is ranged from 4.3 °C in September to 7.7 °C in January.

$$Y = -0.006x + 22.299 \text{R=0.948} \quad \text{(Eq. 2)}$$

2.4- Sedimentological analysis

For sedimentological analysis, some sediment samples were collected at 5 points, from a depth of 1 meter, in the study area (Table 3). The granulometric analysis was conducted to find out the origins of the sedimentary deposits and for each sample the corresponding cumulative curves have been drawn based on the logarithm of grain size (Fig. 4).

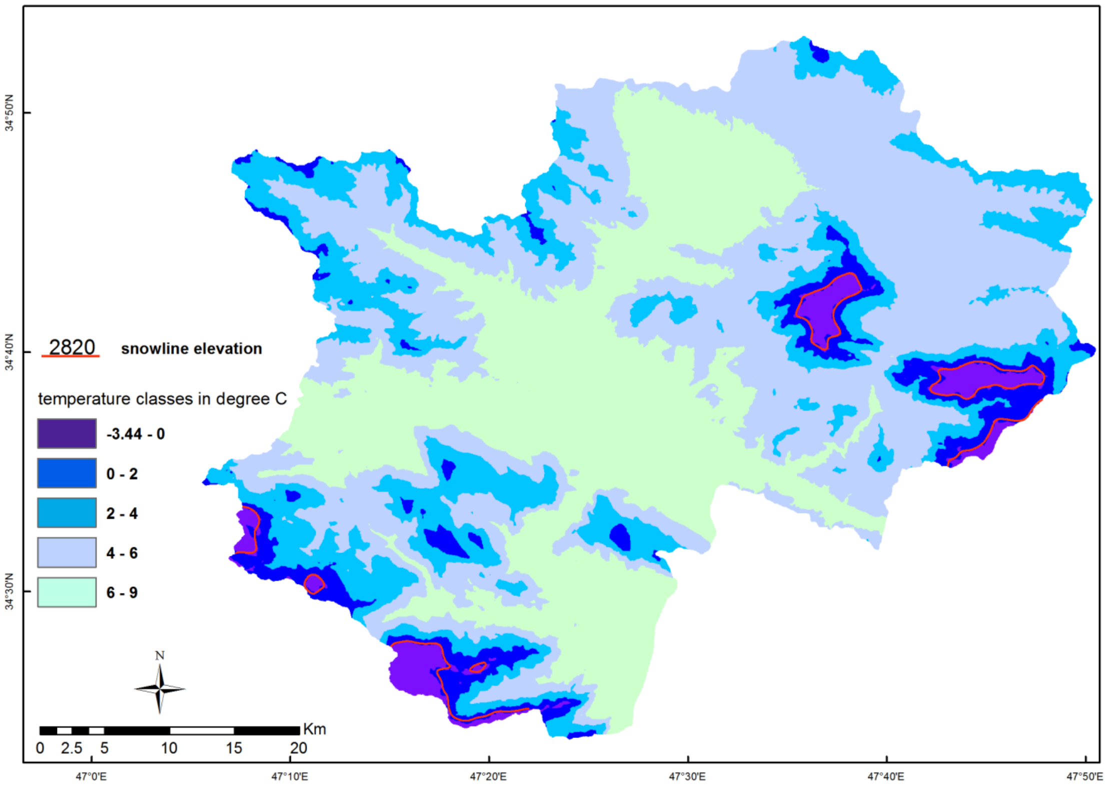

Figure 3) The elevation of snowline and the isotherm map in the last glacial period over Dinevar Basin.

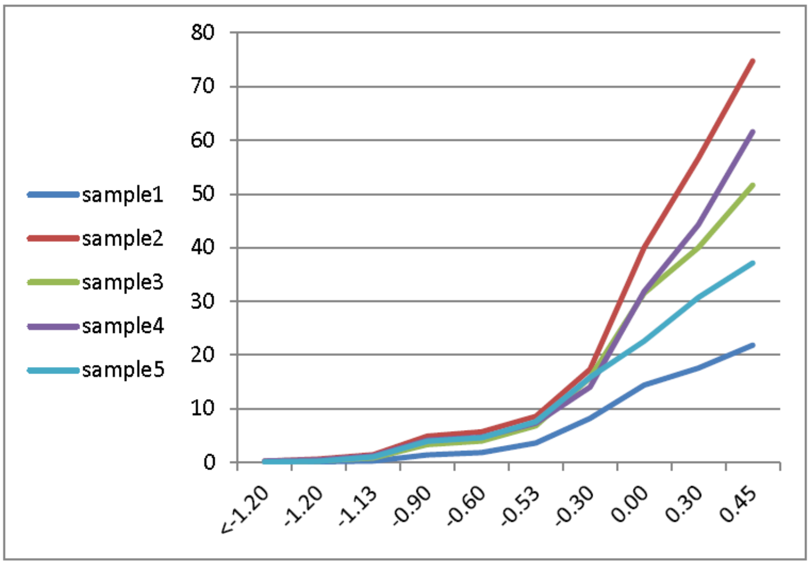

Figure 4) The results of granulometric analysis.

2.5- Statistical analysis

We have used Moment Folk method for statistical analysis of parameters. Table 4 shows the sorting classes based on the method according to equation 3 and 4 (Hubbard, 2005).

$$\emptyset\sigma = \sqrt{\frac{\sum f(m-\bar{x})^2}{100}} \quad \text{(Eq. 3)}$$

$$\bar{x} = \frac{\sum f.m}{n} \quad \text{(Eq. 4)}$$

Where *f* is the frequency of each sediment class, m is the median point of each class in phi scale and $\bar{x}$ is the average of that class.

2.6- Microscopic analysis

Microscopic analysis is a technique to determine the prevalence of water, wind or glacier performance on sediments for better understanding about the origins of the samples (Van der Meer, 1993). The observations by polarizing microscope represented that the grains in terms of roundness can be classified as rounded, half angular and angular (Fischer, 1994).

Table 2) The elevation and the average of annual temperature values in the study area (1980-2007).

No	Station name	Elevation	Average temperature	No	Station name	Elevation	Avergae temperature
1	Bolbolanabad	2015	10.7	7	Eslamabadgharb	1468.8	13.6
2	Ghamlo	1910	10.9	8	Ravansar	1388.0	13.9
3	Ghorveh	1906	11.4	9	Kermanshah	1318.6	15.0
4	Songhor	1700	12.2	10	Doabmerg	1310.0	13.4
5	mochash	1640	12.8	11	Polchehr	1280.0	14.5
6	kangavar	1468	13.2	12	Sarpol	545.00	19.8

3- Results and Interpretations

In the field survey up to 14 cirques were found in the areas ranged from 3140 m to 2340 m in elevation. As the result of the equation 1, according to Wright method, the difference between the maximum elevation of cirque (MaxElevationCirque) at 3140 m and the minimum elevation of cirque (MinElevationCirque) at 2340 m multiplied by 0.6 gives 480 m above the elevation of lowest cirque (MinElevationCirque).

Table 3) The location of sampled sediments.

No	Geographic location	Elevation	Location of the sample
1	The 1st terrace in road	1732	47° 37´ 23´´ E - 34° 45´ 56´´ N
2	Foundation of a building	1712	47° 35´ 51´´ E - 34° 45´ 27´´ N
3	2nd terrace	1718	47° 37´ 34´´ E - 34° 46´ 00´´ N
4	3rd alluvial terrace	1692	47° 36´ 31´´ E - 34° 46´ 07´´ N
5	Along valley (splint)	1731	47° 36´ 26´´ E - 34° 45´ 50´´ N
6	A well 10 meters deep	1688	47° 35´ 37´´ E - 34° 46´ 36´´ N

The elevation of snowline was determined at 2820 m a.s.l. using the difference between the minimum and maximum elevation of cirques and the line with 60% frequency of cirques. Thus, the snowline permanent altitude (x) was determined at 2820 m a.s.l. on the area. The past temperature has been reconstructed based on the linear regression between temperature and elevation and on the snowline altitude. The environmental lapse rate for average of monthly temperature is 6 °C decline per 1000 m increase in elevation. Throughout the year, it has variations from 4.3 °C in September to 7.7 °C in January. The distribution of past temperature in the basin has been estimated based upon the elevation difference between the maximum and minimum altitudes of cirques and the line of 60 percent of cirques and upon the elevation of permanent snowline. The results of sampling of 5 points, 1 meter deep, indicated that the particles revealed a mixture of fine and coarse grains and that they were bad or poorly sorted typical of glaciation process in the area. As the charts show an upward curve, it can be construed that the sediments had been left by a process either unable to transport well or slow in transportation. Therefore, the sediments can be representative of glaciation performance (Table 5) (Hambrey and Harland, 1981).

For a more reliable inference from the results and more precise declaration about the origins of the samples, Microscopic analysis was performed on them to determine the prevalent process (Van der Meer, 1993). Hence, the sediments ranged from 1 mm to 0.063 μ were selected from the sieved particles to prepare sections. Since the main portions of the sampled particles were angular, it can be inferred that the basin was under the influence of glacier prevalence during the glacial cold period (Fischer, 1994, Fig. 5).

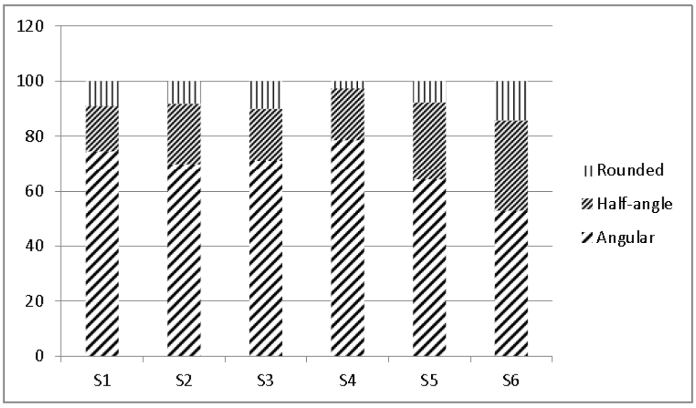

Figure 5) Percentage of roundness and angularity of the sampled particles.

Table 4) The sorting of sediments (Folk, 1957).

No	Sorting value (σ) in ϕ	Sorting type
1	<0.35	Very well sorted
2	0.35-0.5	Well sorted
3	0.5-0.71	Moderately well sorted
4	0.71-1	Moderately sorted
5	1-2	Poorly sorted
6	2-4	Very poorly sorted
7	>4	Extremely poorly sorted

4- Discussion

The region of study has an area of 2145 square kilometers and is extended from 1500 to 3300 meters a.s.l. The presence of 14 cirques, U-shaped valleys and the moraines inside the valleys all are indicative of glacier activity during the last cold period. The results of granulometric analysis exhibited poorly sorted particles and the morphoscopic analysis represented the high percentage of angular sediments both indicate the glacial origins of the sediments.

Table 5) Type of sorting in sampled sediments.

No	Sorting value	Sorting type
1	1.44	Poorly sorted
2	1.40	Poorly sorted
3	1.42	Poorly sorted
4	1.41	Poorly sorted
5	1.12	Poorly sorted

Granulometric analysis of the samples from valley terraces and the foundation of the Sanghar City, on the elevation of 1732-1692 m and distant from the cirques and glacial valleys, indicated a tendency towards coarse grains on the cumulative charts and a sorting value more than 1 which represents a mixture of coarse and fine grains (Table 5). The Microscopic analysis shows 40-70 percent of angular particles in the samples (Fig. 5).

According to the field survey and sediment examinations, there was climate change and a consequent shift in morphogenetic processes, so that during the last cold period on the area there existed glaciers behind which many evidence such as cirques and glacier valleys were left (Aniya and welch, 1981; Hirano and Aniya, 1989). The elevation 2820 m was the boundary between two morphogenesis system of glacial and peri-glacial. In the glacial system the movements of ice were prevalent inside the valleys where their traces can be observed as lines sculpted on the moraines and banks. Below the elevation the fine sediments were provided by freeze and thaw process during the same period. The volume of sediments due to glacial movement and physical weathering in the peri-glacial period were transported down by rainfall flow and ice melted water to cover the lowlands. The angular properties of deposits are here cues for cryoclastic and glacial sediments and the poorly sorted sediments with a mixture of fine and coarse grain particles are cues for the presence of flooding in peri-glacial period.

The snowline determined in the study is to some extent close to that determined by Wright who stated it in Kurdistan in the proximity of the study area at 3000 m a.s.l. and it is so different with the altitude of snowline that Bobek reported in his studies at 1600 m a.s.l. in Ghalyankuh somewhat in the vicinity of this study area. Most of the glacial evidence can be found on the areas above 2820 m a.s.l. The permanent snowline in the last glacial period is about 5.38 degrees. There are differences in the elevation due to mountainous situation of Iran, the mountain arrangements relative to solar radiation, and westerlies. De Morgan had found the glacial cirques at 2440 m a.s.l. for Ghaliankooh (Jedari Eyvazi, 2004). Wright (1962) declared the elevation of snowline in the last glacial period at 1800 m a.s.l. in quaternary for Helgord Region in Kurdistan. The region is not so different from Dinevar Basin in terms of environmental conditions, elevation and mountain arrangement. According to Ghahroudi and Hassani (2011) the snowline elevation in Ghandil Mountain was 1650 m a.s.l. with 150 m difference from Wright statement. The difference can be resulted from the more distance of the mountain from the sources of moisture. According to generalized map of snoeline by Pedrami (1982) the snowline in Dinevar Basin was estimated at 2500 m a.s.l. with 320 m difference from the result of this study. This can be due to map scale issues. According to

Ramesht (2002) the expansion of glaciations toward low lands was observed up to 1600 m a.s.l. This may have been extended by some high peaks above 3000 m a.s.l. and exposure to the westerlies that have been probably in lower latitudes.

5- Conclusion

Dinevar Basin has recorded the evidence of glacial periods as cirques of different sizes, U-shape valleys and moraines. The results have indicated that the snowline altitude had been revealed to be 2820 m a.s.l. during the last glacial cold period. With a climate warming, the flooding flows carried the glacial sediments and deposited them in near lowlands where now some cities like Sanghar are located on. The snowline elevation following the methodology has been estimated and was confirmed by the many previous statements.

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