DEM DATA PROCESSING FOR A LANDSCAPE ARCHAEOLOGY ANALYSIS (LAKE SEVAN - ARMENIA)

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ABSTRACT:

The relationships between the southern Sevan Lake landscape and archaeological sites have been investigated by analysing Digital Elevation Models (DEM) created considering as input both topographic maps and ERS SAR satellite data. The first has been yielded by interpolating contour lines, with 100 m step, of a topographic map. The other DEM was generated by applying interferometry processing to an ERS tandem pair (ERS1 and ERS2 acquired on consecutive days) such as a SLCI (single look complex) product. This DEM has been geocoded on the basis of the Krassovsky ellipsoid, attaining a pixel resolution of about 20 m. The two gathered DEMs have been then overlapped using GCPs chosen along the Lake Sevan coast line, mostly in correspondence of rivers mouths, and at spot heights relative to volcanoes peaks. The DEMs have been processed to derive shaded relief maps, which permit to investigate surface morphological differences expressed as discontinuities in relief. On these thematic maps fortresses and forts have been georeferenced and superimposed taking into account the results of archaeological studies. Landscape assessment was, then, applied to the sites groups, identified up, to now by means of viewshed analysis, height profiles drawing and 3D representation of obtained DEMs.

1. INTRODUCTION

The C.N.R. "*Istituto di Studi sulle Civiltà dell'Egeo e del Vicino Oriente*" (ICEVO) has for years carried on an interdisciplinary "Urartu Project" (Biscione and Parmegiani, 1994-1995-1996-1997; Biscione et al.., 2002), aimed at reconstructing the Urartian civilisation (IX-VII centuries BC; Zimansky., 1985). Since 1994 the ICEVO has been organising campaigns in Armenia in the region of Lake Sevan as the north-eastern periphery of the Urartian state and fortified frontier against invasions of surrounding populations. The investigation has identified, examined and documented about 80 "sites", including fortresses, forts, settlements, necropolis (ranging from the Early Bronze Age to the Medieval period): for each site geographical co-ordinates have been recorded by means of a GPS. The archaeological investigation has highlighted the necessity of a landscape reconstruction addressed to better understand land use and control by ancient communities, also in relation to invasions. Urartian conquest caused withdrawing of pre-existing populations towards elevations greater than 2100 m a.s.l., while Urartian army settled mostly along the Lake Sevan plain up to the foothills (Figure 1). The setting of the Lake Sevan landscape, where Iron Age communities located their settlements, has been reconstructed by analyzing thematic maps derived from DEMs, created considering as input both topographic maps and ERS SAR data.

2. ELEVATION DATA PROCESSING

A first elevation matrix (DEM), corresponding to the southern part of the lake Sevan region ,was set up by interpolating main contour lines, with 100 m step, within two contiguous topographic sheets on a 1:100,000 scale. This DEM was then georeferenced with respect to a UTM projection grid, accomplishing a pixel resolution of 50 m (hereafter mentioned as *UTM-map-DEM*, Parmegiani and Poscolieri, 1999).

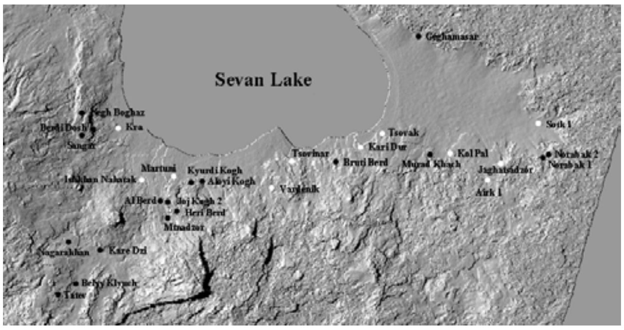

Figure 1. Grey shaded relief obtained from the Krass-ERS-DEM with overlapped Iron Age (black circles) and Urartian (white circles) forts/fortresses (VIII-VII cent. B.C.).

Another DEM, 100x100 Km wide and covering the same area, was generated by applying interferometric techniques (Lichtenegger et al. 1999, Parmegiani et al. 1999) to an ERS-1/2 SAR tandem pair, recorded on August 23-24 1998 and processed as SLC (single look complex) product. This data set, considering as base map the *UTM-map-DEM*, was geocoded taking into account the Krassovsky ellipsoid (hereafter cited as *Krass-ERS-DEM*), obtaining a pixel spatial resolution of about 21 x 18 m. The accuracy of the *Krass-ERS-DEM* was verified by georeferencing with respect to it the *UTM-map-DEM* on the basis of GCPs (Ground Control Points), chosen along the Lake Sevan coast line, mostly in correspondence of rivers mouths, and at spot heights relative to peaks of volcanoes (hereafter named as *Krass-map-DEM*; Parmegiani and Poscolieri, 2002).

The *Krass-map-DEM* and the *Krass-ERS-DEM* were then processed to derive shaded relief maps (Imhof 1982), created by choosing: for the *Krass-map-DEM* a lighting source as located at south-west with an angle of 30° above the horizon; for the

Krass-ERS-DEM a sun azimuth of 300°N and sun elevation of 30° (Figures 1-2).

2.1 Comparing the two DEMs

In order to choose which DEM to use as input for the landscape analysis, a comparison between the two overlapped elevation matrices, made at pixel level, has been carried out highlighting mutual differences or errors. Both *Krass-map-DEM* and *Krass-ERS-DEM* exhibit major drawbacks. In particular, the former presents problems of spatial resolution and precision resulting from digitizing and interpolating topographic maps contours, the latter, even though derived from a real landscape representation (SAR satellite data), exhibits inconveniences, such as shadowed areas, layover, foreshortening, caused by the viewing geometry of the ERS satellite SAR sensor, especially over high relief areas, not disregarding also the lack of coherence between the original images (Lichtenegger et al. 1999, Parcharids et al., in print).

2.2 Results of the DEMs comparison

Krass-ERS-DEM, in the 1900 to 2500 m ranges, exhibits altitude differences with respect to the *Krass-map-DEM* mostly under 50 m; however, in the high relief areas (2500 to 3800 m range) it presents elevation values underestimated up to some hundred meters, particularly in the south-central side of the study area (Parmegiani et al., 2002). Above 2600 m value the *Krass-ERS-DEM* exhibits a depletion of its histogram curve up to 3100 m, while Krass-map-DEM presents an almost stable trend up to 3800 m elevation. This opposite behavior is probably caused by the aforementioned viewing geometry of the ERS satellite SAR sensor which crossing, along a descending orbit, from Northeast looking North-westwards, the SW section of the study area, including the highest summits, generate SAR image with shadowed areas and foreshortening. Therefore, the landscape analysis has been performed by processing the elevation values from Krass-Map-DEM, while base maps for visualization have been considered the shaded relief images derived from *Krass-ERS-DEM* as morphology is more evident.

3. INTEGRATION OF THEMATIC MAPS WITH ARCHAEOLOGICAL DATA

Once having created the described digital maps, the goal of the archaeological analysis was the interpretation of the settlement location choices with respect to the surrounding landscape: this has been possible because during the field surveys each site has been described by a form, pointing out among other data its geographical coordinates recorded with a GPS. The analyzed settlements were 27 Early Iron Age fortifications, selected by Sanamyan (2002) according to structural criteria or to the pottery dating and partitioned into five groups (Figure 2); some were founded in Early Iron Age, while others were already inhabited at an earlier date.

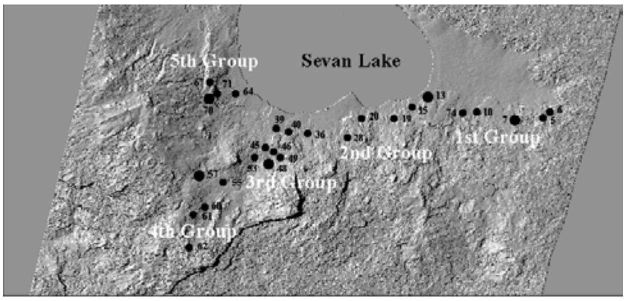

Figure 2. Geographical distribution of the Iron Age forts/fortresses according to the results of Sanamyan

Structural criteria, followed by Sanamyan, are based on:

- surface area covered by fortifications (Table 1), independently on their shape (very large,10 ha and more; large, 9 - 3 ha; medium, 2.5 – 0.5 ha; small, 0.4 – 0.2 ha; very small, less than 0.2 ha.
- Morphological local setting of the fortifications, being generally built in places of difficult access: according to this criterion they can be divided into 4 typologies (hillforts, promontory forts, fortifications on plateau, fortifications on slopes).
- The peculiarities of the local morphology influenced the plans of the fortifications. Hill forts are round or oval, rarely polygonal in plan; promontory forts are triangular, rarely trapezoidal; those built on a plateau are rectangular, almost square or trapezoidal; the ones built on slopes do not have specific shapes. Therefore, the forts can be divided into 6 groups according to the approximate shape of their ground plan (round, oval, polygonal, triangular, rectangular, trapezoidal).

The identified five groups of fortifications correspond to the territory of one “land” mentioned in Urartian cuneiform inscriptions connected with this area. Each of these clusters had its autonomous defensive system, aimed not only at external enemies but also at each other. This does not exclude the fact that in case of external danger some of the groups, or even all of them, could have united, thus forming one integrated defensive system, since the fortification complex of the Early Iron Age controlled not only the whole territory, but also the principal and secondary roads and passes leading to the area.

Among these five groups (Table 1) the first two and the last two are characterized by a main fortress exhibiting the role of central place and the others were at the same lower level, being someone functioning as landscape sight control (watchtower). The third group, instead, is the largest and lies in the central part of the area, between the rivers *Astghadzor* and *Martuni*. Three of the forts are located south of the Sevan lake, on the foothills of the mountain ranges, and form a straight line stretching from east to west (Figure 2). Three forts are in the *Martuni* river valley. In the southern part of the group, on the promontory formed by the river *Martun*i and its western tributary *Mtnadzor*, lies the largest fortress of the group, *Mtnadzor* (N. 48, 3.5 ha), central place of the group. Another fort, *Bardzrashen* (N. 53), is located on a plateau overlooking the Argichi river, functioning as watchtower.

The sites belonging to the first two groups lie along a line, at the foot of the high mountains (up to 3800 m a.s.l.), not crossed by main valleys and overlooking northwards the Sevan lake plain (Figure 2). As regards to the last two groups, the most interesting from a landscape analysis point of view is the 4th one which is located within a highland, bordered by mountains and located in the southwestern side of the study area. This group includes *Nagharakan* (as large as 15.5 ha.), which exhibited the role of “*central place*”, and other sites

(*Kare dzi*, *Belyy Klyuch* and *Tatev)* being at the same lower level. In particular, the *Kare dzi* fort (as large as 0.2 ha) was functioning as sight control site, being placed downhill the *Armaghan* volcano and overlooking southwards the entire *Argichi* watershed (Table 1).

The 4th group has been analysed in terms of spatial relationship, first, by drawing elevation profile between the central place site and the secondary fortifications, to gain insight into the mutual visibility, the pathway difficulties taking into account the distance. Moreover, a viewshed analysis has been carried out considering as sightseeing sites the watchtower of the group (*Kare dzi*).

Furthermore, the last three groups have been analysed by 3D visualization procedures (Figure 3).

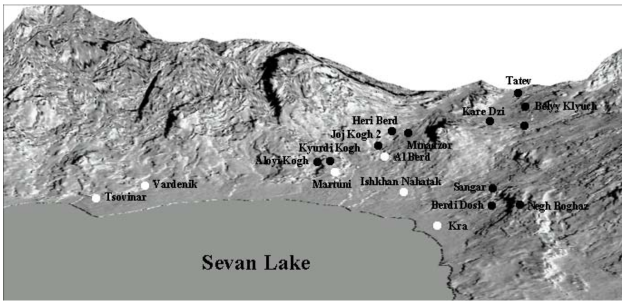

Figure 3. 3D representation of the shaded relief obtained from the *Krass-ERS-DEM*, with position view from north looking southeastwards. Site groups 3, 4 and 5 are depicted

Gr.	Catal. N., site, area	Tipology	Elevation (m)
I			
	5 Norabak 1(ha 3)	Fortress	2160
	6 Norabak 2 (ha 1.2)	Fort	2347
	7 Jaghatsadzor (n.m.)*	**Main fortress**	2114
	10 Kol Pal (ha 6.5)	Fortress	2001
	74 Murad Khach (ha 0.3)	Watchtower	2070
II			
	13 Tsovak (ha 10)	**Main fortress**	1960
	15 Kari Dur (ha 0.9)	Fort	1994
	9 Bruti Berd (ha 0.14)	Watchtower	2088
	20 Tsovinar (ha 5)	Fortress	1970
	28 Vardenik 1 (n.m.)*	Fortress	2075
III			
	36 Aloyi Kogh ha 0.7)	Fort	2179
	40 Kyurdi Kogh (ha 0.4)	Fort	2105
	39 Martuni (ha 1)	Fort	1998
	45 Al Berd (ha 0.8)	Fort	2100
	46 Joj Kogh 2 (ha 1.3)	Fort	2243
	48 Mtnadzor (ha 3.5)	**Main fortress**	2244
	49 Heri Berd 1 (ha 0.15)	Fort	2250
	53 Bardzrashen (n.m.)*	Watchtower	2180
IV			
	55 Kare Dzi (ha 0.2)	Watchtower	2320
	57 Nagarakhan (ha 15.5)	**Main fortress**	2330
	60 Belyy Klyuch (ha 0.4)	Fort	2325
	61 Tatev (ha 0.4)	Fort	2330
V			
	64 Kra (ha 5)	Fortress 1945	
	67 Negh Boghaz (ha 1)	Fort	2360
	70 Sangar (ha 3.5)	**Main fortress**	2206
	71 Berdi Dosh (ha 1.5)	Watchtower	2201

* (n.m.: not measured)

Table 1. Characteristics of sites within five identified groups.

By interpreting the elevation profiles relative to the 4th group, the main fortress of *Nagharakan* is visible only from *Kare dzi* (Parmegiani et al., 2002), while this last one, hosting only a small garrison but overlooking the whole *Argichi* river valley, can see also both *Belyy Klyuch* and *Tatev* (Figure 4), so pointing up its sight control function with respect to the other sites, which, on the other hands, are invisible to one another.

Strictly related to this method is the so-called *Viewshed* analysis that makes inferences about the relationships of intervisibility between related sites within a landscape. All stages of the procedure may be implemented using currently available GIS,

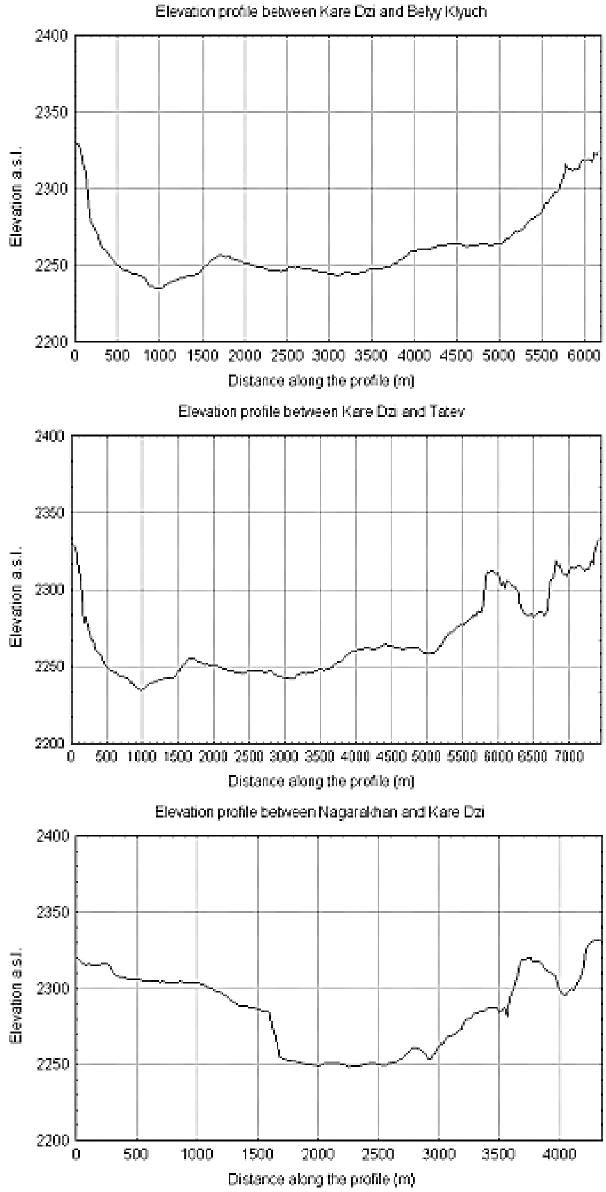

Figure 4. Elevation profile drawn between *Kare dzi* and other 4th group sites

requiring only that a suitable DEM be available, together with the sites locations.

The calculation result may be positive or negative, conventionally coded as a 1 for a visible cell or a 0 for a not visible one. When performed for the entire data set, the result is a binary image where areas of the landscape with a direct line of sight from the source cell are coded as a 1 and those with no

line of sight with 0 (Wheatley, 1995).
This analysis has been applied only to the site of *Kare dzi*, being identified as peculiar reference watchtower. The viewpoint has been set up as the viewer was standing at 1.60 m above ground, and maximum sight distance of 10 km was selected; the result is shown in figure 5 where the area visible from *Kare dzi* is displayed as black.

4. CONCLUSIONS

Starting from DEMs created by interpolating isolines digitized from topographic maps and by processing through interferometric techniques a couple of ERS-SAR scenes, the Lake Sevan landscape has been investigated with respect to the task of the location on the territory of settlements dating back to the Iron Age. Different analysis procedures, such as elevation profile trace, viewshed calculation, and 3D draping have been applied to the study area. Particularly interesting have been the results of the assessment of the spatial relationships among the sites of a peculiar group (the 4th of the Sanamyan classification), performed by taking into account also the geomorphic scenario, which may enlighten specific location choice.

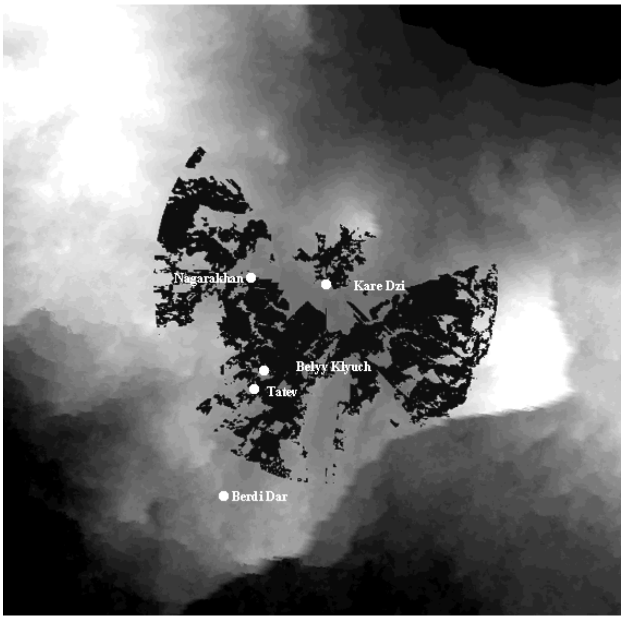

Figure 5. Viewshed area (shown as black) as seen from *Kare Dzi* with respect to *Nagharaka*, *Belyy Klyuch* and *Tatev*.

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