Kuzgun Cave and its Context: the first super-deep cave in the Aladaglar Massif, Turkey

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Introduction

Aladaglar is an outstanding limestone massif located in the Eastern Taurids Range within Adana-Kayseri-Niğde provinces of Turkey. The massif covers an area of 800 km^2 and the local relief extends between 400m and 3750m elevations. The physiography of the area is characterized by Fig.1.

In 2001-2004 extensive field investigations of karst and caves have been carried out in Aladaglar under the joint Turkish-Ukrainian "Aladaglar Karst and Cave Research Project", a part of the "Call of the Abyss Project". These studies resulted in the discovery and exploration of about 150 caves, including the remarkable 1400m-deep Kuzgun Cave, and provided new data and insight into regional karst evolution, hydrogeology and geomorphology. This paper briefly overviews the project background, its preliminary results, and gives a brief introduction to Kuzgun Cave.

Aladaglar Massif

Geology

The southerneast part of Turkey is an active plate boundary where the Arabian and the Eurasian plates are colliding along the Bitlis-Zagros suture. The tectonics of the Aladaglar area is dominated by the nappes structure. During Late Cretaceous pervasive SE- to SSE-vergent folding and thrust faulting occurred within Mesozoic carbonate platform units, associated with southward emplacement of a regionally extensive ophiolite. Autochtonous carbonate formations of Jurassic to Cretaceous age crop out in the eastern part of the area. The main part of the Aladaglar Massif is allochtonous, composed by Triassic limestones, the largest carbonate nappe units (Siyah Aladag, Beyaz Aladag and intermediate nappes). A nappe consisting of ophiolite mélange conceals the boundary between the allochtonous and autochtonous units along the eastern side (Plate 1).

The marine sedimentation ended in the Central Taurus in Late Eocene, and was followed by folding, thrusting and regional emergence above eustatic sealevel (Jaffey and Robertson, 2005). Considerable topography, including the proto-Taurus Mountains, had been established since Oligocene, promoting progressive erosion of the widespread ophiolitic rocks. By Late

Miocene the ophiolitic cover had been removed over considerable areas, revealing Mesozoic carbonate rocks of Aladaglar. The regional evolution is believed to be closely guided by the Ecemis Fault Zone that borders Aladaglar on the west, the site of 60 km of lateral strike-slip movement. The present-day gross morphology of the Aladaglar massif and surrounding basins established during Pliocene. The subsequent geomorphological development in Plio-Quaternary time, as well as the development of karst systems, was strongly affected by the intense uplift of the massif, down-cutting of rivers and by the fluctuations of glaciers in the Aladaglar Massif.

Further details of local geology and hydrogeology can be found in Bayari and Gurer (1993a,b), Tekeli, Aksay, Urgun and Isik (1983) and Jaffey and Robertson (2005).

Geomorphology

The Aladaglar massif is elongated from north to south, being limited on the west by the regional Ecemis sinistral Fault and on the east by Zamanti River (Fig.1). The overall morphology is well illustrated by the digital elevation models produced from the GIS "Aladaglar Karst", developed during this study. 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 part of the Aladaglar massif has been severely glaciated during Pleistocene. Glacial erosion was the dominating factor in the overall surface morphology development, resulting in the formation of numerous glacial valleys, circuses, narrow jugged ridges and pyramidal peaks. Our recent studies suggested that the magnitude and extension of Pleistocene glaciations in Aladaglar was greater than previously thought (Bayari et. al, 2003; Zreda et al., 2005). Although glacial landforms indicate the existence of numerous episodes of glacial advances and retreats, evidences for 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 occurred between 9,500 and 7,500 years BP that corresponds to the so-called Holocene Cooling.

Common glacial valleys extend from source areas at 3100-3300m to altitudes of about 1900-2300m, although some large valleys (such as Hacer, Plate 2) cut as deep as up to 1100m elevation. Glacial geomorphic processes on the karstified limestone substratum gave rise to distinct peculiar features known as glaciokarstic morphology. In the valley bottoms, large and deep (up to 100m) closed glaciokarstic depressions are common, which drained sub-glacial flow into the karst system. They are separated by prominent glacially eroded rock hills (roches moutonneés; Plates 3 and 4) and bars. Ridges and tops that separate major glacial valleys rise up to 3400-3750m.

Glacial valleys morphed during the recent glaciation had entrenched into the already intensely karstified massif. Fresh rocky surfaces of glacial scouring cut and expose numerous well-formed shafts and caves of pre-glacial generations. However, while in vertical rock faces "unwalled" shafts and passage entrances are well preserved (Plates 5 and 6), on subhorizontal surfaces large amount of rock shatter, intensely generated by strong contemporary physical weathering, plugs and conceals most of caves. In the high altitude valleys and plateau of glacial source areas, recent glacial scouring of prominent mesoforms on the one hand, and filling of negative mesoforms by weathering shatter on the other hand, makes appearance of karstified surfaces generally smoother that it can be typically seen in lower-altitude Alpine karst massifs (Plate 7). Hence, karstic morphology in Aladaglar is somewhat obscured as compared to typical Alpine karsts.

The area of the remarkable karst landscape, resembling polygonal karst, with numerous steep-walled depressions, pits and deep karrens, lies along the eastern flanks of the massif, making a ledge at elevations of 1700-2300m (Plate 8). The area of polygonal karst morphology coincides with the belt of Cretaceous limestones stretching along the Aladaglar's eastern flank. In the north-east of Aladaglar and in its southern flank, this type of karst is immediately adjacent to the retreating cover of ophiolitic mélange (Plate 8, C) and Miocene conglomerates.

Hydrology

The aquifer associated with Aladaglar covers about 1900 km^2. The high-altitude part of Aladaglar is assumed to be the main recharge areas of karst hydrologic systems that discharge as large springs at the foot of the massif (Plate 9). Mature karst springs (Yerköprü 3, Yerköprü 1 and 2, Göksu and Kapuzbasi) are grouped in four main localities on the eastern flank of the massif, at elevations ranging between 400 and 750m (Fig. 1). The combined average discharge from the massif to the eastern flank totals about 32 m^3/s, while the individual springs (groups) average discharges vary from 2,6 to 14,2 m^3/s. Hydrochemical and isotopic studies suggest that hydrogeologic connection exists between the high-altitude recharge areas on the allochtonous carbonates and large springs outflowing from the autochtonous formation at the main erosion base level of Zamanti River and its tributaries. The only substancial spring on the western flank of Aladaglar is Pinarbasi, which discharges about 1,5 m^3/s. High degree of flow concentration, together with some peculiarities of groundwater regime and hydrogeochemistry, suggest presence of well-developed conduit systems in the depths of the massif. Structural and hydrogeochemical considerations indicate that the groundwater flow recharged from the high-altitude karst surfaces drains mainly to the eastern flank springs (Bayari and Gurer, 1993). Recent hydrogeochemical studies during this project gave further insight into the aquifer structure and behaviour (Ozyurt, 2005).

The overall depth potential for a karst groundwater circulation system, the important characteristic for evaluation of the potential for a direct cave exploration, is thus well above 2000 meters, being up to 2500-2900m in the best cases. The latter figures suggest that Aladaglar may contain the deepest karst hydrologic system in the world that would supersede the currently deepest proven system Cheve in Mexico with its depth of about 2500m.

Karst study and cave exploration challenges in the Aladaglar high mountains

Preliminary studies and reconnaissance observations in the Aladaglar massif, made before 2000, suggested that karst systems here had the complex multiphase evolution guided by neotectonic processes, paleo-hydrothermal activity, erosional network development and glacial fluctuations. Further inferences on the karst evolution and karst hydrology of the massif required a speleological outlook, but cave data on Aladaglar had been scarce.

In 1992-1993 the speleological club MAD (Magara Arastirma Dernegi) from Ankara explored several caves in the low-altitude (below 2000m) north-east outskirts of the massif, including Subatagi Cave (1700m a.s.l., depth 640m), the deepest cave in the area until recently. In 1992 French expedition (CRS Rhone-Alpes) made a reconnaissance trip across the high central part of the Aladaglar massif but it did not receive any continuation. The French cavers also explored Goksu cave resurgence located along Zamanti River at 650 m elevation (about 100m long upstream exploration of a high-flow passage to a siphon) and several caves at altitudes of about 1600m in the autochtonous limestones of the Divrik Mountain. There were some reconnaissance trips of Italian cavers to the area, but they also were not continued.

Cave explorations at the altitudes above the "deep caves and Alpine Karst optimum" range (approximately 1600-2600m), pose the known problems. These problems are chiefly related to the glacial scouring of karst surfaces during Pleistocene glaciations, resulting in destruction of functional relationships between a karst landscape and cave systems, and in plugging cave entrances by clastic materials. On the conventional Alpine karst altitudes, the modern (post-glacial) dissolution is intense enough to restore some of the landscape/caves relationships during the post-glacial time, and to partially clean out debris filling in the near-surface zone. At the altitudes above 2800m, contemporary periglacial conditions do not favour intense dissolution but do favour strong physical weathering and massive shatter production, which further contributes to the blockage of cave entrances. Open-mouthed shafts and pits, so numerous on conventional Alpine karst massifs, are rare in Aladaglar. But even if found, they are commonly blocked by massive snow-and-ice accumulations.

So, it was obvious that realization of the enormous general potential of the Aladaglar massif for deep caves is a very challenging task that would require development and implementation of special search and exploration strategy and methods, as well as of specific cooperation formats.

Aladaglar Karst and Cave Research Project

The Aladaglar Karst and Cave Research Project has been initiated in 2000 by Dr. Serdar Bayari, Dr. Lutfi Nazik, Koray Tork and Dr. Alexander Klimchouk with the twofold aim: 1) to advance knowledge of evolution and hydrogeology of the Aladaglar karst through a combination of speleological explorations and special geomorphological and hydrogeochemical studies and, 2) to challenge a task to discover and explore super-deep caves in this high-altitude karst. The idea was to combine the special expertise, cave exploration experience and resources of the involved scholars and institutions – General Directorate of Mineral Research and Exploration (MTA), Department of Geological Engineering of the Hacettepe University, Institute of Geological Sciences of the Ukrainian Academy of Sciences and the Ukrainian Speleological Association. The challenge to discover and explore super-deep caves in this particularly difficult environment of the high mountain karst could be met only through systematic speleological investigations in the area. Large and deep caves, if discovered, together with a wealth of regional speleological data, would give indispensable information to advancing key scientific issues of the Aladaglar karst, - its evolution and hydrogeology. In turn, special geomorphological and hydrogeochemical studies would help to develop more efficient strategy and methods for search and exploration of caves. The cave explorations under the Aladaglar project were integrated into the "Call of the Abyss" project searching to overpass the 2000m depth mark in caves.

The field activities under the Aladaglar Karst and Cave Research Project included a reconnaissance trip in October 2000 (10 days, 6 members) and a series of large month-long expeditions in August 2001 (26 members), August 2002 (28 members), July 2003 (26 members) and July 2004 (30 members). The expeditions were composed of cavers from the Ukrainian Speleological Association, MAD and HUMAK speleological clubs of Ankara and karst specialists of MTA and Hacettepe University.

Cave search and exploration in Aladaglar: approach, methods and progress in 2001-2004

Search for caves

The core part and the first stage of speleological investigations under the project was a search for caves, and their standard documentation. A search strategy was developed to account for the above-mentioned specific characteristics of the Aladaglar high mountain karst. It included the following basic principles:

1. Thorough and systematic ‘total’ search on an area-by-area basis, with special attention to small openings and cracks that have more chances to remain unplugged than large eye-catching entrances (Plate 10).
2. The search should be focused on specific geomorphological situations favouring to preserve caves unplugged and hence accessible, e.g. on tops of ridges and at their edges, internal prominent rock hills within glacial trough valleys (roches moutonneés), in the vertical rock faces and other places aloof from debris flows (Plate 11). The focus of search on "hydrologically functionless" areas confronts the conventional caver's wisdom but it accounts for the specific effects of glacial scouring and subsequent periglacial conditions.
3. All openings, including sinkholes and blocked pits, should be checked for air draft. Strong and cold draft, even if it blows from a seemingly impassable boulder choke or a squeeze, is a good indication of the connection to a large system and signifies that the obstacles should be further negotiated using special efforts and methods.
4. Search for caves should be accompanied by a complete documentation of inspected objects and their registration to a large-scale map.
5. Special geomorphological and structural investigations and mapping, aimed to reveal factors that favour cave location and accessibility, should accompany search efforts to give directions to areas of closest attention.

Cave inventory

This strategy has proven its efficiency. The expeditions in 2001, 2002 and 2003 resulted in exploration of almost 150 caves with the total depth of 5240m, not counting the deepest Kuzgun Cave. Of them 32 caves are deeper than 50m and 12 caves are deeper than 100m. Fifty-seven explored caves are located above 3000m altitude, the highest entrance being located at 3410m. The cave inventory is managed using the SpeleoBase program and the cave data are registered and integrated into GIS "Aladaglar Karst". Fig.1 shows a view to the 3D model of Aladaglar, one of the outputs of this GIS, which proven to be very useful for for managing cave search and inventory, as well as for geomorphological and tectonic analysis. Cave locations on the models are shown by small red dots.

A thorough and systematic search, exploration and documentation of caves laid a basis for the Aladaglar cave inventory, which serves to various scientific needs as well as to the task of revealing of deep cave systems.

Breaking to depth

Systematic exploration of caves in Aladaglar has revealed several problems, specific to a high altitude karst, in accessing deep systems. Some of them were foreseen while others were realized in the course of the work.

The first set of problems is attributive to pits and shafts opened to the surface. They are normally heavily blocked by debris plugs formed due to the high intensity of contemporary physical weathering, or by snow-ice accumulations (Fig. 2, A-C). Another type of blockage is plugging of pits by a kind of cemented diamicts deposited from melting at the base of accumulated ice columns that contained weathering clasts (Fig. 2, D). Such meltout diamicts represent a type of cave deposits which has not been recognized previously, so it deserves a characterization in a separate paper. Because of various types of blockages, single pits of varying depths constitute a majority of documented caves. The above-mentioned focus in the search strategy on the specific geomorphic situations which favored to preserve caves unplugged, helped to find several caves among the many explored where it was possible to go farther than the first pit.

The second problem is that inclined passages ("meanders") between pits at depths up to approximately 200m in larger caves are commonly critically narrow and not penetrable. This is because flow concentration in such depth interval is not sufficient to develop wider meanders. In result of rapid uplift of the Aladaglar massif during Pleistocene-Holocene, cave streams downcut quickly forming high (few to 20-30m) but narrow (10-30cm) meanders (Fig.3). In this situation, breaking into a deep system is possible only through a hard work on enlarging a passable way through such narrow passages in most promising caves.

After two expeditions devoted to the systematic search (in 2001 and 2002), several caves have been selected as targets for special efforts during the expedition of 2003, to free up narrow meanders and break to depth. In the Kemikli trough valley such caves were 185m deep Gulcitay Cave with the entrance at the altitude 3050m (Plate 11, B), and 125m deep Kosmodrom Cave located at 3010m. Two weeks of hard digging efforts gave slow advance in both caves but in the middle of the expedition another large cave has been discovered and captured all attention.

The cave, named Kuzgun (=Crown's Cave in Turkish), had been found on a small ledge near the top of an elongated rock hill in the middle section of the Kemikli valley, at the altitude of 2840m (the location is shown on Fig.1, see Plate 2 and Plate 10, right photo). The cave was a complex structure consisting of several generations of cavities. It provided an easy access to depth of -180m where narrow meanders suspended the exploration. The remaining two weeks of the 2003 expedition had been spent to free up these meanders. The major breakthrough had been made two days before the end of the expedition. During the remaining very last day the cave was explored in a single trip to the depth of -400m. Greater dimensions of the deeper part of the cave, several effluences and tributaries left unexplored, strong air draft and the open continuation with a large pit ahead - all suggested that one of large cave systems of Aladaglar had been eventually opened. Further exploration of Kuzgun Cave had been left for the subsequent year.

Expedition of July 2004: Kuzgun Cave

Kuzgun Cave was a main target of the project expedition in July 2004. During 20 days of operations in the cave it has been pushed from -400m to -1400m, possibly the greatest depth advance ever made during a single expedition. The cave became the second deepest cave in Turkey and in Asia, after Evren Gunay Mehmed Ali Dudeni in the western part of Taurus, pushed in August 2004 by Turkish and Bulgarian cavers from –1377m –1429m.

The present Kuzgun Cave morphometry is as follows:

- Depth: 1400m (of them 1000m surveyed in the 2004 expedition)
- Length: 3187m (of them 2075m surveyed in the 2004 expedition)
- Total vertical length of the survey network: 2080m (of them 1350m surveyed in the 2004 expedition)

Kuzgun Cave has been explored and surveyed to the depth of 1400m in the main branch, and to the depth of –600m in the Veterok branch that deviates from the main one at –480m (Fig. 4). In both branches several open leads remained unexplored. The exploration in 2004 has been stopped due to the lack of time and equipment.

Kuzgun is a truly remarkable and important cave that integrates at least three generations of cavities:

1. Pre-glacial vadose invasion cave consisting of vertical pits and shafts (cascades of pitches) alternating with inclined meanders, - a typical alpine cave system. Pitch-ramp morphological assemblages, characteristic for many alpine caves in rapidly uplifting mountains, are clearly identifiable and common in the cave (Fig. 3, Plate 12). At the depths below 120-140m the pre-glacial shafts bear clear signs of active contemporary dissolution. The entrance is a vertical pit of this generation, decapitated by glacial scouring at the top of a rocky hill (Plate 2 and Plate 10, right photo). In the plan and profile this genera of cavities is shown by a yellow-pale (above –400m) and white (below –400m) backgrounds. The cave splits into several branches in the meandering interval of -480… -550m. The progression of the main branch is generally very steep, with several intervals of more gentle gradient at -

180, -480…-500…-550m, -670…-700m, -1060m and -1100…-1110m. The nature of these "tiers" is structural rather than evolutionary.

2) Ancient (Late Miocene?) cavities represented by large steeply inclined chambers with massive flowstone formations of various ages (Plates 13 and 14). A large series of cavities of this genus was intercepted by the vadose shaft system at depth of 130m. This series, called French Kiss (shown by a light-brown background on the cave plan and profile), has a vertical extend of 140m. It is likely that a chamber that lies between -300 and -330m, also belongs to this type.

3) Presumably hydrothermal cavities (shown by a pink background on the plan and profile) represented by a series of chambers of considerable sizes encountered by the invasion system at the depth interval of 150…170m, and by several seemingly isolated pockets of few decimetres to few meters in cross-section, truncated by the vadose shafts at various depth. A smooth ceiling morphology with domes and cupolas, dark red-brown thin (up to 0.5cm) ferriferous crust on dissolution surfaces and a characteristic crust of palisade-like calcite crystals, that almost completely lines such chambers and pockets, are indicative of cavities of this type. The crystal crust is 10-20cm thick and brown-reddish in colour. There are also boxwork-like formations in some places. Hydrothermal cavities are probably truncated by the vadose system in many places, in the upper parts of passages and shafts, as suggested by the presence of broken fragments of the crystal crust on the floor in many localities.

In the plan view (Fig. 5) the cave displays a complex structure up to depth of about 500m. Starting from -480m, the main branch stretches generally to east, along the glacial valley axis, zigzagging between NEE and SEE fragments. However, the Veterok branch displays a separate trend to south-east.

The upper part of the cave (above -400m) contains an enormous variety of secondary formations, such as various types of diversely coloured stalactites, stalagmites and flowstones of several generations, helictites and crystals (Plate 15). Among crystals, there are remarkable large frost-like assemblages of presumably aerosol origin (Plate 16). There are unusual formations still need to be classified (for instance, Plate 17). Ongoing special investigations of mineral formations and sediments of Kuzgun Cave will give much information about speleogenesis and evolution of karst in the region.

Preliminary conclusions

The Aladaglar Karst and Cave Research Project has proven to be very successful in terms of both cave exploration and studies of karst hydrogeology, geomorphology and evolution. A scientific approach to cave search and exploration, adjusted to specific features of glacial and post-glacial geomorphic processes in high mountains and combined with a well trained and organized caving force, has allowed discovering a deep cave system in the conditions previously regarded as unfavorable, if not hopeless, for finding deep caves. Together with regional cave inventory information, special studies in Kuzgun Cave will provide a clue to solving major problems of karst evolution in the Aladaglar Mountains.

Considering huge general potential for deep caves in Aladaglar, Kuzgun Cave has very good chances to become the second deepest cave in the world, if not the second cave on Earth deeper than 2000m.

Acknowledgements

We would like to acknowledge remarkable enthusiasm, dedication, persistence and faith to the success of many cavers involved into the recent cave explorations in Aladaglar: Fedotov Dmitry, Ghuravel Valentyn, Ilingin Evgeny, Ishchenko Feliks, Kadubenko Oleksandr, Karpechenko Oleksandr, Khapov Oleksandr, Kondrat'ev Al'bert, Koptchynsky Aleksey, Kovalyov Andriy, Lyakhovets Sergiy, Markovskoy Kyrylo, Medvedyeva Kateryna, Romanenko Andriy, Romanov Yevgen, Ryazanova Olga, Samokhin Gennadiy, Shevchenko Olena, Sokolchuk Ihor, Solovyov Mykolay, Sytsykhovskiy Dmytro, Tivilev Eugeny, Tsebenko Oleg, Tymoshevska Yuliya, Verchenko Andriy, and Yablokova Natalia (Ukraine); Baydar Tarik, Coskuner Turkay, Erdogan Alisar, Ozel Emrah, Ozel Emrullah, Ozyurt Nur, Pekkan Emrah, Altay Birhan and Sahin Cumhur (Turkey); Taylor Marcus and Wiseman Andrew (Britain). See Plates 18 and 19 – members of 2003 and 2004 expeditions).

The studies and explorations in Aladaglar were supported by the General Directory of Mineral Research and Exploration (MTA), Department of Geological Engineering of the Hacettepe University (Ankara) and Institute of Geological Sciences of the Ukrainian Academy of Sciences (Kiev). Mr. Emrullah Ozel and Dr. Nur Ozyurt provided invaluable contribution to both organization and field studies. Certain expeditions of the project in 2001-2004 had been partially sponsored by the Ukrferry Company (Odessa, Ukraine), Motor Sich (Zaporozhje, Ukraine), Onyx Company (Simferopol, Ukraine), Leica Geosystems (Switzerland), Kim Cunningham's Foundation (USA). The project expedition in 2004 had been partially sponsored by the National Geographic Society (USA).

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Figure and plate captions (in the order of their appearance in the article):

Fig. 1. Physiography of the Aladaglar Massif. The drawing is based on the digital elevation model and GIS "Aladaglar Karst and Caves". Distribution of explored caves is shown by small red dots, major springs are indicated by blue dots. Compiled by A.Klimchouk and S.Bayari.

Plate 1. View from Kuzgun Cave, Kemikli valley, eastward, to Divrik Mountain and Zamanti River. Photo by S.Ljakhovets.

Plate 2. Hacer glacial valley and its paleo-source area – Yedigoller plateau (bakground, right). Photo by A.Kopchinsky.

Plate 3. Kemikli glacial valley. The entrance to Kuzgun Cave is located at the top of a glacially eroded rock hill (roches moutonneés). Photo by A.Klumchouk.

Plate 4. A glaciokarstic depression (the camp place) and a glacially eroded rock hill (roches moutonneés) in the Kemikli glacial valley.

Plate 5. Unwalled shafts in the northern side of the Kemikli valley. An entirely unwalled shaft continued by a meander erased by the glacier. Traces of this meander are identified in the slope beneath. A boulder pile at the left, with some boulders bearing fragments of the shaft dissolution surface, indicates that the wall destroyed after the glaciation.

Plate 6. Unwalled shafts and cave entrances in the northern side of the Hacer valley. The upper arrow on photo B point to the entrance of a shaft (Profesor's Cave) that opens to the wall 130m below (lower arrow). The wall between the shaft and the vertical rock face is 3-20m wide. A similar shaft in the right side of the rock face can be well seen from below, through its lower outlet. Such situations are numerous on subvertical walls of glacial walleys,

Plate 7. Appearance of the high altitude glaciokarstic landscape in Aladaglar. Glacial scouring in the recent past makes appearance of karstified surfaces generally smoother that it can be typically seen in lower-altitude Alpine karst massifs. A = Yedigoller Plateau, a paleo-source area for the Hacer valley glacier at the altitudes of 3100-3400m; B = Harmancik Plateau, a paleo-source area for the Kemikli valley glacier at the altitudes of 3100-3200m. Photos by E.Medvedeva (A) and A.Kopchinsky (B).

Plate 9. The Kapusbasi group of springs (left) and Goksu spring (right) – some of the major resurgences of the Aladaglar karst system.

Plate 10. Shafts with small entrances, remained after glaciers scoured away upper sections of caves, have more chances to remain unplugged by debris and snow accumulations. Left = Gocholo Cave, right – Kuzgun Cave.

Plate 11. The search for large caves was focused on specific geomorphological situations preventing debris flow into openings. A = Pyrr's Victory Cave is located at the upper steep part of the ridge slope, in a debris flow "shadow". However, this 130m-deep shaft is filled with snow-ice, as it is not protected from snow accumulation. B = the entrance to 185m-deep Gulchitay Cave was created by a weathering niche that intercepted a vadose shaft inside the ridge. Because of glacial rearrangement of the relief, the shaft itself has opening to the surface.

Fig. 2. Different types of blockages responsible for plugging open-mouth shafts in the high-mountain karst.

Fig. 3. A sketch illustrating the development of a pitch-ramp morphology. Vertical pits can readily enlarge in diameter even by small water flows, while flow concentration within the upper part of vadose zone is not sufficient to develop wide meanders when flow migrates laterally along bedding planes. In result of rapid uplift of the Aladaglar massif during Pleistocene-Holocene, cave streams downcut quickly forming high but narrow meanders between vertical pits.

Fig.4. Kuzgun Cave profile.

Fig. 5. Kuzgun Cave plan.

Plate 12. A pitch-ramp morphology in Kuzgun Cave, a descent to a narrow meander at the bottom of a pit. The Pysanka meander at –180m.

Plate 13. A heavily decorated chamber in the French Kiss Series, Kuzgun Cave.

Plate 14. Flowstone formations in Kuzgun Cave. On the photo A, a massive ancient flowstone, that shows signs of dissolution, is partly covered by a more recent flowstone.

Plate 15. Formations in Kuzgun Cave. Photo by S.Ljakhovets.

Plate 16. Frost-like formations of presumably aerosol origin in Kuzgun Cave. Photo by S.Ljakhovets.

Plate 17. Unusual formations in Kuzgun Cave. Photo by S.Ljakhovets.

Plate 18. Members of the Aladaglar-2003 expedition, when Kuzgun Cave had been discovered and explored to –400m.

Plate 19. Members of the Aladaglar-2004 expedition, when Kuzgun Cave had been explored to –1400m.

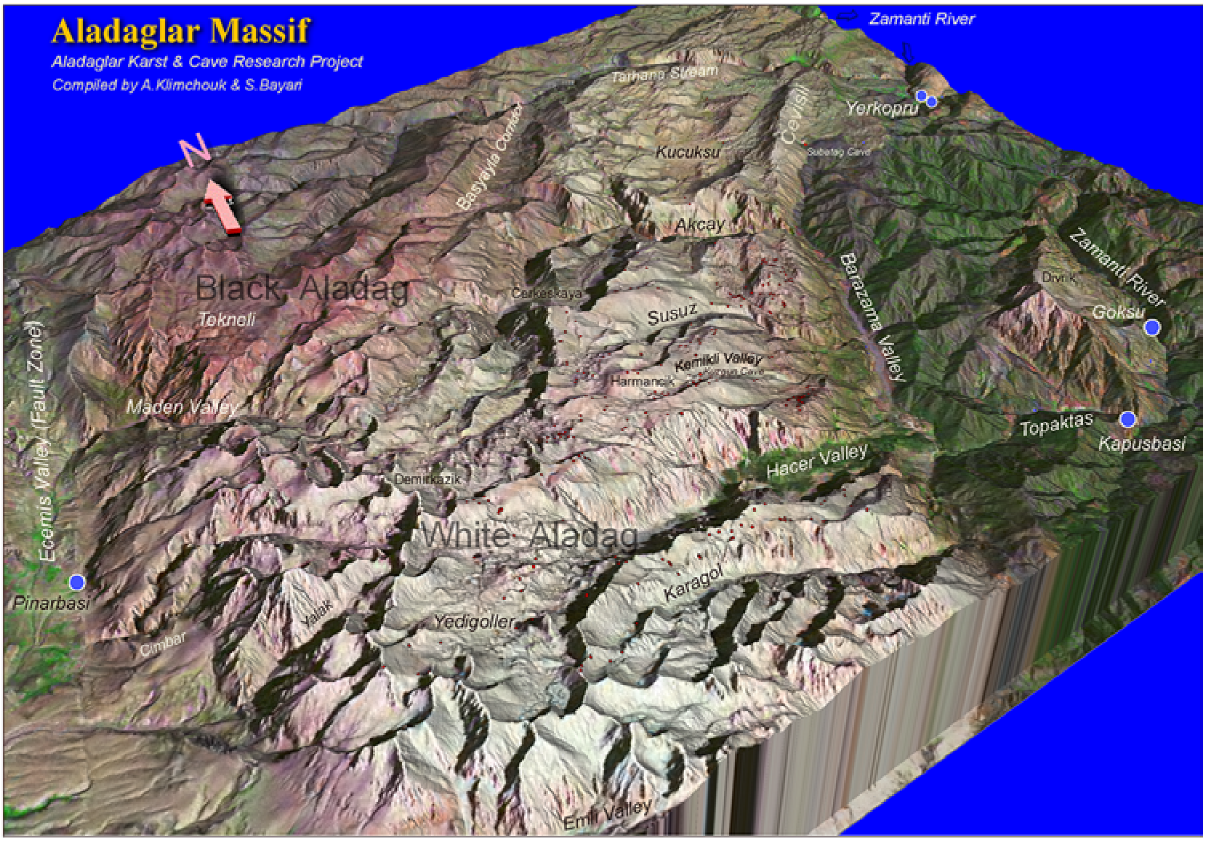

Fig. 1. Physiography of the Aladaglar Massif. The drawing is based on the digital elevation model and GIS "Aladaglar Karst and Caves". Distribution of explored caves is shown by small red dots, major springs are indicated by blue dots. Compiled by A.Klimchouk and S.Bayari.

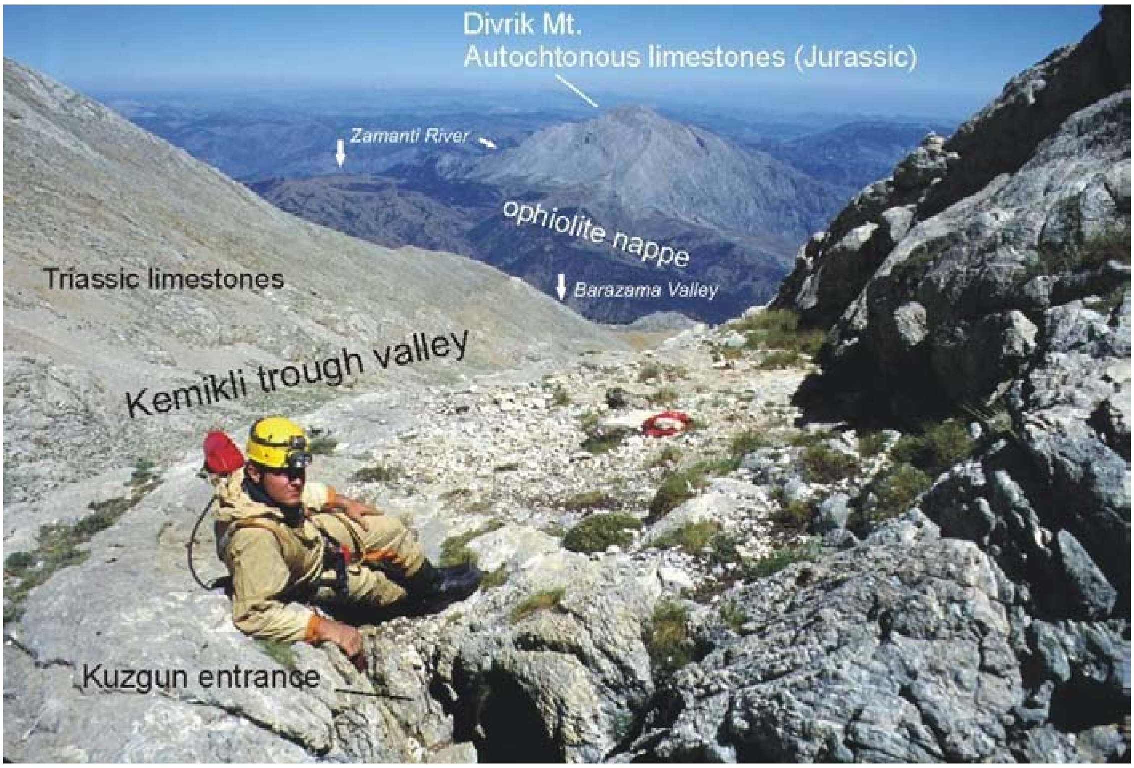

Plate 1. View from Kuzgun Cave, Kemikli valley, eastward, to Divrik Mountain and Zamanti River. Photo by S.Ljakhovets.

Plate 2. Hacer glacial valley and its paleo-source area – Yedigoller plateau (bakground, right). Photo by A.Kopchinsky.

Plate 3. Kemikli glacial valley. The entrance to Kuzgun Cave is located at the top of a glacially eroded rock hill (roches moutonneeś). Photo by A.Klumchouk.

Plate 4. A glaciokarstic depression (the camp place) and a glacially eroded rock hill (roches moutonneés) in the Kemikli glacial valley.

Plate 5. Unwalled shafts in the northern side of the Kemikli valley. An entirely unwalled shaft continued by a meander erased by the glacier. Traces of this meander are identified in the slope beneath. A boulder pile at the left, with some boulders bearing fragments of the shaft dissolution surface, indicates that the wall destroyed after the glaciation.

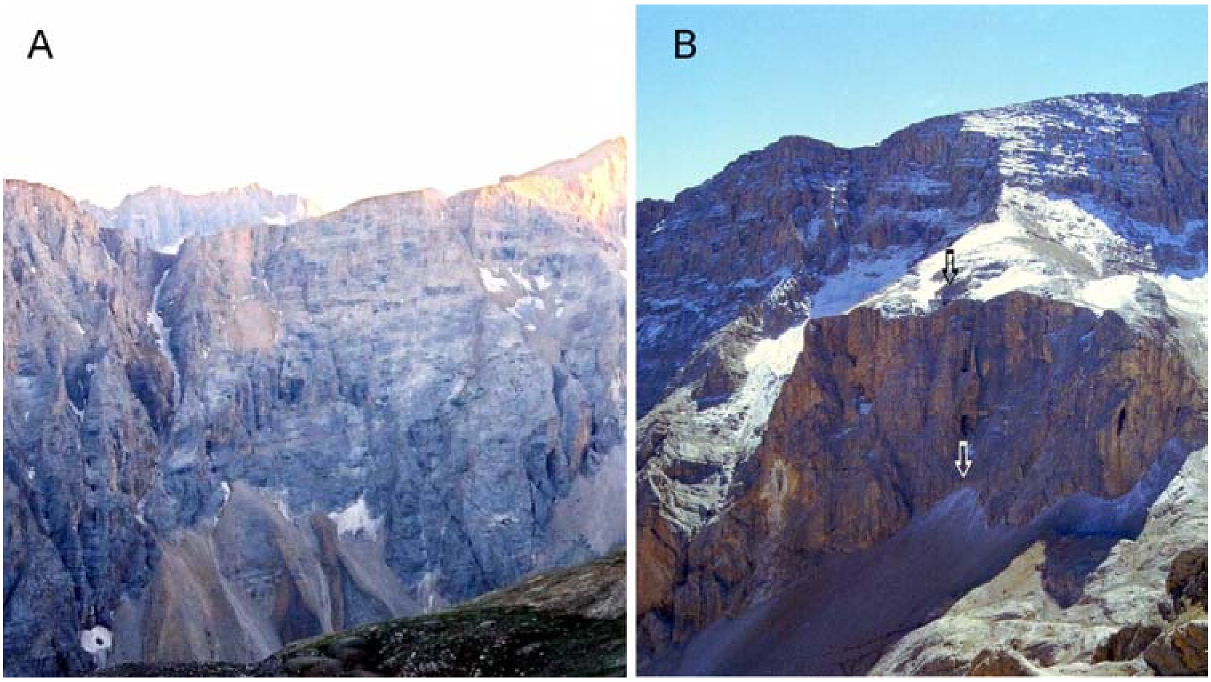

Plate 6. Unwalled shafts and cave entrances in the northern side of the Hacer valley. The upper arrow on photo B point to the entrance of a shaft (Profesor's Cave) that opens to the wall 130m below (lower arrow). The wall between the shaft and the vertical rock face is 3-20m wide. A similar shaft in the right side of the rock face can be well seen from below, through its lower outlet. Such situations are numerous on subvertical walls of glacial walleys,

Plate 7. Appearance of the high altitude glaciokarstic landscape in Aladaglar. Glacial scouring in the recent past makes appearance of karstified surfaces generally smoother that it can be typically seen in lower-altitude Alpine karst massifs. A = Yedigoller Plateau, a paleo-source area for the Hacer valley glacier at the altitudes of 3100-3400m; B = Harmancik Plateau, a paleo-source area for the Kemikli valley glacier at the altitudes of 3100-3200m. Photos by E.Medvedeva (A) and A.Kopchinsky (B).

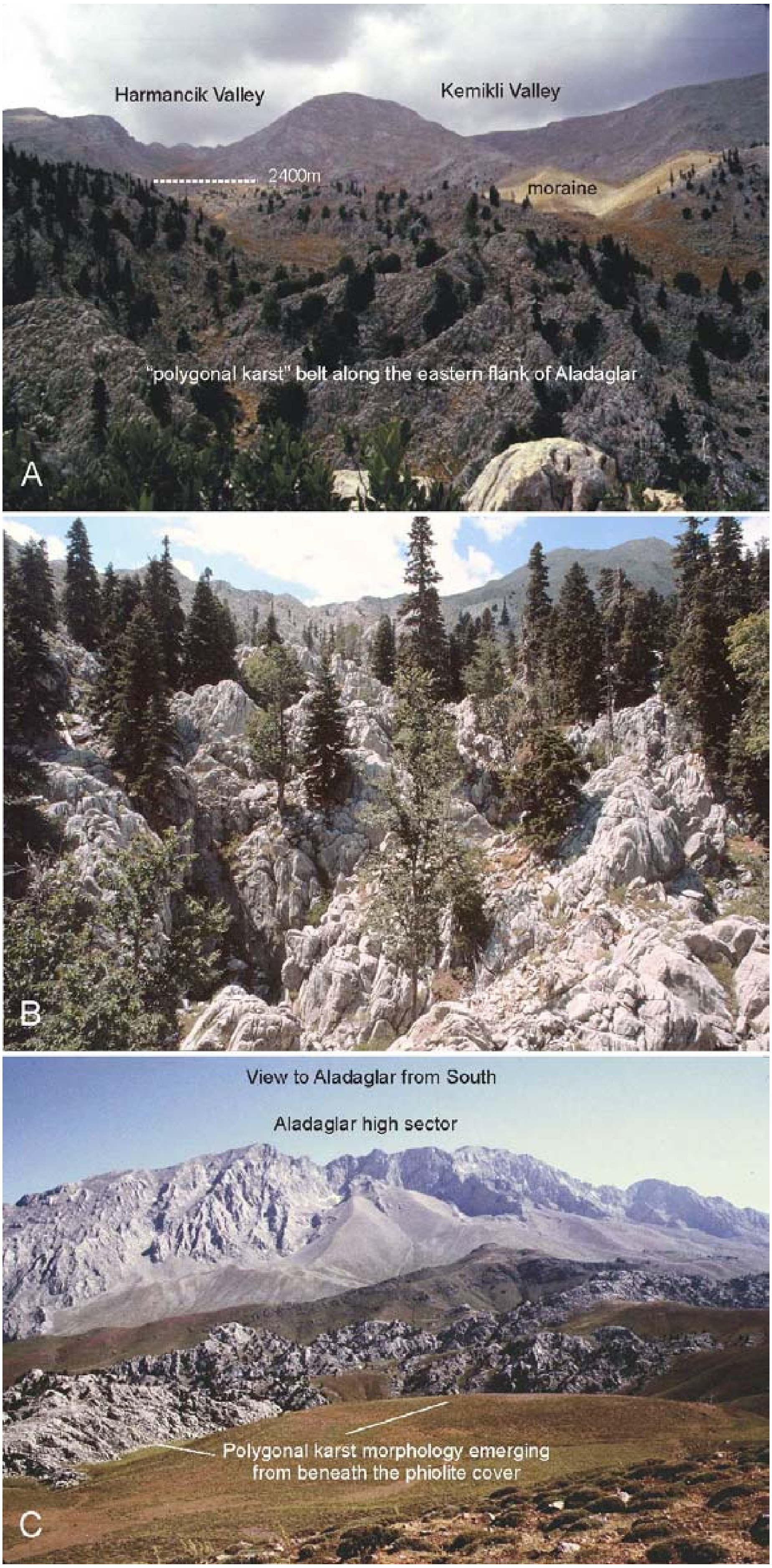

Plate 8. Polygonal karst morphology in Aladaglar at altitudes of 1700-2400m.: A and B = the area stretching along the eastern flanks of the Aladaglar Massif, C = the area at the Aladaglar's southern flank.

Plate 9. The Kapusbasi group of springs (left) and Goksu spring (right) – some of the major resurgences of the Aladaglar karst system.

Plate 10. Shafts with small entrances, remained after glaciers scoured away upper sections of caves, have more chances to remain unplugged by debris and snow accumulations. Left = Gocholo Cave, right – Kuzgun Cave.

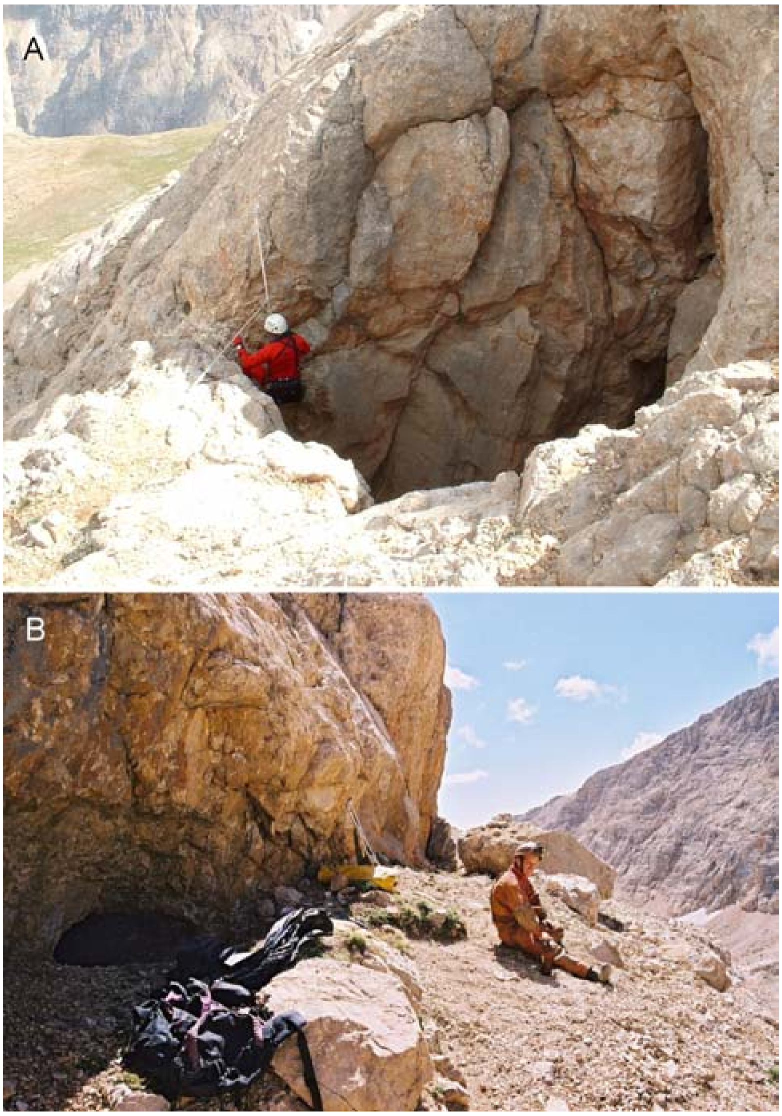

Plate 11. The search for large caves was focused on specific geomorphological situations preventing debris flow into openings. A = Pyrr's Victory Cave is located at the upper steep part of the ridge slope, in a debris flow "shadow". However, this 130m-deep shaft is filled with snow-ice, as it is not protected from snow accumulation. B = the entrance to 185m-deep Gulchitay Cave was created by a weathering niche that intercepted a vadose shaft inside the ridge. Because of glacial rearrangement of the relief, the shaft itself has opening to the surface.

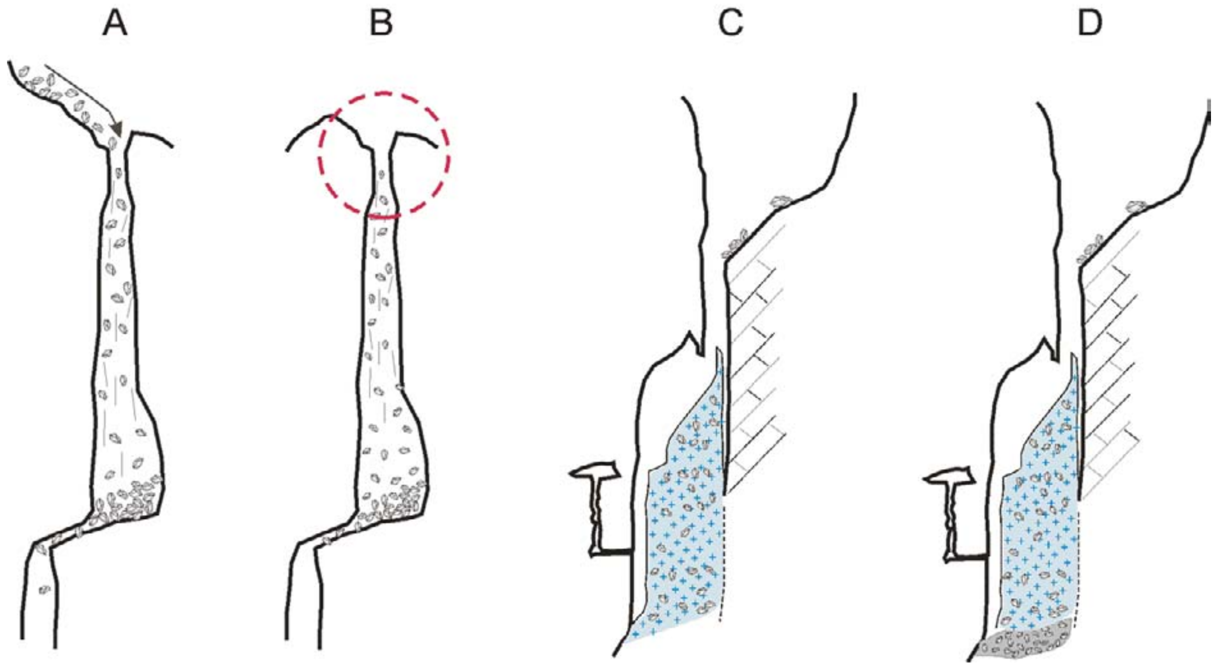

Fig. 2. Different types of blockages responsible for plugging open-mouth shafts in the high-mountain karst.

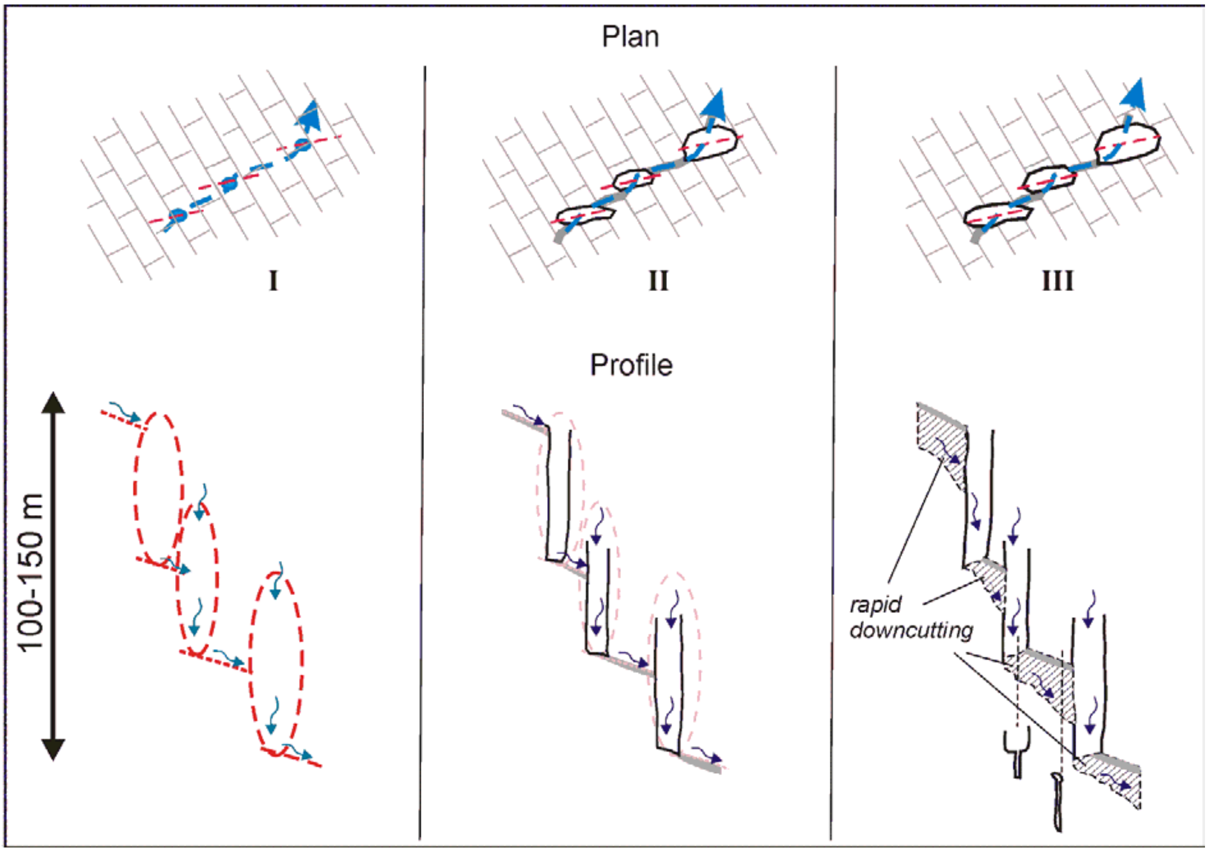

Fig. 3. A sketch illustrating the development of a pitch-ramp morphology. Vertical pits can readily enlarge in diameter even by small water flows, while flow concentration within the upper part of vadose zone is not sufficient to develop wide meanders when flow migrates laterally along bedding planes. In result of rapid uplift of the Aladaglar massif during Pleistocene-Holocene, cave streams downcut quickly forming high but narrow meanders between vertical pits.

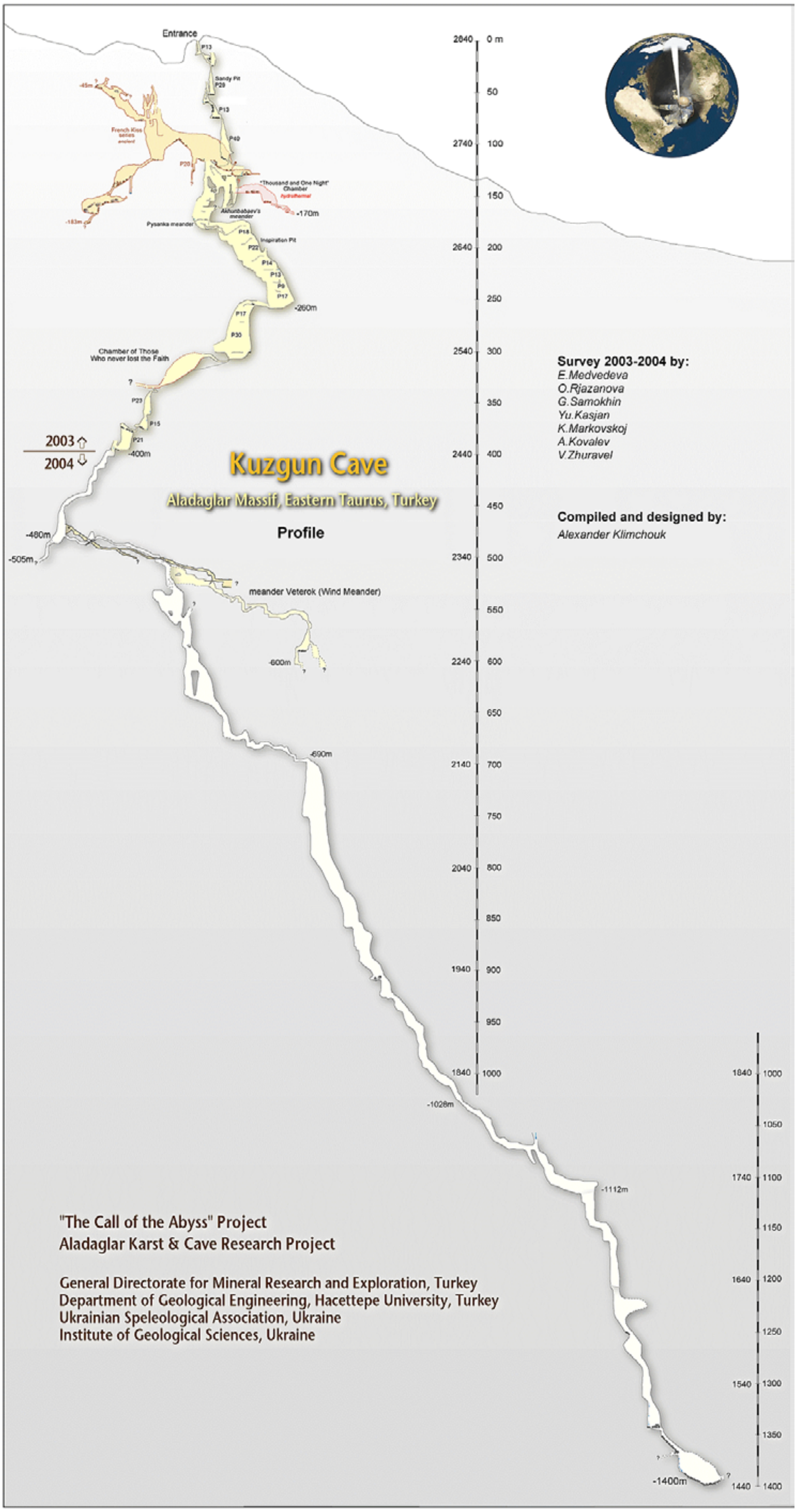

Fig.4. Kuzgun Cave profile.

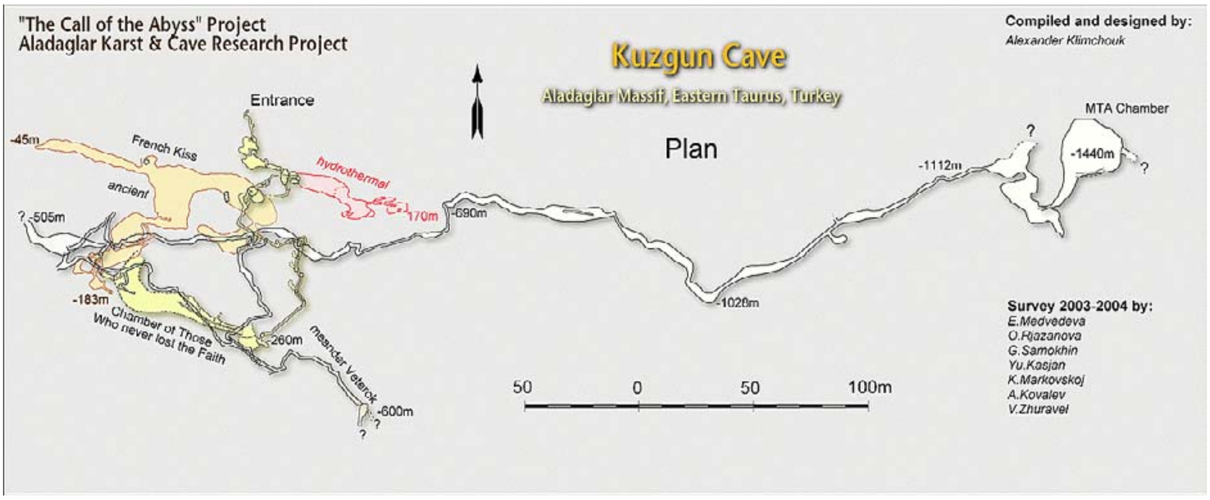

Fig. 5. Kuzgun Cave plan.

Plate 12. A pitch-ramp morphology in Kuzgun Cave, a descent to a narrow meander at the bottom of a pit. The Pysanka meander at –180m.

Plate 13. A heavily decorated chamber in the French Kiss Series, Kuzgun Cave.

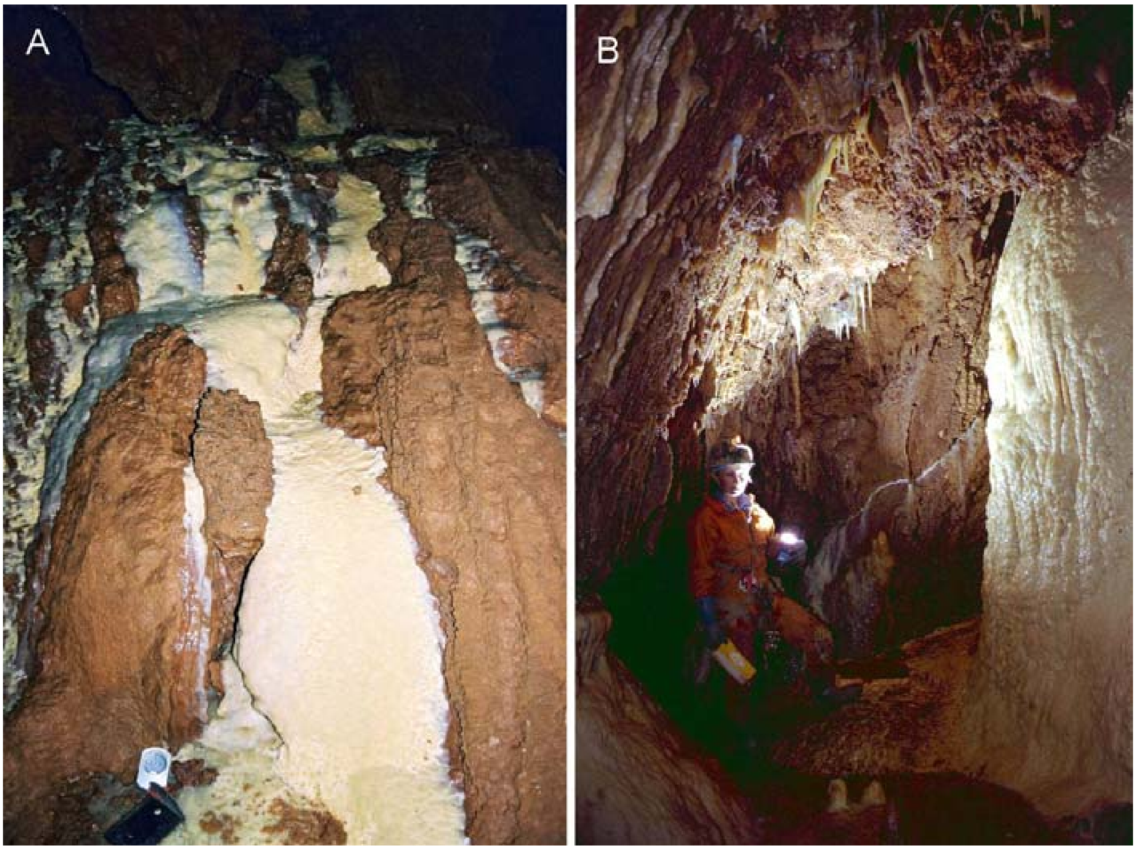

Plate 14. Flowstone formations in Kuzgun Cave. On the photo A, a massive ancient flowstone, that shows signs of dissolution, is partly covered by a more recent flowstone.

Plate 15. Formations in Kuzgun Cave. Photo by S.Ljakhovets.

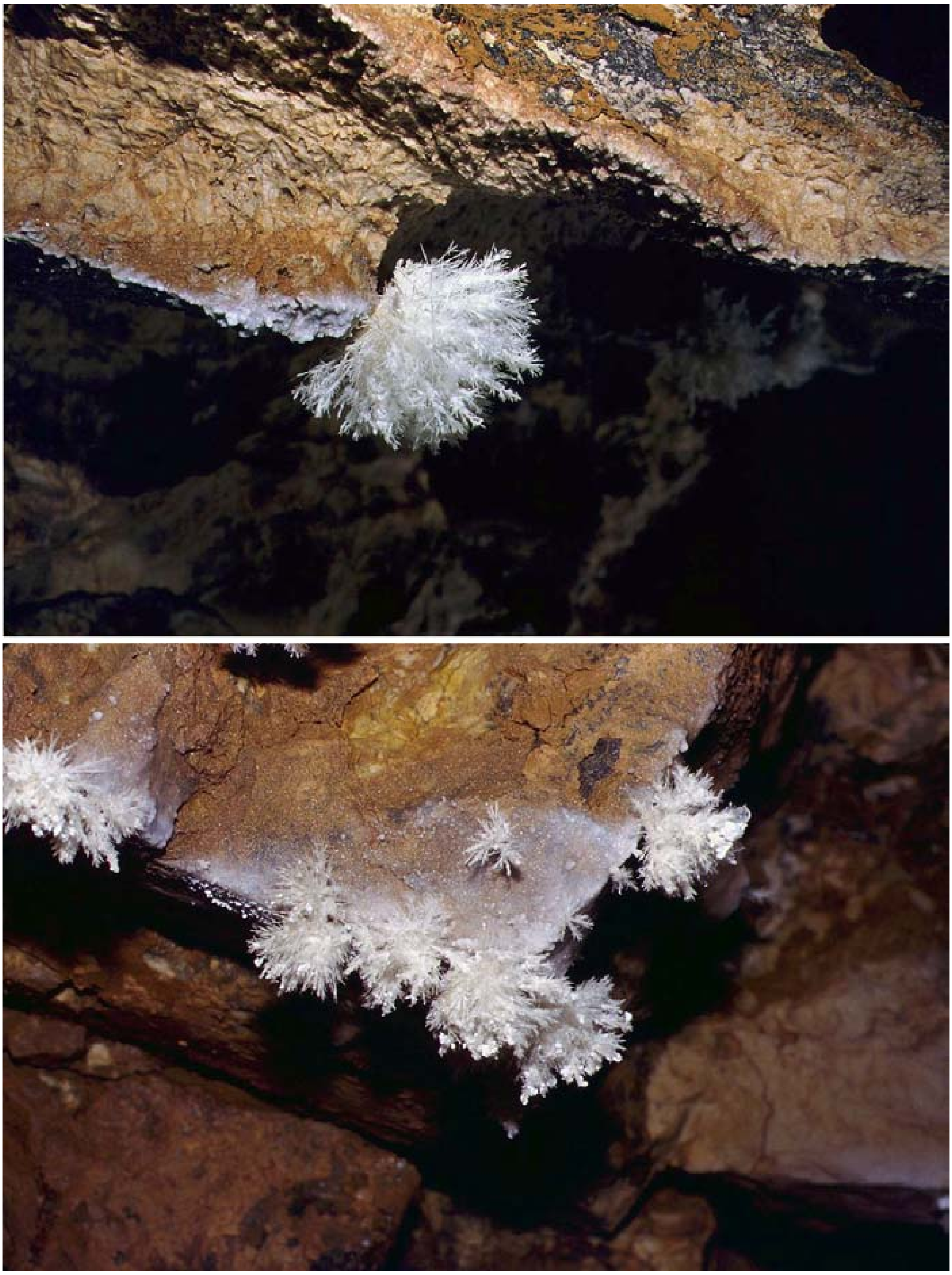

Plate 16. Frost-like formations of presumably aerosol origin in Kuzgun Cave. Photo by S.Ljakhovets.

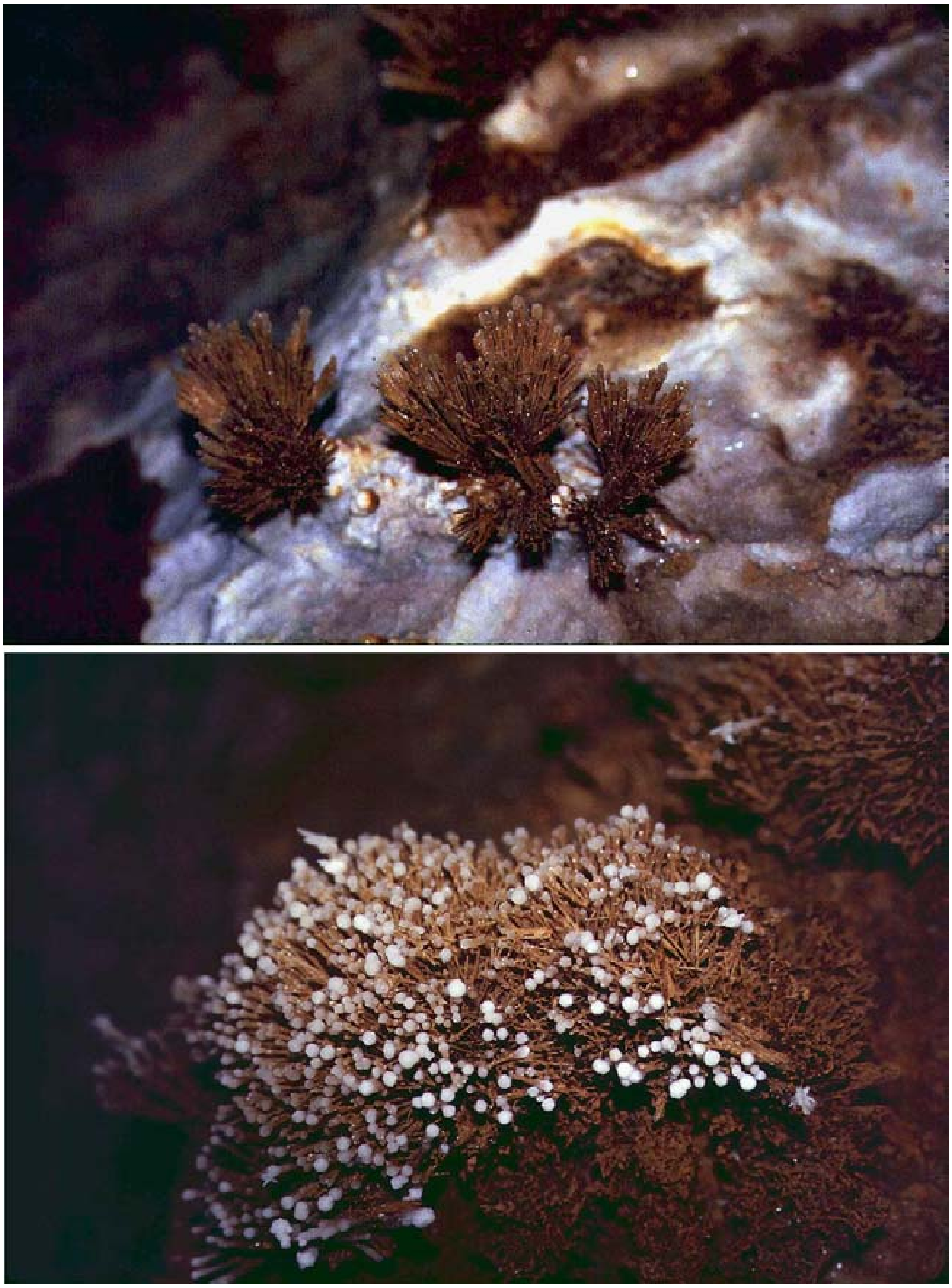

Plate 17. Unusual formations in Kuzgun Cave. Photo by S.Ljakhovets.

Plate 18. Members of the Aladaglar-2003 expedition, when Kuzgun Cave had been discovered and explored to –400m.

Plate 19. Members of the Aladaglar-2004 expedition, when Kuzgun Cave had been explored to –1400m.