COBISS: 1.01

GLACIAL DESTRUCTION OF CAVE SYSTEMS IN HIGH MOUNTAINS, WITH A SPECIAL REFERENCE TO THE ALADAGLAR MASSIF, CENTRAL TAURUS, TURKEY

LEDENIŠKO UNIČENJE VISOKOGORSKIH JAMSKIH SISTEMOV: PRIMER MASIVA ALADAGLAR, CENTRALNI TAURUS, TURČIJA

Aleksander KLIMCHOUK[1], Serdar BAYARI[2], Lütfi NAZIK[3] & Koray TÖRK[3]

Abstract UDC 551.331:551.44(560)

Aleksander Klimchouk, Serdar Bayari, Lütfi Nazik & Koray Törk: Glacial destruction of cave systems in high mountains, with a special reference to the Aladaglar massif, Central Taurus, Turkey

Erasure of karst features and dissection of karst are among the main destructive effects of glacial action upon karst (Ford, 1983). They lead to destruction of functional relationship between the relief and a karst system, and to glacial dissection of pre-glacial cave systems. Stripping of the epikarstic zone and upper parts of cave systems on sub-horizontal surfaces results in prevalence of *decapitated shafts* in high mountains affected by glaciations. Vertical dissection of a karst massif by glacial erosion creates cave openings in sub-vertical surfaces (cliffs), a well known feature. Observations of vertical shafts exposed by cliffs are less common. Such shafts, unwalled by surface geomorphic processes, are in a certain way an analogous to the “unroofed” caves, exposed by denudational lowering of sub-horizontal surfaces. The Aladaglar Massif (Central Taurus, Turkey) is an outstanding example of high mountain karst. The high-altitude part of the massif has been severely glaciated during Quaternary. Glacial erosion was the dominant factor in the overall surface morphology development, resulting in the formation of numerous glacial valleys, cirques, ridges and pyramidal (horn) peaks. The overall relief between the highest peaks and the lowest karst springs in Aladaglar is 3350 m. The local vertical magnitude of relief between bottoms of glacial valleys and surrounding ridges is up to 1700 m. Recent studies suggest that the most recent major glaciation occurred in the Aladaglar massif during the Holocene Cooling and terminated between 9,300 and 8,300 years BP. This paper describes *unwalled shafts* at sub-vertical surfaces, a feature which is common in Aladaglar but is not so common, or overlooked, in other high mountain areas. Exposure of such shafts is mainly due to intense gravitational processes induced by the combined effect of the removal of the ice support to cliffs and the glacial rebound.

Keywords: glaciations, karst, denuded caves, unwalled shafts, Aladaglar, Central Taurus, Turkey.

Izvleček UDK UDK 551.331:551.44(560)

Aleksander Klimchouk, Serdar Bayari, Lütfi Nazik & Koray Törk: Ledeniško uničenje visokogorskih jamskih sistemov: primer masiva Aladaglar, Centralni Taurus, Turčija

Erozija kraških površinskih oblik in zarezovanje v kras so najbolj uničujoče posledice ledeniškega delovanja na krasu (Ford, 1983). Rezultat je prekinjena funkcijska povezava med reljefom in kraškim sistemom ter razrez predglacialnih jamskih sistemov. Na površinah z majhnim naklonom, ledeniško delovanje prizadene predvsem epikras in vrhnje dele jamskih sistemov. Na takih površinah najdemo veliko brezen, ki jim je ledeniška erozija odstranila vrhnje dele (t.i. obglavljena brezna). Zaradi vertikalnega vrezovanja v kras, se v stenah masivov odpirajo jamski vhodi, redkeje pa naletimo na vzdolžno prerezana, izpostavljena brezna. Taka, »brezstenska« brezna, so na nek način analogija brezstropih jam, ki so nastale kot posledica denudacije sub-horizontalnih površin.

Masiv Aladaglar (Centralni Taurus, Turčija) je izreden primer visokogorskega krasa. Višji deli masiva to bili tekom kvartarja močno poledeneli, zato tam prevladuje tipična ledeniška morfologija v vseh pojavnih oblikah. Višinska razlika med najvišjimi vrhovi Aladaglarja in najnižjimi kraškimi izviri je 3350 metrov, lokalni vertikalni razpon med ledeniškimi dolinami in okoliškimi grebeni doseže 1700 m. Novejše raziskave kažejo, da je bila zadnja velika poledenitev v Aladaglarju med holocensko ohladitvijo, ki je trajala med 9300 do 8300 leti pred današnjostjo. V članku obravnavamo »brezstenska brezna«, ki so v stenah Aladaglarja pogosta. Takih brezen je v drugih visokogorskih masivih malo, ali pa so bila prezrta. Razkritje brezen je delo gravitacijskih procesov ob umiku ledenikov.

Ključne besede: poledenitev, kras, denudirane jame, brezstenska brezna, Aladaglar, Centralni Taurus, Turčija.

[1] Ukrainian Institute of Speleology and Karstology, Ministry of Education and Science, NASU, Ukraine; klim@speleogenesis.info

[2] Hydrogeological Engineering Section of Hacettepe University, Turkey; e-mail: serdar@geo.hacettepe.edu.tr

[3] General Directorate of Mineral Research and Exploration, Turkey

Received / Prejeto: 27.07.2006

INTRODUCTION

During the last decade considerable attention has been given by many researchers to so-called unroofed (denuded) caves. It was generally appreciated long ago that lowering of the karst surface due to ongoing denudation ultimately results in uncovering and destruction of caves. However, it was the work of Mihevc and his colleagues (Mihevc, 1996; Mihevc et.al., 1998) that drew specific attention to the topic. Subsequent publications by many scholars shed light on several aspects, to which the specific study of unroofed caves gave useful information. Unroofed caves were recognized as adistinctive sub-type of surface karst, a cave partially transformed by surface processes. More understanding arises about their roles in the formation of karst landscape and about the overall denudation progress in karst. Based on observations in tropical karst, Klimchouk (2005) revived the view that unroofing of caves can be a large-scale geomorphic process. The cosmogenic nuclide exposure dating (Gosse & Phillips, 2001) of rock surfaces exposed due to cave unroofing can give invaluable information on aging of unroofing events and relevant landforms – a sound possibility which is still to be tested and realized.

Most of studies of unroofed caves came from the areas of moderate to low relief karst topography, so that consequently they were focused on sub-horizontal passages that were unroofed by the sub-horizontal denudation surface. This is reflected by the very term "unroofed caves", which implies opening of sub-horizontal cave elements that had a roof. Works that investigate this topic in high mountain environment, are rare (see Mais, 1999 for an examples from Alps). In high mountains there is considerable vertical relief, which introduces more complexity into the conceptual representation and genetic consideration of the phenomena: as a consequence the term "unroofing" seems to be insufficient to describe various relations of caves with the surface.

Our recent karst and cave studies in the Aladaglar Massif, Central Taurus, Turkey, yielded a variety of instructive observations on different types of caves exposed to the surface by various geomorphological processes. In particular, this study revealed extraordinary examples of the exposure of vertical caves (shafts) by sub-vertical surfaces. In this article we present these observations, which inspired discussion of some general terminological and geomorphological aspects and gave insights to some problems of local geomorphological evolution.

GENERAL REMARKS ON TERMINOLOGY

The initial term "roofless caves" has been gradually replaced by the more correct "unroofed caves". A general definition is that unroofed caves are old caves that have been exposed due to the lowering of karst relief. This tacitly implies a sub-horizontal orientation of the lowering surface, hence – sub-horizontal caves are the most readily available for observations when truncated (unroofed) by such surface. Interestingly enough, vertical shafts cut by lowering of the sub-horizontal denudation surface are not considered as something of special interest in the context of "unroofing" as they retain the capacity of entrances to the underground space. Shafts retain their status as underground forms, and they are not going to be erased geologically as fast as sub-horizontal caves do when unroofed. Apparently, the term "unroofed caves" does not apply to vertical shafts.

Four types of shafts can be distinguished according to the mode of their exposure to the sub-horizontal surface. ***Ponor shafts*** are those developed in a direct genetic (hydrologic) relationship with the surface and still retaining this relationship, such as shafts swallowing streams formed on adjacent non-karstic rocks or catchments where dispersed infiltration is prevented by patches of a low-permeability cover. ***Epikarst shafts*** are those developed at the bottom of the epikarstic zone as epikarst-draining paths, and opened to the surface due to its gradual lowering and collapse (Klimchouk, 2004). ***Collapse shafts*** are those formed by collapsing of large underground rooms. ***Decapitated shafts*** are those exposed due to erasure of the upper part of a massif by some high energy agency, commonly by glacial stripping. The latter category is pertinent to the subject of this article.

In the high mountain karst steep to vertical surfaces such as cirque headwalls are common. They can be hundreds of meters in height, and sometimes more than 1500 m. Interception of sub-horizontal passages by sub-vertical surfaces creates open cave entrances, a common phenomenon. This article focuses on vertical shafts opened by such sub-vertical surfaces, a less known phenomenon. Their nature within the topography can differ because they can be created by fluvial incision or glacial erosion and/or gravity (rock detachment, fall and slide).

In general terms we are considering the intersection of 3D daylight surfaces with 3D systems of underground caves. The daylight surface is polygenetic, and its intersection with a polygenetic 3D cave system will be guided by a number of geomorphic agents, as well as by the topology of both systems. The Table 1 clarifies the terminology for intersection features based on simple geometric considerations.

Tab. 1: *Features resulting from intersection of the daylight surface and a 3D cave system*

Components of a 3D cave system	**Geomorphic agencies dominating in creation of differently oriented surfaces that open caves in high mountains**	
	Sub-vertical faces	**Sub-horizontal surfaces**
	fluvial incision, glacial erosion, gravitational destruction (rock detachment and slide)	denudation due to dissolution, weathering mass wasting and areal erosion, glacial erosion by icecaps and at the bottoms of glaciers
Sub-horizontal cave elements (passages)	cave openings (entrances)	unroofed caves
Sub-vertical cave elements (shafts)	unwalled shafts	shaft openings (entrances)

Inclined cave components and inclined surfaces can produce a variety of features at their intersection. However, they can be assigned to one of the basic categories distinguished in the table and do not need specific terms. Cave and shaft openings (entrances) do not imply destruction of respective underground forms themselves. Unroofed caves and unwalled shafts are the two major types of disintegrating cavities, which can be collectively referred to as *denuded (or exposed)* caves.

The term "cave ruins" is also used to describe various kinds and states of cave disintegration (Mais, 1999). It could be used to describe fields of closely spaced disintegrating underground forms, when individual unroofed passages are barely recognizable.

THE ALADAGLAR KARST

Aladaglar is an outstanding karst massif located in the Central Taurus Range in the Adana-Kayseri-Niğde provinces of Turkey. It is situated between the regional Ecemis Fault to the west and the deeply incised Zamanti River valley to the east (Figs 1 and 2). The southeastern part of Turkey is an active plate boundary where the Arabian and the Eurasian plates are colliding along the Bitlis-Zagros suture. This determined the intensity of neotectonic processes and uplift since Late Oligocene, with the highest rates occurring in the Plio-Pleistocene. The Aladaglar Massif is composed chiefly by Triassic, Jurassic and Cretaceous limestones and rises up to 3750 m in elevation. The overall relief between the highest peaks and the lowest karst springs is 3350 m. The altitudinal distribution of the principal components of the surface geomorphology and the major known cave system is illustrated in Fig. 3.

The Zamanti River valley provides the general base level of erosion, towards which the karstic underground drainage is directed. The overall morphology is well illustrated by digital elevation models produced from the "Aladaglar Karst" GIS database developed during this study (Fig. 2). Morphologically, the northern (Black Aladag), central and southern (White Aladag) sectors can be distinguished, with the local relief increasing from north to south.

The high-altitude parts of the Aladaglar massif have been severely glaciated during Quaternary. Aladaglar belongs to the Pyrennean type of glacial landscape, i.e. glaciers there were confined to high areas but not occupied lower valleys where the outputs of a karst system occurred (Ford & Williams, 1989). Glacial erosion was the dominant factor in the overall surface morphology development, resulting in the formation of numerous glacial trough valleys, cirques, arêtes (narrow jagged ridges) and horn (or pyramidal) peaks. Our recent studies suggested that the magnitude and extension of Quaternary glaciations in Aladaglar was greater than previously thought (Bayari et. al, 2003; Zreda *et al.*, 2005). Although the glacial landforms indicate there have been numerous episodes of glacial advance and retreat, evidences of the older glaciations are largely erased by the effects of the last, remarkably extensive, glaciation. Cosmogenic ^{36}Cl dating of morainic boulders in the Hacer Valley suggests that it terminated between 9,300 and 8,300 years BP there.

Glacial geomorphic processes acting on the karstified limestone substratum gave rise to the distinct pecu-

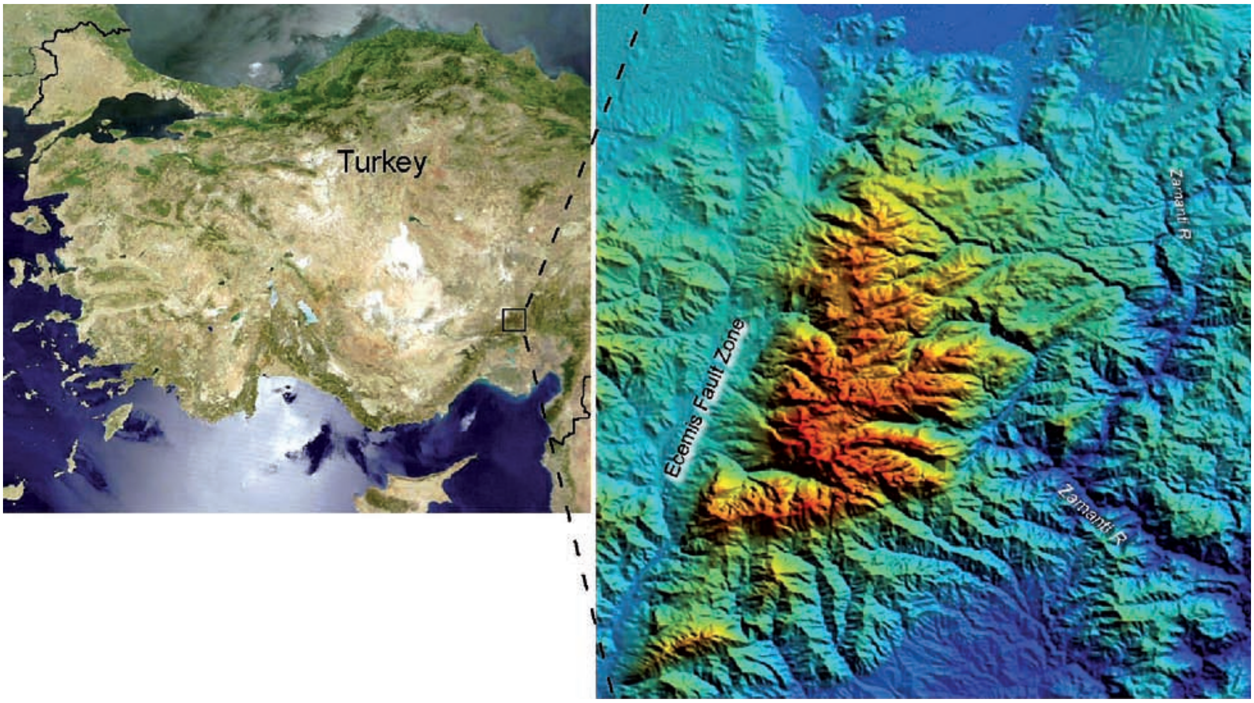


Fig. 1: Location of the Aladaglar massif (left) and its overview digital elevation model.

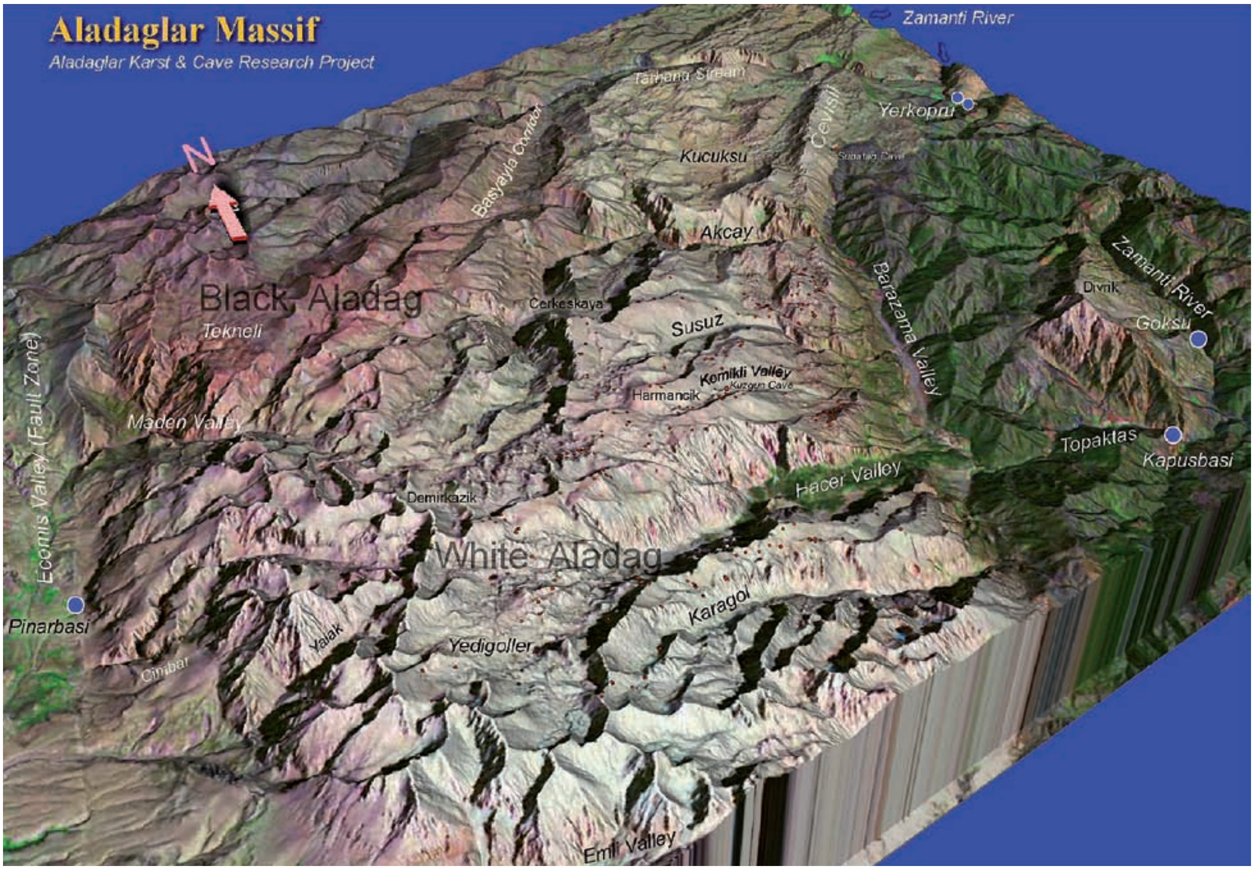
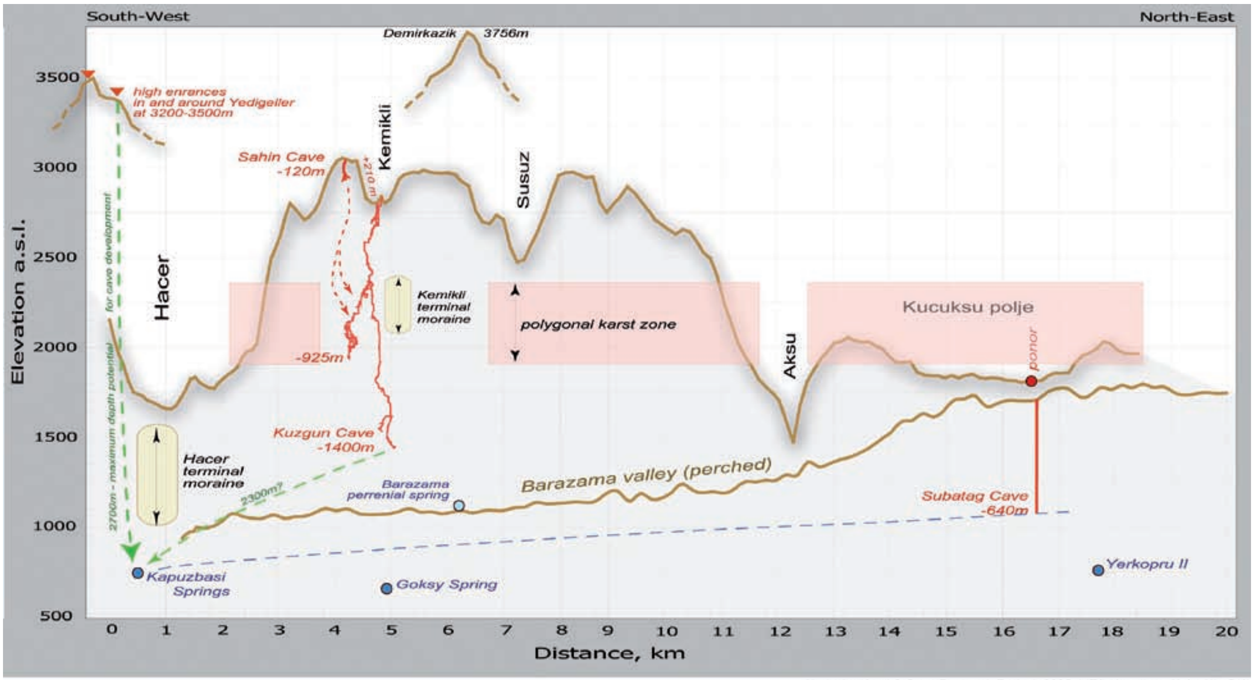


Fig. 2: Physiography of the Aladaglar Massif. The DEM is based on the 1:25,000 topographic map, overlain by a Landsat satellite image and data layers from the GIS "Aladaglar Karst and Caves". Distribution of explored caves is shown by small red dots and major springs are indicated by blue dots.



Aladaglar Karst & Cave Research Project, 2005: MTA-Hacettepe Univ.-Ukr.S.A.

Fig. 3: Altitudinal distribution of principal denudation and erosion levels, springs and caves in the Aladaglar Massif, Central Taurus, Turkey. A composite profile SW-NE, sub-parallel to the Barazama Valley.

liar features known as glaciokarstic morphology. However, in local areas of moderate relief (glacial source areas and valley bottoms) recent glacial scouring of prominent mesoforms on the one hand, and filling of negative mesoforms by weathering (frost shatter) debris on the other hand, makes appearance of karstified surfaces generally smoother that it can be typically seen in lower-altitude Alpine karst massifs (Fig. 4).

Glacial valleys created during the Quaternary glaciations were entrenched into an already intensely karstified massif. Smaller glacial valleys extend from source areas at 3100-3300 m down to altitudes of about 1900-2300 m, while some large valleys (such as Hacer) incised as low as 1100 m asl. The local altitudinal ranges between ridges and

Fig. 4: Characteristic high altitude glaciokarstic landscape in Aladaglar. Glacial scouring in the recent past has made appearance of karstified surfaces generally smoother than can be typically seen in lower-altitude Alpine karst massifs, where the last glaciation terminated earlier. A = Yedigoller Plateau, a paleo-source area for the Hacer valley glacier at the altitudes of 3100-3400 m; B = Harmancik Plateau, a paleo-source area for the Kemikli valley glacier at the altitudes of 3100-3200 m. Photos by E. Medvedeva (A) and A. Kopchinsky (B).

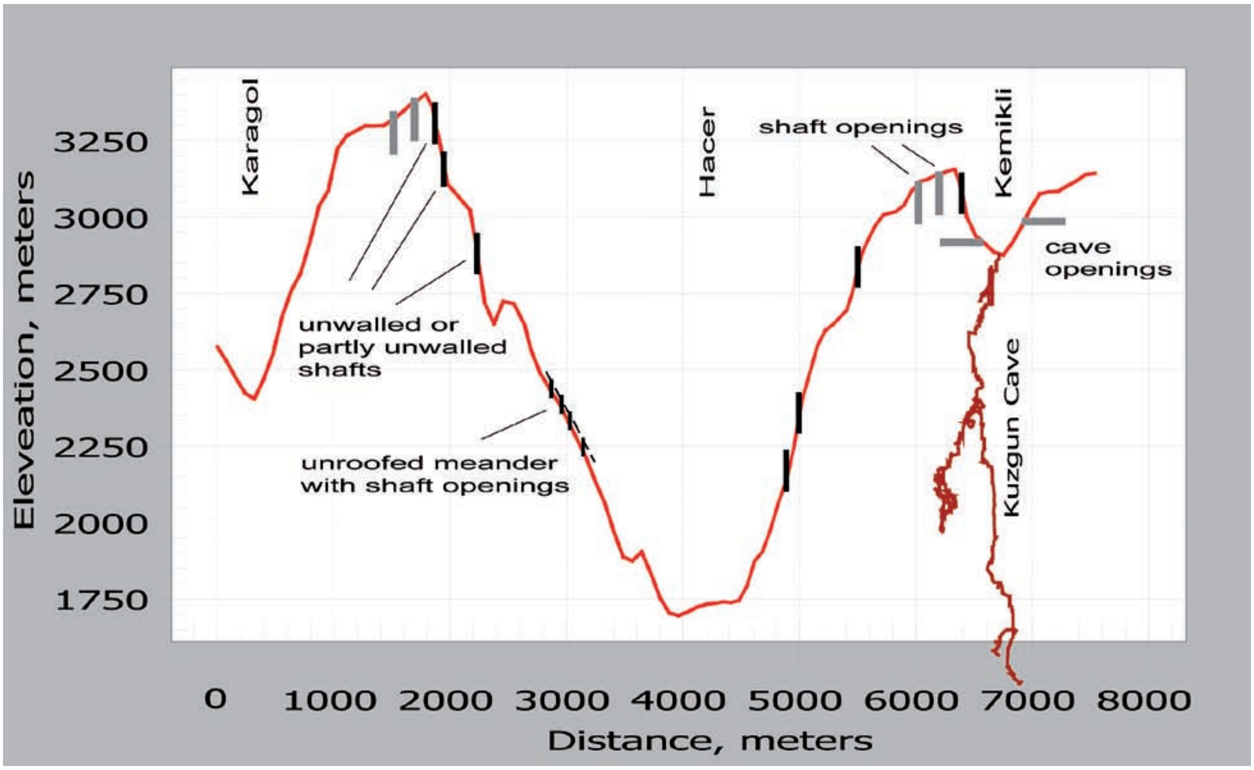


Fig. 5: Section across the Karagol, Hacer and Kemikli valleys, showing local elevation differences and the typical occurrence of caves and shafts intersected by variably oriented surfaces.

Fig. 6: Kemikli glacial valley. Note an unwalled shaft in the cliff on the left and a train of boulders on the scree apron and glacially stripped bedrock at the foot of the cliff. Photo by A.Klimchouk.

valley bottoms can be as great as 1700 m in large valleys, although in smaller valleys they are only of 200-700 m (Fig. 5 and 6). The steep valleys, with their many subvertical faces, are subject to intense gravitational processes.

The freshly glaciated rocky surfaces have many different orientations and thus expose numerous pre-glacial cavities (in the sense that they are older than at least the last major glaciation), creating all types of intersections outlined in Table 1: shaft openings and unroofed caves on sub-horizontal surfaces and cave openings and unwalled shafts on sub-vertical surfaces.

DECAPITATED SHAFTS

During 2001-2004 over 150 caves were explored in the Aladaglar Massif. They were mainly vertical, with an aggregate total depth of 6640 m. Of them 32 caves are deeper than 50 m, and 12 caves are in excess of 100 m. Fifty-seven caves are located above 3000m, the highest explored example being at 3410 m.

The great majority of shafts explored in the high karst zone are decapitated shafts that had been exposed due to erasure of the upper part of the massif by glacial stripping. Erasure of karst features by mechanical abrasion of bedrock at the base of ice is a known effect of glaciations on karst (Ford, 1983). Abundant evidence in Aladaglar suggests that this effect can be greater than was previously thought. Our observations suggest that the bedrock thicknesses up to several tens of meters, including the entire epikarstic zone and large dolines, can be stripped away by the glacier action.

Shafts entrances in valley bottoms and other low areas are blocked and obscured by debris, the result both of plugging by debris during glaciations and intense post-glacial physical weathering. Most shaft entrances that remain open are found at the crests of ridges or topographic eminences within valleys, such as roche moutonnées, – those places which were sites of intense glacial scour but have limited or no contemporary catchments to supply frost debris (Fig. 6). The smoothed tops of some ridges at altitudes of 3100-3300 m, along with the presence of polished surfaces and decapitated shafts, suggest that an icecap of some considerable thickness may have covered these ridges during the recent glaciation.

When decapitating shaft openings, glacial erosion stripped the upper portion of the rock together with the epikarstic zone and some upper sections of pre-glacial cave systems. Discovery of a decapitated shaft entrance on the surface and likenhood of finding an explorable cave beneath it depend on which particular component of a cave system was intersected and how the opening is situated in the relief (Fig. 7). If a large internal pit of

Fig. 7: Shafts decapitated by glacial erosion. Left panel – Aladaglar, right panel – Crowsnest Pass, Rocky Mountains, Canada. Photos by A. Klimchouk.

substantial diameter got exposed, it had little chance of remaining unplugged by frost shatter debris from weathering in the shaft mouth catchment. Hence, most shafts of this type are simple single pits blocked at the bottom. Some large shafts located in the tops of ridges are blocked with ice, which contains numerous bands of frost debris within it (e.g. there is about 100m in the Ice Cave). Complex and deep caves are commonly those which got exposed by stripping at the level of a narrow meander passage that continues to a next vertical pit.

UNWALLED SHAFTS

In the steep to vertical slopes of the Aladaglar glacial valleys, many unwalled or partially unwalled shafts are clearly displayed. We illustrate this with examples from the particularly deep Hacer glacial valley (Figs 8 and 9) and an example from the smaller and shallower Kemikli valley (Fig. 10).

Fig. 8: Exposed caves in the southern side (northern face) of the Hacer glacial valley. The vertical extent of the cliffs in the photographs is approx. 1000 m. Numbers indicate samples of: 1 = unwalled shafts, 2 = partly unwalled shafts, 3 = unroofed meanders with shaft openings. Many similar features, recognisable on photos, are not indicated in order to avoid clutter.

Fig. 8 shows the southern side of the central sector of the Hacer valley, where it has the maximum cross-sectional vertical extent of about 1700 m. Individual unwalled shafts more than 100 m in the vertical extent can be seen. Some shafts are partly unwalled, while others are open only at the upper or lower ends within inclined and hanging faces. On inclined faces some unroofed meandering passages, interspersed with shafts, can be traced for hundreds of meters.

Fig. 9 shows the cliff face in the upper Hacer valley, where there is a cave that is almost parallel to the external face. The wall that separates the shaft from the cliff is only a few to 20 m thick. It is apparent that this cave will become unwalled in the near geological future.

Fig. 10 shows an unwalled shaft in the southern cliff of the Kemikli valley. Two other shafts, partly unwalled in the upper parts, are seen in the right background. The presence of a pile of boulders beneath this cluster of unwalled shafts (some of them with fragments of shaft solution morphology) indicates that the unwalling occurred as a rockfall, and that this event post-dated the last glaciation. See also Fig. 6, where a fall of boulder-sized blocks is well seen on the left, scattered on the scree apron at the foot of the cliff and on the glacially scoured rock surface below it. If the shaft unwalling had occurred before or during the last glaciation, boulders would have been be removed by the glacier.

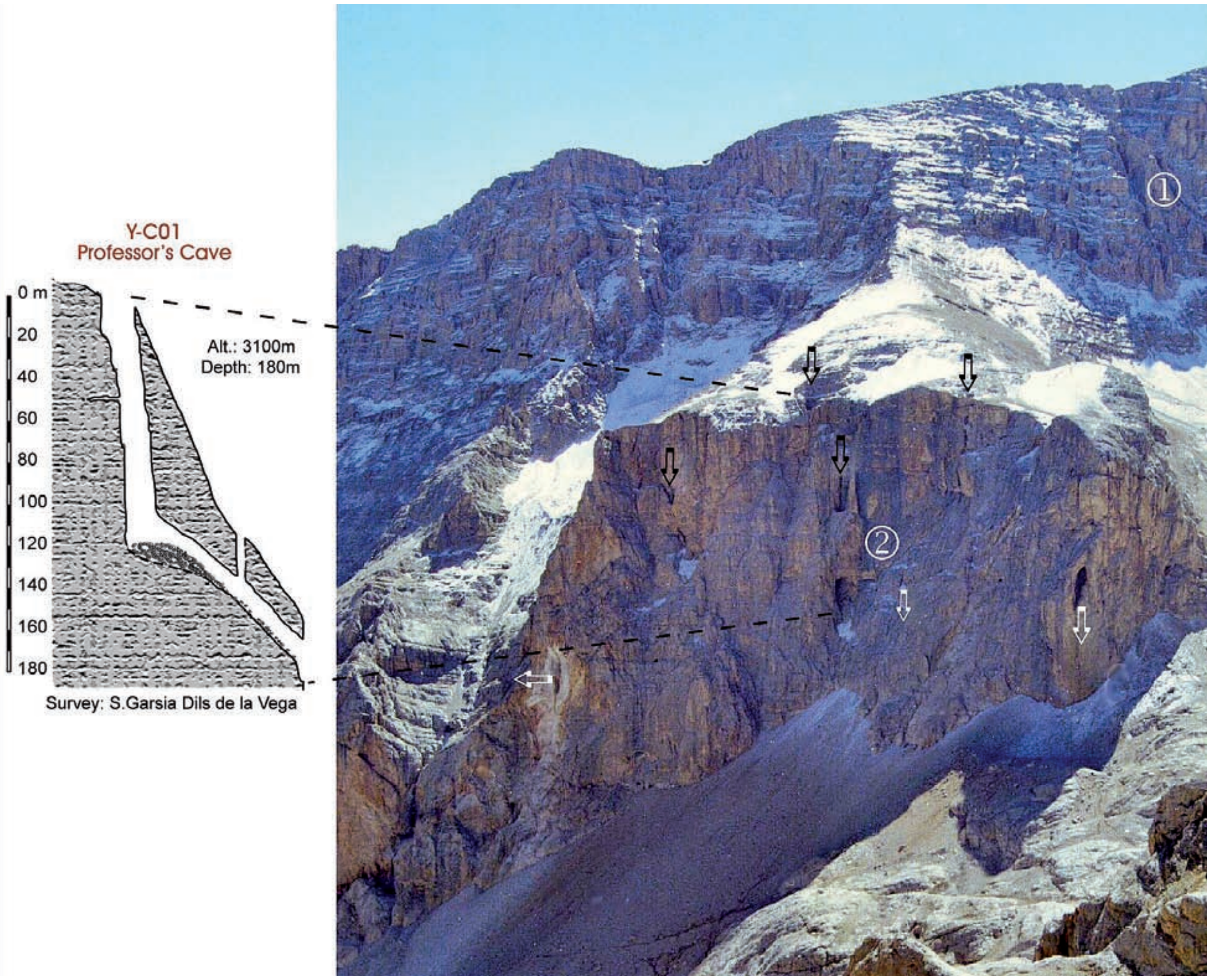


Fig. 9: Right: Exposed caves in the rock cliff in the upper part of Hacer glacial valley (northern facing). Numbers indicate: 1 = unwalled shafts, 2 = partly unwalled shafts. Black vertical arrows point to shaft openings, white vertical arrows indicate lower (downward-open) shaft outlets, a horizontal arrow indicates a cave opening. Left: The profile of the Professor's Cave, with the shaft entrance located some 10 m far from the drop and the lower outlet opened to the cliff. The wall between the shaft and the vertical rock face is 3-20 m wide.

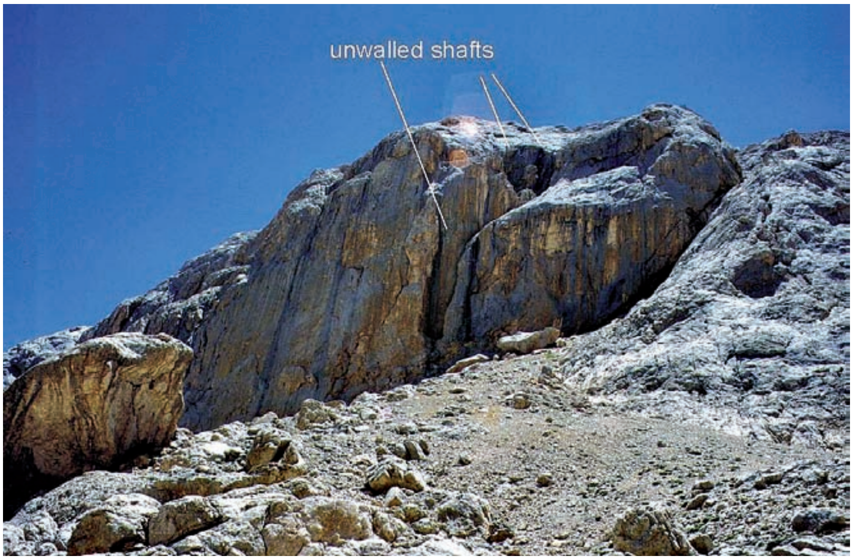


Fig. 10: Unwalled shafts in the Kemikli valley. Photo by A. Klimchouk.

DISCUSSION AND CONCLUSION

The creation of a considerable vertical component during the development of relief in highly energetic Mountain settings leads to the vertical dissection of previously formed cave systems. It is an important part of the cave disintegration process. Cave (passage) openings in sub-vertical surfaces (the holes-in-the-wall) are common and well-known features. Shafts unwalled in sub-vertical surfaces are the less acknowledged phenomena, but they are common and easily recognisable in the Aladaglar massif.

Although fluvial entrenchment can create very steep surfaces on valley sides, it usually cannot directly erode away any intercepted shafts to make them unwalled. Unless the stream is very large, it will be captured and channeled down the shaft, rather than dissecting it. Instead, by creating a steep relief, fluvial erosion may induce gravitational rock falls and slides, which then can expose the shafts, unwalling them on sub-vertical surfaces. More commonly, however, fluvial downcutting exposes cave openings by intersecting passages that are sub-horizontal.

Direct glacial erosion, applied to those parts of valley slopes that were in contact with ice, can be the shaft-unwalling agency. However, in Aladaglar unwalled shafts are also found on the higher sections of slopes that apparently were not in a direct contact with valley glaciers that produce the most of the lateral erosion (i.e. they are above the glacial trimlines). Gravitational processes, chiefly rock falls and slides, thus are the dominant processes in shaft unwalling.

Glacial erosion results in destabilization of sub-vertical slopes due to both additional downcutting and lateral undercutting in valleys. Both the glacial erosion and the glacial load cause considerable rearrangement of the strain field. When the ice recedes its support of the cliff face is removed. Glacial rebound and stress release after the ice removal further contribute to the cliff destabilization. As a result, a cliff may experience one major topple, fall or slide as a consequence of a particular glaciation. Those shafts that turned to be near sub-vertical external faces, were readily unwalled soon after the last glaciation. Subsequently there may be further falls, etc. but they are usually much lesser in scale.

Although the mechanism of the shaft unwalling is quite obvious, it remains unclear why unwalled shafts are more abundant in Aladaglar, as compared to most of Alpine karst massifs and many other formerly glaciated mountain karsts. One of the reasons could be the difference in the rates of the surface processes in different climatic settings and at different altitudes (2800-3700 m in Aladaglar versus 1800-2700 m in most of the typical Apline karsts). Unwalled shafts are not long-living surface features. Most likely, their morphology gets reworked fast by denudation agencies, giving rise to various kinds of grooves and small gorges in steep to sub-vertical slopes. Therefore, the difference in the amount of time since the ice receded in various regions could be another reason. The relatively large number of unwalled shafts in Aladaglar can probably be explained by the combination of both these reasons: very recent end of the last glaciation (Early Holocene) and slower rates of remodelling of the face morphologies since that due to the high altitudes. Other massifs of the comparable height and climate conditions may simply have a lower degree of pre-glacial karstification. And, eventually, the differences in the uplift rates between regions may also play a role.

Abundance of decapitated and unwalled shafts in Aladaglar clearly suggests that extensive and deep cave systems were already well developed there before major glaciations commenced.

The most pronounced and immense effect of mountain glaciations on karst is the destruction of functional relationship between the relief and the karst system and glacial dissection of the karst system (Ford, 1983). This is affected through erasure of the epikarstic zone and upper parts of cave systems on sub-horizontal surfaces (decapitation of shafts) and vertical dissection of cave systems by overdeepened valleys (unwalling of shafts).

ACKNOWLEDGEMENTS

This study was supported by the General Directorate of Mineral Research and Exploration of Turkey (MTA) and the Ukrainian Speleological Association. The field seasons in 2004 and 2005 were supported by the expedition grants of the National Geographic Society. This paper has greatly benefited from comments and editing by Derek Ford. Our thanks are also due to cavers from the Ukr.S.A and Hacettepe University Speleological Club for their dedicated efforts on exploring and documenting the Aladaglar caves.

REFERENCES

Bayari, S, Zreda, M., Ciner, A., Nazik, L., Törk, K., Ozyurt, N., Klimchouk, A. & Sarikaya, A., 2003: The Extent of Pleistocene ice cap, glacial deposits and glaciokarst in the Aladaglar Massif: Central Taurids Range, Southern Turkey. XVI INQUA Congress, Paper #55360, XVI INQUA Congress, Reno Nevada USA, 23-30 July 2003, Abstracts, 144.

Gosse, J.C. & Fillips, F.M., 2001: Terrestrial in situ cosmogenic nuclides: theory and application.- Quaternary Science Reviews, 20, 1475-1560.

Ford, D., 1983: Effects of glaciations upon karst aquifers in Canada.- Journal of Hydrology, 61, 149-158.

Ford D.C. & Williams P.W., 1989: Karst Geomorphology and Hydrology. London: Unwin Hyman, 600 pp.

Mais, K., 1999: Roofless Caves, a polygenetic status of cave development with special references to cave regions in the Eastern Calcareous Alps in Salzburg and Central Alps, Austria.- Acta Carsologica, 28, 2, 145-158, Ljubljana.

Klimchouk, A.B., 2004: Towards defining, delimiting and classifying epikarst: Its origin, processes and variants of geomorphic evolution. In: Jones, W.K., Culver, D.C. and Herman, J. (Eds.). Epikarst. Proc. of the symposium held October 1 through 4, 2003 Sheperdstown, West Virginia, USA. Karst Water Institute special publication 9, 23-35. (republished in: Speleogenesis and Evolution of Karst Aquifers (www.speleogenesis.info), 2004, 2, 1.

Klimchouk, A.B., 2005: Cave unroofing as a large-scale geomorphic process. Cave & Karst Science 32, 2-3, 93-98.

Mihevc, A., 1996: The cave Brezstropa jama near Povir (in Slovene, English abstract).- Nase jame, 38, 65 – 75, Ljubljana.

Mihevc, A., Slabe, T. & Šebela, S., 1998: Denuded caves – an inherited element in the karst morphology: the case from Kras.- Acta Carsologica, 27, 1, 165-174, Ljubljana.

Zreda, M., Ciner, A., Bayari, S. & Sarikaya, A., 2005: Remarkably extensive early Holocene glaciation in Turkey. EGU 2005, 24-29 April 2005 Vienna, Geophysical Research Abstracts, v. 7 (06068).