Annexe 2 du compte rendu

Köýtendag 2023

Turkménistan

6 au 22 mai 2023

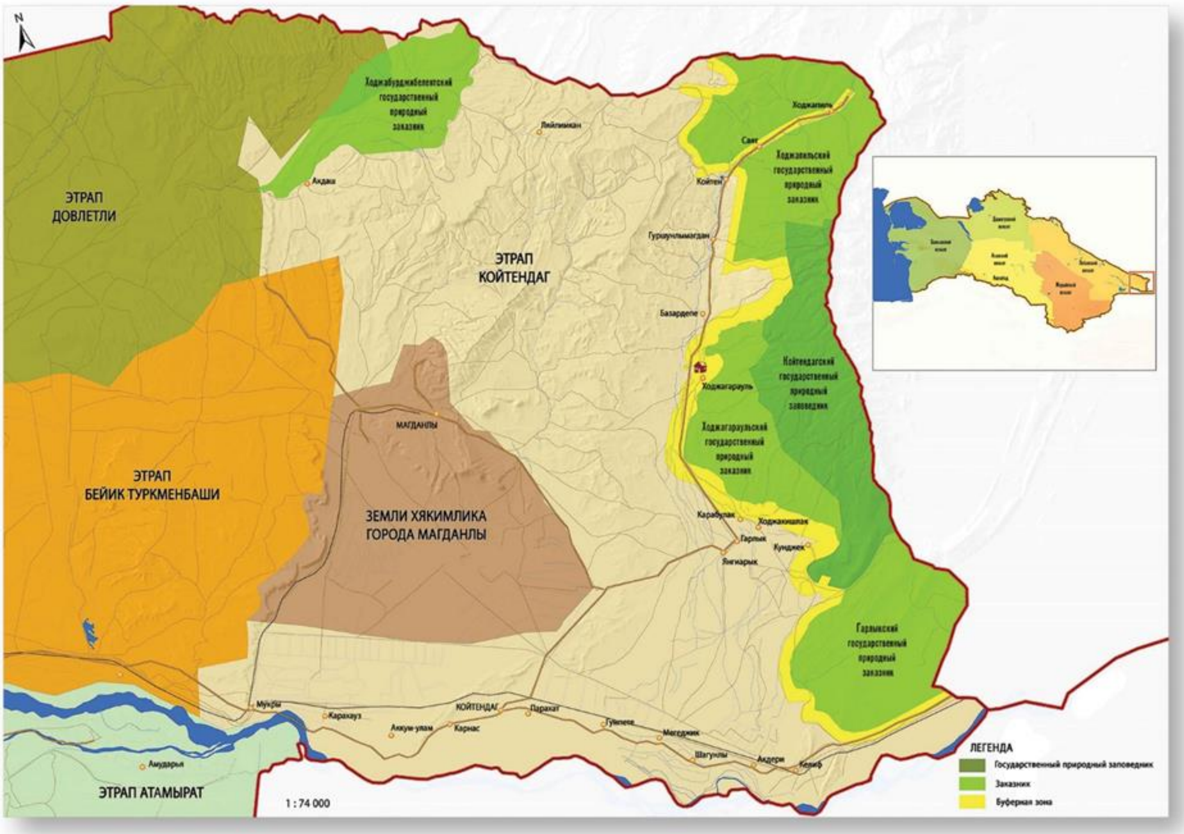
Documents annexés d'après des recherches effectuées au Centre National de Documentation Spéléologique, Lyon avec l'aide de Patrick Deriaz, Société Suisse de Spéléologie.

Mise en forme par Jean Philippe Grandcolas

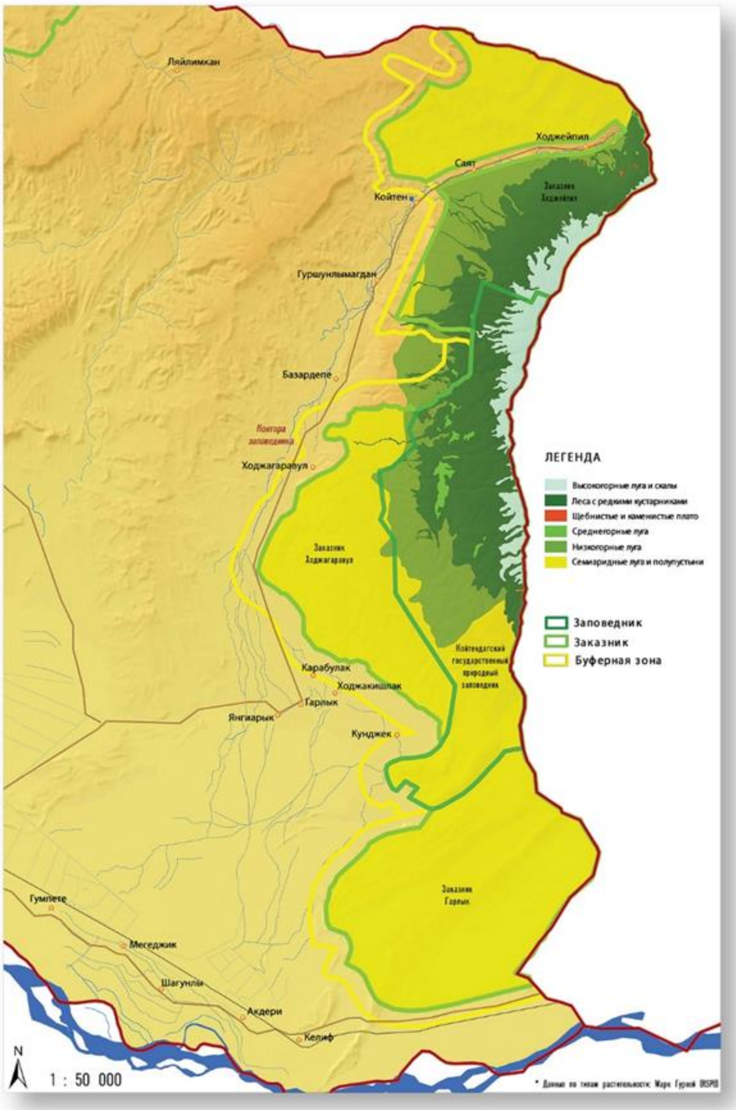
Version 3, Mars 2024 - Alexandre Pont

SOMMAIRE

Les documents qui suivent sont issus des publications suivantes :



Carte du Koytendag



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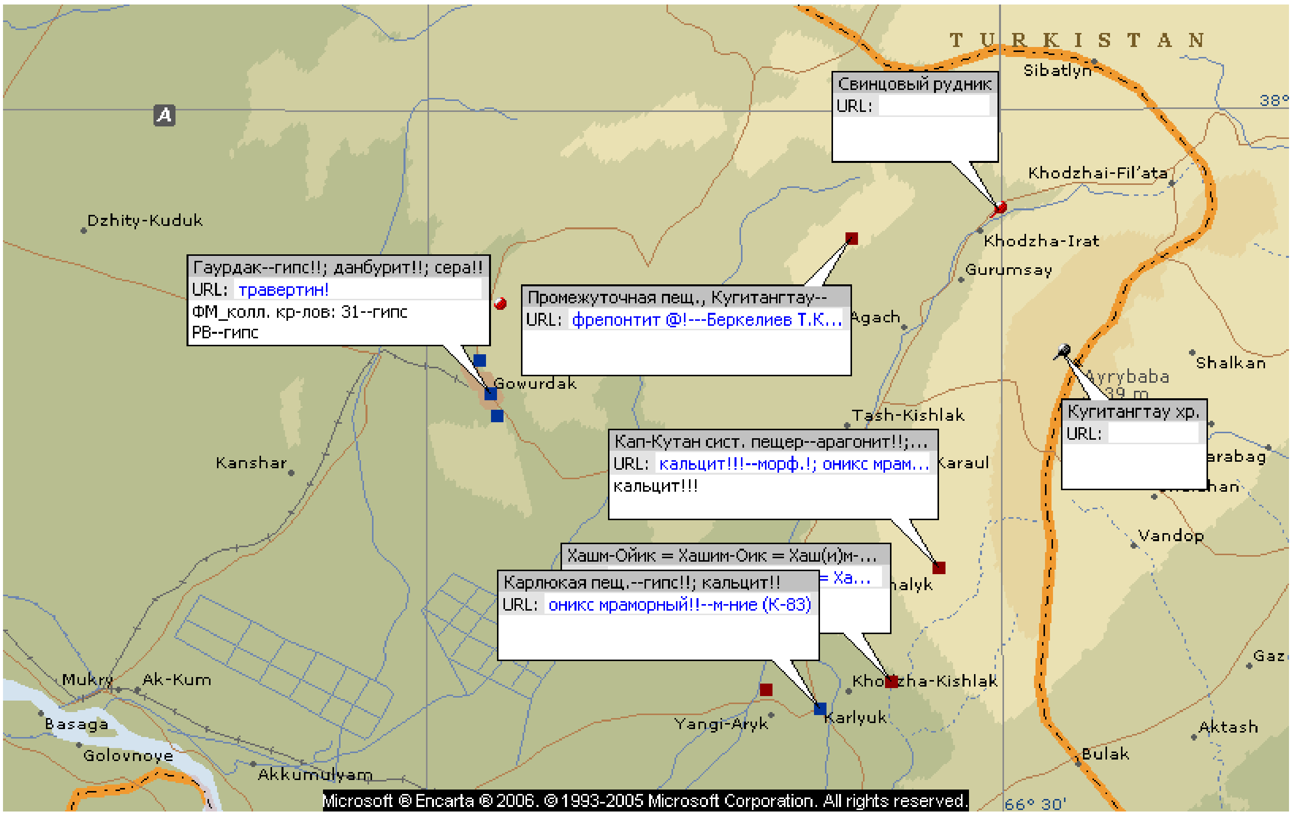

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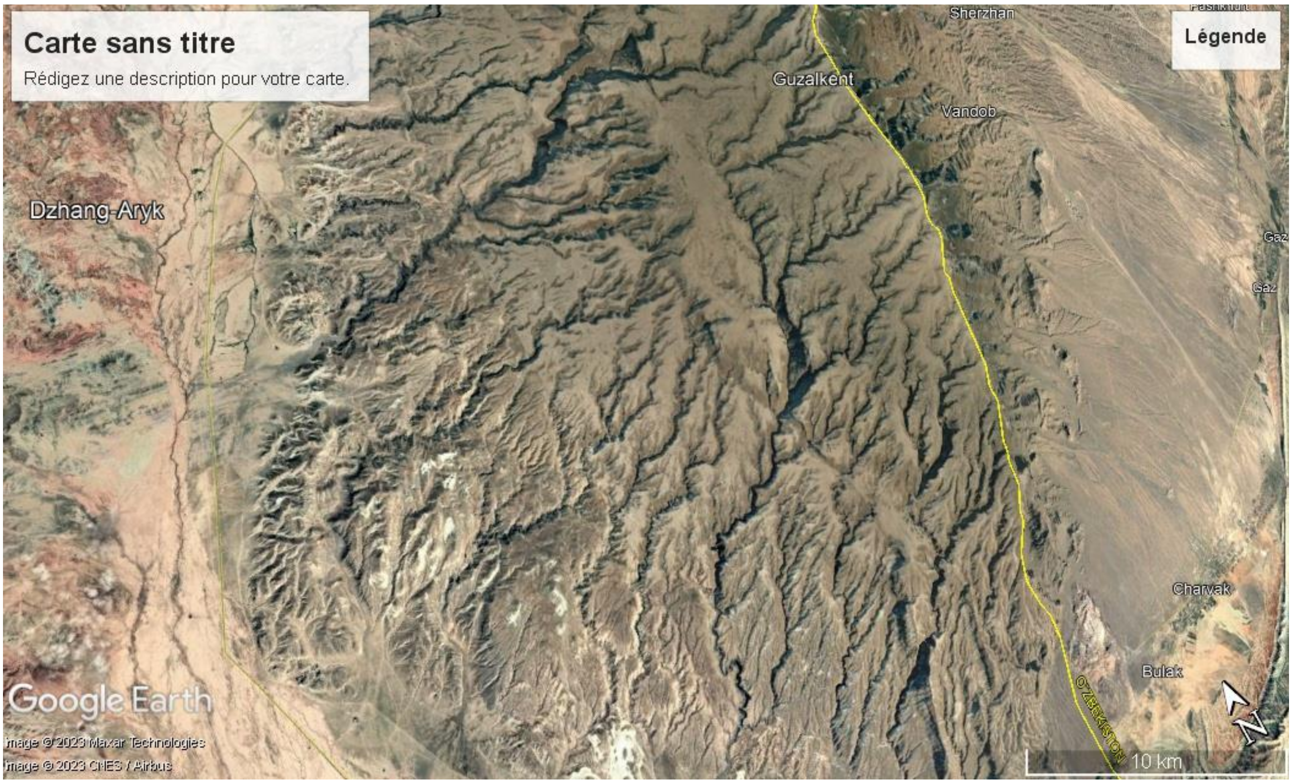


Koytendag Kap Kutan

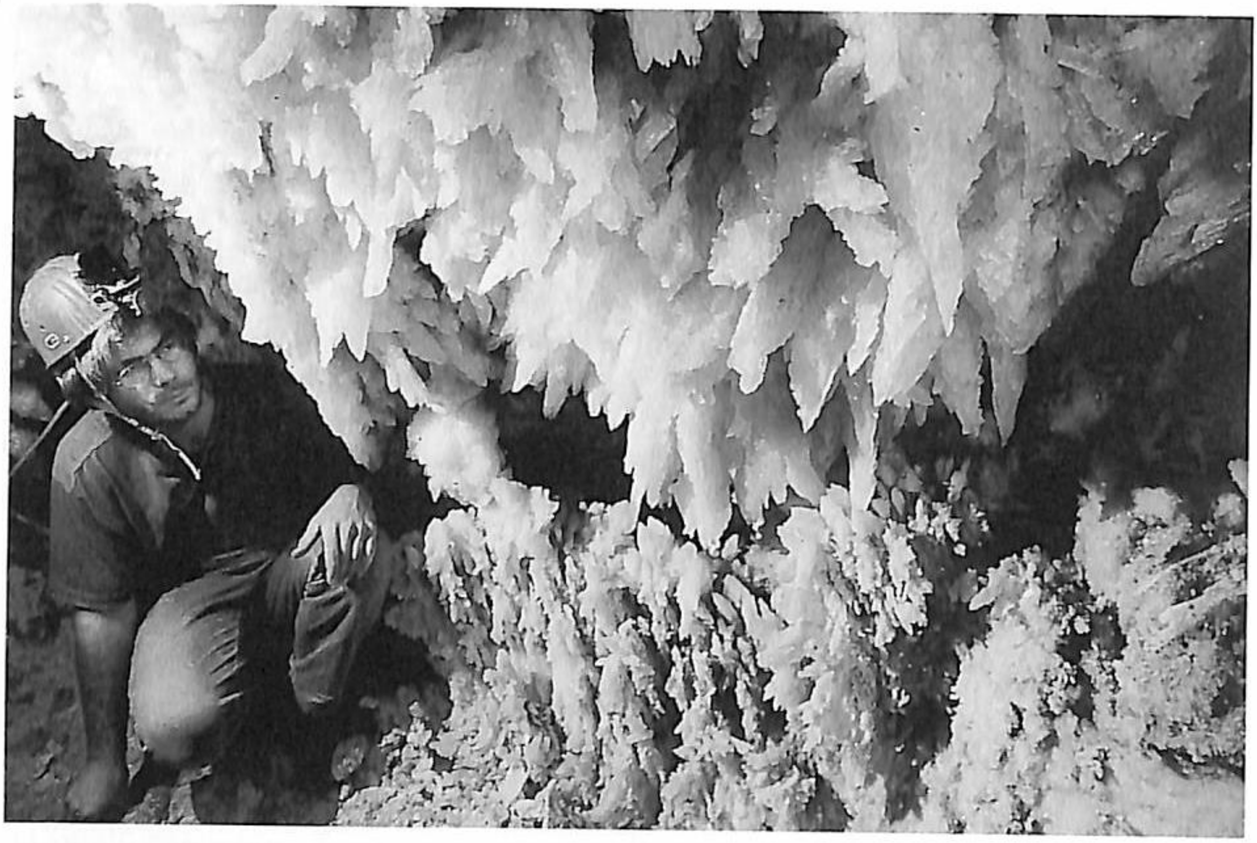
02 Extrait : Stalactite 46, 1, 1996.

Expédition au Turkménistan

Au printemps 1995, six spéléos suisses se sont rendus sur le massif du Kugitang, au Turkménistan, à proximité immédiate de la frontière avec l'Afghanistan et l'Ouzbékistan. L'expédition poursuivait deux buts : la visite des

Extrait de Stalactite 46, 1, 1996, page 60.

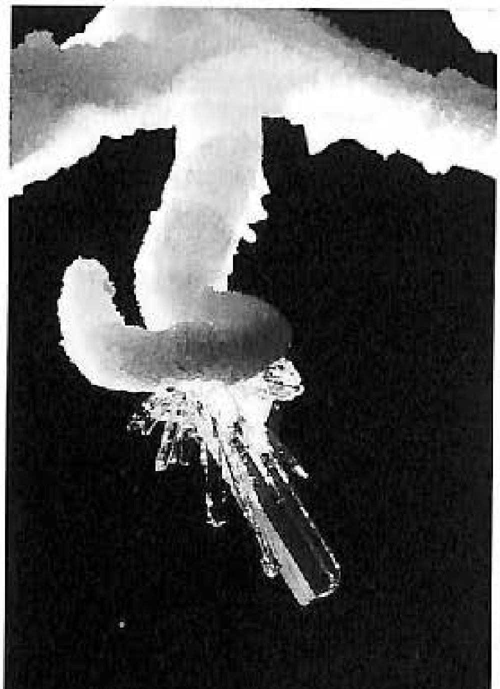
Brèves nouvelles.



Grotte de Tush-Yurruck, Kugitang, Turkménistan, Cristaux de gypse (Photo R. Wenger).
Höhle von Tush-Yurruck, Kugitang, Turkmenistan, Gipskristalle.

La massif du Kugitang est prospecté depuis plusieurs années par des équipes russes. La plus grande cavité connue à ce jour est le réseau de Cupp-Coutunn – Promeszutochnaya qui totalise plus de 50 km de galeries. Dans les environs immédiats, quelques autres grottes plus modestes mais tout de même dignes d'intérêt, ont également été découvertes.
L'attrait essentiel de ces cavités réside dans leur richesse minérale exceptionnelle. Selon les scientifiques qui les étudient, plus d'une centaine de minéraux différents peuvent y être observés (dolomite, fluorite, hydromagnésite, mirabilite, célestine, aragonite,...) Mais c'est le gypse qui offre les formations les plus spectaculaires: chandeliers, tapis d'aiguilles longues de 30 cm, colonnes évidées, etc...
Mettre sur pied une expédition dans cette république de l'ex-URSS n'est pas une sinécure. Espérer s'y rendre sans être accompagné de spéléos russes est illusoire. Trois collègues moscovites étaient donc du voyage. Malheureusement, cela ne nous empêcha pas de nous trouver confrontés à de grosses complications administratives comme, par exemple, l'impossibilité d'obtenir un visa d'entrée dans le pays ou l'interdiction (non respectée bien sûr...) de réaliser des photos dans les grottes. Tant et si bien qu'une grande partie de l'énergie de l'équipe dut être consacrée à essayer de régler les difficultés relationnelles que nous rencontrâmes avec les locaux. Notre séjour prit ainsi les allures d'un voyage hallucinant où il s'est agi, entre autres, d'entrer dans le pays incognito en se dissimulant au fond d'un train de nuit ou de planquer continuellement notre matériel photo. La présence dans les grottes de pilleurs de minéraux, armés et peu enclins au dialogue, ajouta encore du piment à cette situation peu rassurante.
Si finalement tout se passa sans ennui sérieux, nous fûmes tout de même très absorbés par ces problèmes durant tout le séjour. Celui-ci prit d'ailleurs brusquement fin lorsque nous fûmes expulsés de notre camp de base et conduits, sur le pont d'un camion et en pleine nuit, jusqu'à proximité de la frontière...
Un compte-rendu détaillé ainsi qu'une présentation des cavités a paru dans Cavernes N°1/2 (1995).
Participaient à l'expédition:
Cédric John (SVT), Youri Kossoroukov (Moscow University Caving Club), Andrey Markov (MUCC), Edouard Marmillod (SCPF), Bulat Mavlyudov (MUCC), Jérôme Perrin (GSL), François Pinsard (SVT), Rachel Rumo (SCPF), Rémy Wenger (GS Troglolog).

R. Wenger



Cristallisation (longueur 10 mm) dans le réseau Cupp-Coutunn – Promeszutochnaya, Kugitang, Turkménistan (Photo R. Wenger).
Kristallisation (Länge 10 mm) im Réseau Cupp-Coutunn-Promeszutochnaya, Kugitang, Turkmenistan.

Quelques liens communiqués par Peter Bosted ivs17hi@gmail.com

Contact : Annie et Philippe Crochet

http://www.fadr.msu.ru/caves/malpic_e.html

http://www.ubss.org.uk/resources/proceedings/vol19/UBSS_Proc_19_2_117-149.pdf

Voici quelques liens supplémentaires vers des résumés :

https://legacy.caves.org/pub/journal/PDF/V52/v52n2-Maltsev-Malishevsky.htm

https://eurekamag.com/research/018/663/018663762.php

http://www.caving-library.org.uk/catalogue/BCL/code/php/library.php?action=search&lib=&type=any&search=author&search_string=Vladimir%20A.%20Maltsev

https://www.semanticscholar.org/paper/GEOCHEMISTRY-OF-FLUORITE-AND-RELATED-FEATURES-OF-Maltsev-Korshunov/866d7167a0453db8424eaa7ab39e7bb5653bd56d

NOTES :

SPELEO EN ASIE CENTRALE

Expé-thriller au Turkménistan

par Rémy Wenger (Troglolog)

L'action se déroule aux confins de l'Ouzbékistan, de l'Afghanistan et du Turkménistan, une région aride balayée par les vents durant l'hiver et grillée par une chaleur torride l'été. Sont en présence trois spéléos russes, six autres venus de Suisse, auxquels il convient d'ajouter quelques fonctionnaires locaux et corruptibles, un minéralogiste imbibé de vodka ainsi qu'une poignée de pilleurs de minéraux. Tels sont les acteurs de cette étrange aventure. En toile de fond: les grottes du Kugitang, un massif montagneux zébré de profonds canyons sauvages et escarpés. Ah! j'oubliais un «accessoire» capital, pôle d'intérêt primordial et objet de toutes les convoitises : notre argent!

Voilà. Tout est en place pour le récit d'un double voyage : celui, bien concret, entrepris au sein des superbes cavernes du Kugitang et celui, plus subtil et délicat, mené au travers des états d'esprits confondus et confondants de nous autres, petits Suisses pétris de cartésianisme; de ceux de nos coéquipiers russes, empreints de débrouillardise et d'audace; et de ceux, enfin, des Turkmènes, formés aux sources mêmes du négoce et du troc, sujets aux palabres interminables et aux remises en cause perpétuelles.

S'en aller explorer des grottes au cœur de l'Asie centrale. Une drôle d'idée peut-être : mais au fait, pourquoi pas ?

DE CHAMONIX À TERMEZ

Cela débute à Chamonix par la rencontre avec Maxim Moskalevsky et Bulat Mavlyudov, glaciologues. Tous deux travaillent à l'Institut de géographie de l'Université de Moscou. Maxim est chargé de recherches sur les calottes polaires, essentiellement dans l'Antarctique. Bulat, lui, a la responsabilité des glaciers continentaux (CEI). Avec les difficultés économiques pléthoriques que connaît la Russie, seul le premier est en mesure d'accomplir son travail et de mener à bien ses projets car l'intérêt scientifique porté à l'Antarctique est réel et les moyens financiers (y compris ceux provenant d'Occident) existent encore. Par contre, pour le second, il est très difficile de mettre sur pied des déplacements vers le Caucase ou les Tien-Chan. Sans argent, pas de recherches, donc, pas de travail : seulement un poste, une fonction, dont le salaire ne permet d'ailleurs tout simplement plus de vivre décemment... Dans le cours de notre discussion, une proposition tombe : organiser une expédition commune au Turkménistan. Là-bas, se trouvent des réseaux souterrains aux ramifications innombrables (56 km de galeries connues à ce jour) et riches d'une variété fabuleuse de minéraux. Peu d'informations supplémentaires. Ces descriptions ne sont-elles pas surfaites ? Est-il bien sage de mettre sur pied un voyage sur la base de données aussi fragmentaires? Allez ! Vaille que vaille : l'hésitation ne dure que peu de temps: nous partons. L'intérêt d'un projet tel que celui-ci ne réside-t-il pas justement dans sa part de mystère et d'inattendu ?

En quelques semaines, l'expédition est mise sur pied. D'un point de vue technique, rien de bien compliqué : les grottes que nous allons parcourir ne présentent pas d'obstacles sérieux et offrent un climat on ne peut plus agréable avec une température ambiante de plus de 20°C. La substance des messages échangés par fax entre Moscou et la Suisse durant cette phase concerne plutôt les aspects financiers et administratifs. Avec l'éclatement de l'empire soviétique, il nous faudra non pas un visa mais trois puisque notre itinéraire passera par la Russie, l'Ouzbékistan et le Turkménistan. Une invitation écrite étant nécessaire pour chacune de ces trois républiques avec description précise de notre itinéraire. En plus, pour les deux républiques centre-asiatiques, un télex devra être envoyé par leurs Ministères des affaires étrangères à l'Ambassade de Russie en Suisse. Ces démarches ne sont pas simples mais Bulat se veut optimiste : pas de problème, tout arrivera et se réglera à temps.

Quelques jours avant le départ, les informations deviennent pourtant moins rassurantes. Du côté de l'Ouzbékistan et de la Russie, cela s'est arrangé (quoique l'obtention de deux visas, et non pas un, ait été nécessaire puisque nous allions ressortir du pays pour se rendre en Ouzbékistan et y entrer à nouveau lors du retour...). Mais le Turkménistan refuse, lui, d'envoyer son télex. Selon Bulat, nous obtiendrons notre visa «sur place».

L'un des nombreux canyons qui lézardent le plateau incliné du Kugitang (photo Rémy Wenger)

Termez, frontière afghano-ouzbek, minuit. Avec plus de douze heures de retard sur l'horaire prévu, notre avion, un Tupolev ayant appartenu à l'Aéroflot et repeint aux couleurs d'Ouzbékistan Airways (à déconseiller aux anxieux...), se pose enfin. Transfert à la gare dans le bus de l'aéroport, affrêté pour l'occasion. Discrète et rapide montée dans le train. Tombant de sommeil après deux jours de voyage, nous ne voyons rien du passage en pleine nuit de la frontière turkmène. Y-a-t-il eu contrôle douanier ? Le train est, paraît-il, moins surveillé que la route. De plus, il est bondé et quasiment obscur. Ce qui fait notre affaire, car, en fin de compte, nous pénétrons au Turkménistan... sans visa. L'obtenir aurait été possible mais pour cela il aurait fallu se rendre à Ashabad, la capitale, distante de huit cent kilomètres. De plus, l'obtention de ce papier supposait l'annonce «officielle» de notre itinéraire et du but de notre voyage. Nous aurions pu le faire, mais ce qu'il faut savoir – nous l'avons appris lors de notre arrivée à Moscou – c'est que les grottes du Kugitang s'ouvrent dans une «réserve» et qu'en conséquence, leur accès est réglementé et ce, essentiellement pour les étrangers (entendre par là les Occidentaux). Et à quoi donc sert une réglementation ? A obtenir de l'argent, pardi ! Combien ? nous ne l'avons jamais bien su. L'accès à la «réserve» se monnaie donc, mais il est en plus assorti du paiement sonnant et trébuchant de toutes les prises de vues qui y sont réalisées. Tarif : cinq à dix dollars par photo ! Autant dire un prix totalement prohibitif et inacceptable. Après présentation du problème, il fut donc décidé de renoncer au visa et d'entrer illégalement dans la réserve... pour y faire nos photos clandestinement. Advienne que pourra !

BIENVENUE AU TURKMÉNISTAN

«Don't speak with the local people!». A peine descendus du train dans l'aube naissante du village de Charshanga, ce message sec donne à notre arrivée dans ce pays un goût saumâtre. Bulat et Youri Kossoroukov (un astronome sans job et fervent pratiquant de spéléo qui, en compagnie de Bulat et d'Andrey Markov, nous accompagne depuis Moscou) s'en vont à la recherche d'un véhicule pouvant nous transporter à proximité des grottes, distantes de quarante kilomètres. Peu après, miracle de l'Asie et des petits billets verts, nous faisons route dans un engin brinquebalant alors que le soleil se lève sur les reliefs enneigés de l'Hindu Kush. Juste entrevus furtivement au travers des vitres sales du bus, les villages turkmènes s'éloignent déjà de notre vue. Nos Russes sont pressés d'arriver aux grottes. Nous les sentons légèrement crispés.

Au premier obstacle sérieux rencontré sur la piste, le chauffeur nous prie de descendre. On s'exécute pendant qu'il remet le moteur en marche d'un tour de manivelle énergique fourni de l'avant du véhicule. Nous voilà seuls. Le paysage est majestueux, l'air frais et limpide. Des buissons épineux et rabougris garnissent la plaine qui file jusqu'aux méandres de l'Amou-Daria. Au delà, vers le sud : l'Afghanistan. Derrière nous, au nord : une immense dalle calcaire s'élève. De cinq cents mètres d'altitude où nous sommes, elle s'étire sur plus

Disque dans Cupp-Coutunn (photo Rémy Wenger)

Le service du porridge vespéral au bivouac de Cupp-Coutunn: signe certain que 24 h se sont écoulées depuis le moment où le précédent porridge fut absorbé... (photo Rémy Wenger)

de vingt kilomètres en une ligne parfaite pour atteindre, à sa crête, une élévation de près de trois mille deux cents mètres. Si la carte de géographie ne l'indiquait pas, nous aurions de la peine à croire à une telle différence de niveau, tant la pente est douce. De plus, les taches de neige distinguées entre nuages et rochers prouvent la véracité de cette cote.

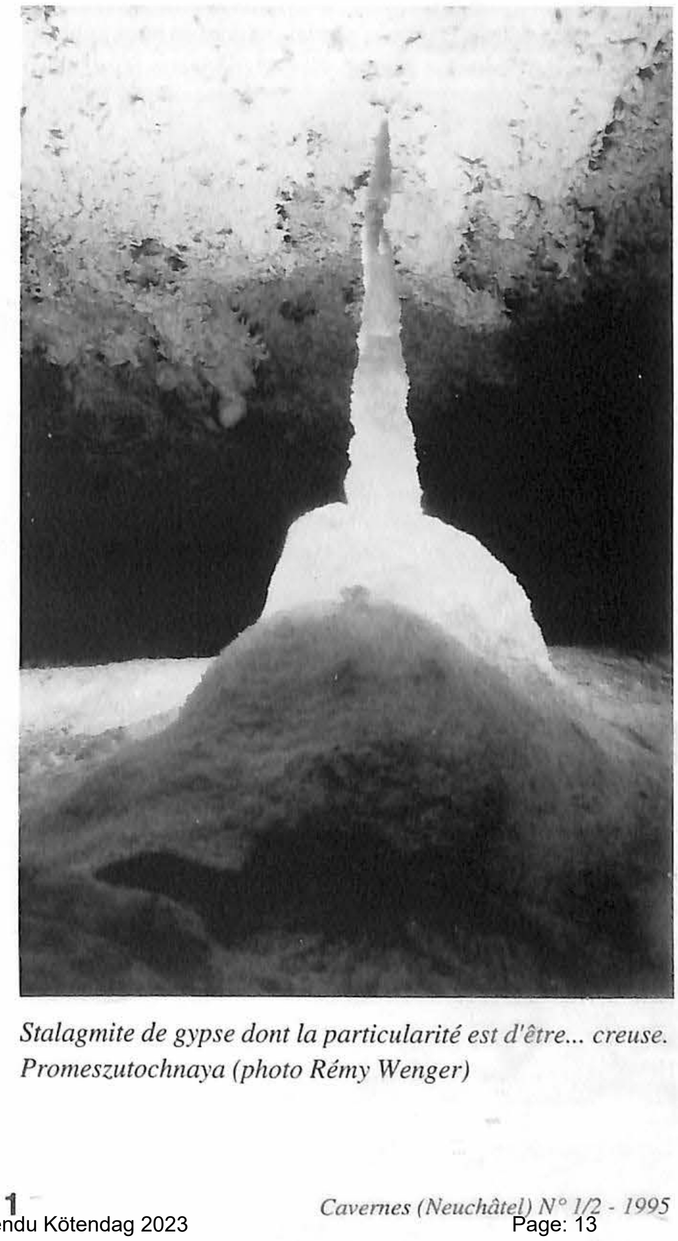
Sentant le moment de l'action arriver enfin – cette fois-ci les grottes sont proches, nous nous hâtons de boucler nos sacs, pressés de nous lancer dans la marche d'approche. Après deux jours et trois nuits de voyage, cet instant s'annonce comme un soulagement.

Mais soudain, trouble-fête, un homme apparaît au loin sur la piste. D'un pas décidé, il se dirige vers nous. De sa poche, il extrait prestement une carte rouge déclinant sa fonction : garde de la réserve... Devinant que la discussion qui s'engage entre les Russes et lui ne va pas se clore si rapidement, les sacs – déjà sur le dos – sont remis à terre. Au bout d'un moment, quelques billets changent de main et ordre est donné de recharger les sacs et... de planquer les appareils photographiques. On se dit que tout est réglé et que cette fois-ci nous allons enfin pouvoir gagner l'entrée du réseau souterrain. Manque de chance, l'homme à la carte rouge nous emboîte le pas. Déjouant son regard, une ou deux photos sont tout de même tirées à la va-vite.

Afin d'être à l'abri des regards indiscrets, nous décidons d'installer notre bivouac dans la grotte plutôt qu'à l'extérieur, sous un abri sous roche par exemple. En nous faufilant dans l'orifice exigu de Cupp-Coutunn cave, nous éprouvons un malin plaisir à l'idée que notre homme, qui n'est pas équipé de lampe, va se retrouver seul dehors. Effectivement, c'est ce qui se produit non sans qu'une nouvelle et longue palabre ne se soit à nouveau engagée entre Bulat et le garde.

Alors que nous progressons dans la vaste galerie d'entrée de la grotte, Bulat nous fait un petit compte rendu de ses tractations. Grâce à l'argent remis à l'homme et aux paroles données : «nous ne ferons pas de photos, c'est promis», un gentleman agreement a été conclu avec lui. Nous devrions donc en principe être tranquilles. Mais au fait, qu'est-ce qu'un principe en Asie centrale ?

Subitement, dans l'immensité de la caverne, se mettent à résonner les aboiements d'un chien. On s'approche. Oh surprise ! Des lumières nous font face. La grotte n'est donc pas déserte, y aurait-il des troglodytes dans la région ou alors quelques «égarés», comme nous ? A nouveau, le même scénario : nous autres Suisses restons en retrait de la discussion qui s'engage. Celle-ci est plutôt vive et prend des allures triviales. Visiblement, notre présence n'a pas l'heur de plaire, du moins l'accueil n'est pas des plus chaleureux. Même si notre compréhension du russe est pratiquement nulle, le fait que le mot «photo» apparaisse plusieurs fois dans la conversation ne nous échappe pas. On cherche à deviner à qui nous avons à faire. Youri nous confie que l'une des personnes est encore une fois un garde, les autres étant des spéléos de St-Petersbourg. On apprend aussi que des pilleurs de minéraux traînent dans les parages. Notre étonnement va donc croissant: va-t-on réussir à avoir la paix dans cette grotte et allons-nous parvenir à prendre des photos sans être constamment pourchassés ?



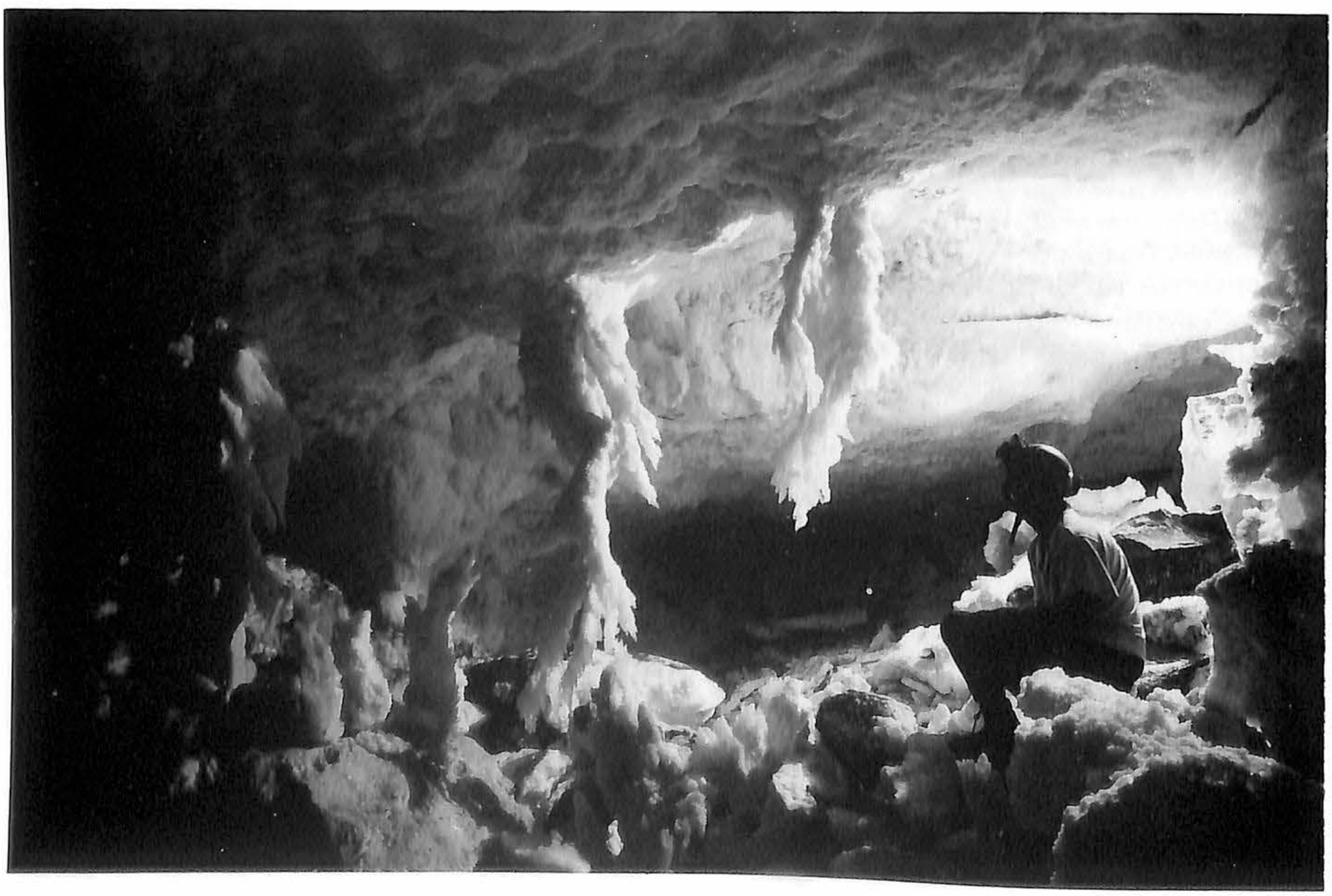
Stalagmite de gypse dont la particularité est d'être... creuse. Promeszutochnaya (photo Rémy Wenger)

EXTRAVAGANCES SOUTERRAINES

Une fois de plus, l'argent et les promesses permettent de régler le problème, du moins de le repousser. Nous installons notre campement souterrain au centre d'un labyrinthe de galeries. Le ronronnement des réchauds ne tarde pas à signaler l'instant du premier porridge ; repère culinaire immuable qui nous rappellera durant les dix jours suivants qu'il est l'heure du souper. Traditionnellement aussi, les réveils seront rythmés par l'arrivée dans nos assiettes d'un mélange de kacha (sarrazin mondé) et d'une sorte de viande non identifiée en conserve venue de Chine (les mauvaises langues prétendant que l'on mange du... Chinois). A l'usage, statistique et expressions faciales à l'appui, le porridge du soir s'avèrera plus facile à engloutir (le mot est peut-être un peu fort, disons plutôt avaler) que le petit déjeuner. Toutefois, il serait exagéré de dire que cela fut immangeable. Il est des circonstances – un bivouac en grotte en est une – où l'on fait ventre de (presque) toute nourriture, une petite dose d'abnégation étant certes de rigueur.

Les jours suivant notre arrivée dans la grotte de Cupp-Coutunn nous permettent de découvrir la complexité de ce réseau tentaculaire connu, il faut le rappeler, sur près de cinquante-six kilomètres. A plus d'une reprise, Andrey, le seul à être déjà venu ici il y a de cela quelques années, se perd en nous guidant au travers de l'entrelas des galeries. Expérience faite, nous devenons plus vigilants et en arrivons à assumer nous-mêmes le bon retour au point de départ ! A plusieurs reprises nous ressortons de la grotte et entreprenons de belles randonnées afin d'aller visiter d'autres cavités. Geophyzicheskaya en est une. On l'atteint après avoir traversé trois canyons successifs. Protégée par une porte au système d'ouverture compliqué, elle nous livre des visions étonnantes de cristallisations de gypse géantes. Tels de longs bras aux formes excentriques, ces concrétions étincelantes descendent des plafonds et semblent attendre le spéléologue de passage pour s'articuler soudainement et l'enserrer avec force. Dans un conduit voisin, le gypse a pris l'aspect beaucoup plus doux de très fines aiguilles répandues à même le sol donnant ainsi l'apparence d'un tapis de cheveux d'ange. Ici la nature s'est laissée aller à de merveilleuses folies.

Dans la grotte d'Hushm-Oyeek, le gypse, encore lui, a formé de hautes colonnes blanches et boursouflées faisant penser à d'étranges créatures figées soutenant les voûtes des vastes salles de la caverne. En y regardant de plus près, on est surpris de constater que ce soutien n'est qu'une illusion, car ces colonnes sont... creuses ! Par des ouvertures latérales, on peut passer la tête ou parfois même le corps et éclairer en transparence leur mince croûte translucide. Se glisser à l'intérieur d'une concrétion ; voilà bien un rêve de spéléologie que nous n'aurions pas osé imaginer !



Geophyzicheskaya. Chandeliers de gypse (photo Rémy Wenger)

Geophyzicheskaya. Sol recouvert d'aiguilles de gypse disposées en forme de nid. Diamètre : 20 cm (photo Rémy Wenger)

Mais, toujours dans Hushm-Oyeek, une autre formation minérale encore plus folle nous attendait au détour d'une galerie : creusé dans le sol, se trouvait un tube vertical haut de plusieurs mètres et large de deux, dont les parois était formées uniquement d'une multitude de cristaux orangés enchevêtrés. Comme sur un puits, nous avons pu nous y pencher et admirer cette particularité géologique probablement unique en son genre.

LA VODKA DU DOCTEUR MALTSEV

Au fil des jours, nous constatons non sans surprise que les cavernes du Kugitang sont plus fréquentées qu'il n'y paraît. Chose inattendue pour un endroit aussi retiré. Déjà en arrivant à la grotte de Geophyzicheskaya, nous avions rencontré un autre groupe de spéléologues venus de Moscou. Accompagnant Volodia Maltsev, un minéralogiste pour le moins original et «grand spécialiste» de l'étude des cavités du massif, cette équipe installa ensuite son bivouac à proximité du nôtre. Une nuit, alors que nos rêves nous berçaient déjà, nous fûmes dérangés par des éclats de voix et des rires venus du campement du docteur Maltsev – que l'on nous avait décrit comme quelqu'un de très bien, un chercheur respecté et respectable. Visiblement, l'excès de vodka faisait son effet et les fêtards perdaient le contrôle de leurs faits et gestes. Encore à moitié endormis, nous ne prîment pas garde à ce qui se préparait. Tout à coup, s'étant approché, l'un d'eux enflamma des fumigènes et les jeta au milieu de notre bivouac. En l'espace de quelques secondes, la fumée envahit tout le volume de la galerie. Cette fois-ci tout le monde était bel et bien (mal) réveillé. Etait-ce une hallucination collective ou un coup des gardes de la réserve ou encore une attaque de l'armée turkmène qui venait nous expulser ? Non, rien de tout cela, juste un grand savant qui s'amusait. Par chance, un faible courant d'air parcourait notre campement ce qui favorisa la migration des gaz en direction du bivouac des auteurs du forfait (hi hi hi!!!). A peine le temps de nous réinstaller dans nos sacs de couchage en prenant garde, comme il convient, de ne pas se pincer la barbe dans la fermeture éclair, qu'un son de clochette retentit dans l'obscurité. Que se passait-il encore ? Rouvrant un œil, nous

Cristallisation géante en gypse dans la grotte de Tush-Yurruck (photo Rémy Wenger) vîmes alors une sorte de procession apparaître dans l'enfilade de la galerie. Gênés par les volutes de fumée résiduelle, il était difficile de voir de quoi il s'agissait au juste. De petites loupiottes s'agitaient, tenues par des mains chancelantes ou fixées dans la gueule ouverte du squelette d'un crâne de cheval disposé tant bien que mal au-dessus de la (grosse) tête du docteur, laquelle était dissimulée sous une sorte d'ample cape sortie d'on ne sait où. Dans un mélange d'inquiétude et de sourire, nous observions, ébahis, cette scène quasiment surnaturelle. Soudain, les lumières vacillèrent, la clochette chuta et les joyeux drilles firent demi-tour. Certains se percutèrent en émettant des sons et des paroles incohérentes. Le chemin les ramenant vers leurs bouteilles (vides sans doute) fut on ne peut plus laborieux et chaotique.

Le lendemain matin, grâce certainement à une grande accoutumance, Volodia Maltsev et ses acolytes alcooliques étaient sur pied de bonne heure et, de surcroît, présentables.

La veille, j'avais déjà eu l'occasion d'apprécier ce personnage loufoque en effectuant en sa compagnie une expédition nocturne dans une autre partie du réseau de Cupp-Coutunn. D'emblée, je fus frappé par la tenue vestimentaire du bonhomme : il avait enfilé trois combinaisons «de travail» superposées. Pour ma part, mon pantalon de coton et mon T-shirt me suffisaient amplement. S'il n'avait pas fallu franchir des passages exigus et râpants, des shorts auraient, à mon goût, suffi. Imaginez la sudation entraînée par un effort dans une grotte à 21°C et pratiquement saturée en humidité ! La tenue de Volodia m'étonna donc. Je lui en fis part. Il m'expliqua qu'effectivement il était très habillé mais comme la plupart du temps on est... arrêté lorsque l'on est sous terre, cela permettait de se sentir très bien dans ces moments-là. Et en effet, je constatai que, sur une quinzaine d'heures d'expédition, la bonne moitié fut consacrée en pauses cigarettes, discussions, pensées philosophiques et métaphysiques...

ONYX SOIT QUI MAL Y PENSE

Un beau matin, alors que la kacha tentait péniblement d'atteindre nos estomacs rebelles, apparaît au bivouac le garde rencontré le jour de notre arrivée. Un autre homme, inconnu de nous, est avec lui. Bulat offre le thé et engage civilement la conversation pendant que Youri s'active aux réchauds et que Andrey, flegmatique, allume une cigarette. En traduction quasi simultanée, on apprend que le garde est venu jusqu'ici dans le but d'obtenir un petit supplément aux bakchichs déjà reçus. Mais, il vient aussi nous annoncer que ce matin, il serait préférable de ne pas nous diriger vers la sortie de la grotte car nous risquerions de nous trouver nez à nez avec une équipe de pilleurs d'onyx en plein travail d'extraction. En effet, ce genre de contact est si possible à éviter. La rencontre fortuite le lendemain d'un autre groupe de mineurs à l'entrée de la grotte de Promeszutochnaya devait d'ailleurs nous en convaincre car ces gens, peu scrupuleux pour ce qui est de la protection des grottes, devaient-ils l'être davantage face à d'éventuels empêcheurs de tourner en rond comme nous, riches de surcroît ? Les armes qu'ils portaient à la ceinture incitaient en tout cas à rester poli avec eux...

Mais là où la situation devient franchement ubuesque, c'est lorsque nous comprenons que l'homme qui accompagne «notre» garde est lui-même pilleur d'onyx ! Comment se fait-il, alors, qu'il se promène tranquillement avec un employé de la réserve ? En principe, celui-ci devrait justement l'empêcher d'agir et protéger les richesses minérales de la grotte. Mais, justement, si les principes sont une chose, la réalité sociale et économique en est ici une autre.

A deux ou trois reprises, les visites surprise du garde au bivouac se répètent. On finit par le trouver presque sympathique car il profite de ses allées et venues pour nous approvisionner en légumes. Parfois accompagné d'autres personnes, il reste un moment, boit le thé, discute longuement, puis repart, les poches un petit peu plus remplies. Notre campement devenant à nos yeux un peu trop visité, nous décidons de ne plus l'abandonner et de laisser, durant nos excursions, une personne en faction. L'éventualité d'une fouille impromptue de notre matériel étant évoquée par notre garde-collabo et puisqu'il nous est répété que chaque photo nous coûtera dix dollars, nous prenons également l'initiative de planquer les pellicules déjà exposées. Un interstice entre de gros blocs situés près du bivouac fait l'affaire.

L'ARGENT, NERF DE LA SPÉLÉOLOGIE EN EX-UNION SOVIÉTIQUE?

Les pourboires s'additionnant aux pourboires et les palabres s'ajoutant au palabres, on finit par s'inquiéter auprès de nos coéquipiers russes de l'importance de ces pots-de-vin. Nous souvenant, de plus, que l'on est ici sans autorisation (ce que les gardes évidemment savent) et sans visa (ce qu'ils ne savent pas...), nous nous demandons jusqu'à quand ce jeu pourra durer. Comme toujours, Bulat se veut rassurant et calme nos inquiétudes. On est presque gênés face à lui, car, avec beaucoup de compétence, il se démène continuellement pour l'ensemble du groupe afin d'aplanir les difficultés administratives rencontrées. En raison des obstacles linguistiques, nous autres Suisses ne pouvons de toute manière rien faire d'autre que d'assister, impuissants, aux négociations. Impossible d'apporter son petit grain de sel dans le but de faire avancer le débat. Au contraire, intervenir compliquerait sans doute les choses.

Au sein de notre groupe, l'entente entre Russes et Suisses est excellente. Toutefois, notre rapport commun avec les questions d'argent reste assez trouble. Précisons que sans la participation de spéléologues russes, jamais nous n'aurions pu venir dans ce coin magnifique mais difficile d'accès. A l'inverse, il aurait été tout aussi impossible à Youri, Andrey et Bulat de réaliser cette expédition sans... notre argent ! Même s'ils sont tous trois enseignants ou chercheurs de niveau universitaire, leurs difficultés économiques (directement liées à celles, immenses, de la Russie) rendaient tout projet de voyage irréaliste. Mieux au courant des coûts que nous, ce sont eux qui, dès le début, établirent le budget de l'expédition. Le fait qu'en réalité le financement de l'expédition allait être assuré presque exclusivement par les Suisses ne fut jamais discuté franchement et clairement. Cette situation ambiguë, bien que pouvant être gênante, ne fut pas un obstacle à nos bonnes relations. Sentant qu'ils ne cherchaient pas à nous arnaquer et voulant éviter de les mettre mal à l'aise, nous avons préféré ne rien dire à ce sujet aux Russes. Eux, n'ont certainement pas osé nous avouer que notre apport financier leur permettait de participer à l'expédition et, peut-être même, d'en retirer un petit gain. Connaissant leur situation à Moscou – Bulat a dû trouver un deuxième puis un troisième job en plus de son poste à l'Institut de géologie pour pouvoir vivre..., nous n'avons pas eu l'indécence de les soupçonner de profiter de nous.

HAPPY (BUT TOO QUICK) END !

En cette fin de journée, le ciel s'embrase. A l'horizon, la boule rougeoyante du soleil s'efface au-dessus des louvoiements de l'Amou-Daria. Pénibles au début de l'expédition, les montées-descentes d'un bord à l'autre des canyons sont devenues, avec l'entraînement, une partie de plaisir. La tête pleine des superbes paysages souterrains découverts et photographiés aujourd'hui, nous marchons d'un pas décidé en direction de la grotte de Cupp-Coutunn où notre humide mais douillet bivouac nous attend. La faim aidant, on se réjouirait presque du porridge vespéral. Arrivés en vue de l'orifice nous apercevons Bulat (qui aujourd'hui surveillait le camp). Il est en compagnie de six gardes parvenus jusque là en camion. Les regards sont noirs et c'est à peine si nous avons le temps de déposer nos sacs à dos qu'une fouille hâtive est entreprise. Immanquablement, le matériel photo apparaît ce qui provoque entre Russes et Turkmènes un échange de propos très vifs. En aparté, Bulat, très tendu, nous enjoint de ne pas parler. Penauds, nous attendons que quelque chose se passe. Interdiction nous est donnée de rentrer au bivouac. Les gardes commencent à s'énerver. L'un d'eux, celui qui semble être le chef, exige soudain nos passeports. Youri tend le sien en expliquant que les nôtres sont au bivouac. Finalement, alors que la nuit tombe, nous prenons le chemin du bivouac avec pour ordre de l'évacuer rapidement. Trois Turkmènes nous accompagnent. Au cours du trajet, Bulat nous apprend que cela fait plus de six heures qu'il parlemente avec les gardes. Il les a rencontré alors qu'il effectuait des mesures climatologiques pas très loin du camp. Un de leurs buts était bien de fouiller notre matériel. Par une série de subterfuges, il a alors cherché à gagner du temps en attendant notre retour. Aux gardes qui voulaient trouver notre bivouac, il indiqua le chemin à suivre en montrant le départ d'une galerie étroite et sinueuse... ce qui était totalement erroné.

Parvenus au bivouac, nous plions bagage avec nervosité. La menace d'une fouille et d'une confiscation étant toujours présente, nous devons trouver une cachette pour le transport des films exposés. Discrètement, nous allons les récupérer sous les pierres où nous les avions dissimulés et dans la pénombre je les glisse dans la poche d'un vêtement de Youri moins suspecté que moi d'en transporter... Le dernier sac bouclé, toute la troupe regagne l'extérieur. Sous un ciel tapissé d'étoiles, nous nous entassons sur le pont du camion. Destination inconnue.

En cours de route, le camion tombe en panne d'essence. Le solde de la benzine utilisée pour nos réchauds est déversé dans le réservoir et c'est reparti, ouf ! A quelques reprises, on s'arrête pour déposer l'un des hommes et finalement, après quarante kilomètres, nous reconnaissons les alentours de la gare de Charshanga. Mais le chauffeur ne nous y dépose pas. Il emprunte une piste et stoppe son véhicule, tous feux éteints, dans un terrain vague situé de l'autre côté des voies de chemin de fer, à quelques centaines de mètres de la station. Il nous indique la gare et nous laisse filer. On ne se fait pas prier et, tel un commando de terroristes, nous rejoignons la station en rasant les murs dans la pénombre. Plus tard, nous comprenons que les gardes craignaient de perdre leur travail car le responsable de la réserve avait eu vent de notre présence dans les grottes. Il fallait donc que nous disparaissions au plus vite.

Quelques heures plus tard, recroquevillés parmi nos volumineux sacs à dos, nous quittons le Turkménistan comme nous y étions entrés : cachés dans un sinistre train de nuit, sans avoir vu autre chose que les beautés souterraines de ce pays. Etrange périple s'il en fût.

Participaient à l'expédition :

Cédric John (SVT), Youri Kossoroukov (Moscow University Caving Club), Andrey Markov (MUCC), Edouard Marmillod (SCPF), Bulat Mavlyudov (MUCC), Jérôme Perrin (GSL), François Pinsard (SVT), Rachel Rumo (SCPF), Rémy Wenger (GS Troglolog).

04 Présentation géographique et géologique des grottes du
Kugitang (Turkménistan, Cédric John et Jérôme Perrin)
Cavernes (Neuchâtel N° 1/2 1995)

Présentation géographique et géologique des grottes du Kugitang (Turkménistan)

par Cédric John (SVT) et Jérôme Perrin (GSL)

GÉOGRAPHIE

Le Turkménistan, ex République Soviétique, située en Asie centrale, est bordé sur sa frontière est par l'Ouzbékistan, et au sud par l'Afghanistan. L'Amou-Daria fait office de frontière naturelle entre Afghan et Turkmen et il a amené la vie dans ces région arides; son exploitation récente pour la culture du coton est à la base de la tristement célèbre catastrophe écologique de la mer d'Aral.

Les grottes que nous avons visitées s'ouvrent dans la région du Kugitangtau, à une quarantaine de kilomètres au nord de la gare de Charshanga, ce qui nous amène à une trentaine de kilomètres de l'Amou-Daria et donc de l'Afghanistan que nous pouvions apercevoir au loin (voir fig.1 et 2).

Kugitangtau est un terme moitié Ouzbek moitié Tadjik signifiant «montagne - canyon - montagne» (vous comprendrez alors pourquoi notre périple fut empli de hauts et de bas !). Dans la vie courante, les locaux emploient uniquement le terme Tadjik de "Kugitang" pour désigner cette chaîne montagneuse, bien qu'il puisse y avoir confusion entre ce lieu-dit, un lac, une rivière et un village !

GÉOLOGIE

La région est constituée, grosso modo, d'un plateau calcaire incliné vers le sud et coupé régulièrement de canyons se prolongeant eux aussi vers le sud (voir fig. 3). Le plateau s'élève jusqu'à plus de 3000 mètres d'altitude, alors que sa "base" est la plaine alluviale de l'Amou-Daria, 2500 mètres plus bas ! C'est absolument magnifique de se promener sur cette surface régulière, lézardée de profonds canyons, et de voir que malgré la pente assez faible (7°), le sommet et la base, tous deux bien visibles, sont fort éloignés : l'un est plongé dans la chaleur étouffante, antichambre du désert du Karakorum, alors que l'autre, couvert de neige, rappelle plus les Tian Shan lointains.

Il n'y a pas de karst au sens propre du terme. Pas de lapiés ni même de dolines ici, seulement ces canyons dans lesquels s'ouvre parfois une petite grotte ou encore l'entrée d'un réseau de plusieurs dizaines de kilomètres.

STRATIGRAPHIE

Le socle cristallin du plateau est constitué de gneiss d'origine précambrienne. La série de 300 mètres de flysch du Trias et du Jurassique inférieur est en discontinuité au-dessus de ces gneiss. Par-dessus viennent les 400 mètres de calcaires de la série du Kugitang datant du Jurassique supérieur, puis vient la série de Gaurduk, épaisse de 200 mètres, constituée de gypse et de calcaires, datant également du Jurassique supérieur. Cette série affleure très bien près de l'entrée des grottes.

Pour finir, la série de Gaurduk est couverte en discontinuité par des roches du Crétacé.

HISTOIRE KARSTIQUE

La première évidence est que les cavités sont plus anciennes que les canyons, et c'est au cours de la formation de ces derniers que l'entrée de la plupart des grottes ont «vu le jour».

D'autres observations, tant souterraines que superficielles, ont permis de démontrer l'existence de trois phases karstiques successives :

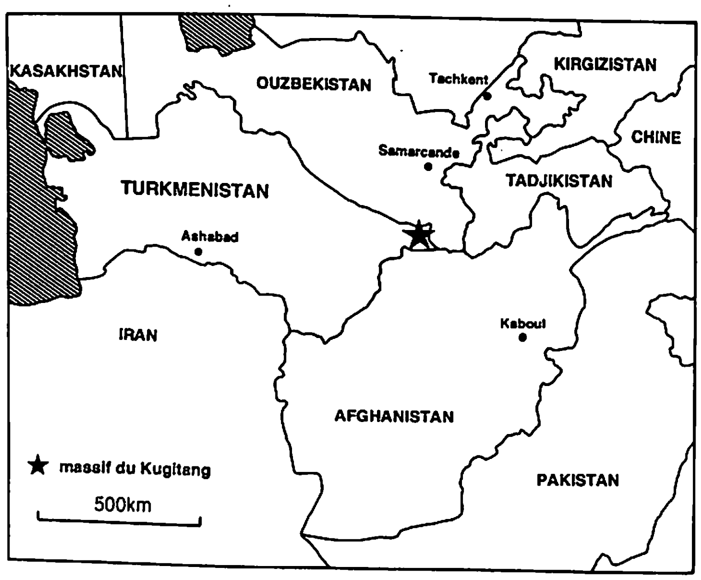


Fig. 1 : Situation géographique du Turkménistan et du massif du Kugitang

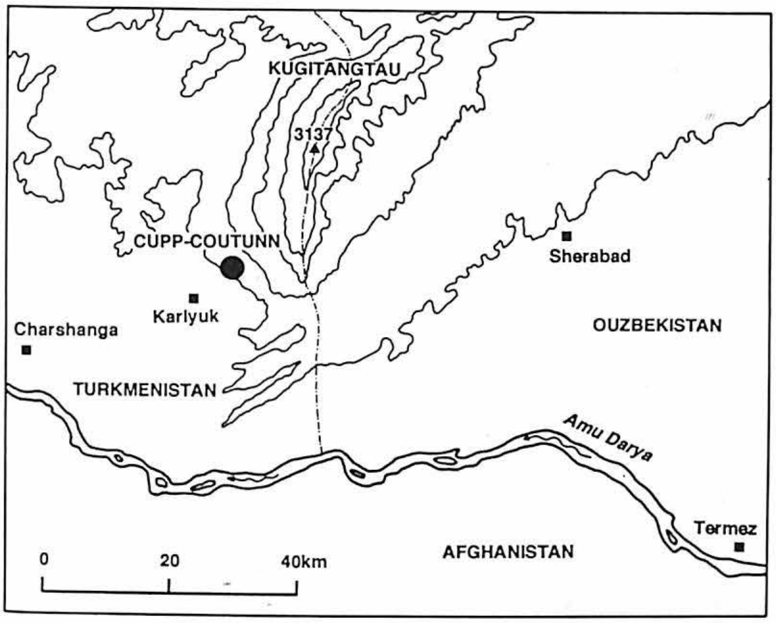


Fig. 2 : Plan de situation du réseau de Cupp-Coutunn au carrefour de l'Afghanistan, de l'Ouzbékistan et du Turkménistan

1. Karstification ancienne

En Asie centrale, une très ancienne période de karstification précédant la formation des montagnes a existé. L'âge proposé pour cette période est mi-Crétacé (environ 85 millions d'années !!), un âge plus récent est cependant possible...

Dans le réseau, on a pu trouver plusieurs preuves que cette première phase est antérieure à l'orogenèse alpine s.l.: ce réseau primitif était de type phréatique comme le montre le plan de la cavité principale (Cupp-Coutunn). Paléogéographiquement, cette nappe phréatique était influencée par une étendue d'eau salée dont la mer Caspienne serait le dernier témoin.

Les réseaux phréatiques se sont développés parallèlement aux strates. Trois étages principaux correspondant à des variations du niveau de la nappe phréatique sont visibles dans Cupp-Coutunn. De plus, si le pendage des couches n'avait pas été horizontal, le drainage aurait été mieux organisé.

Au Crétacé terminal, on enregistre une transgression de la mer sur le continent qui correspondrait au remplissage du réseau karstique. Les sédiments témoins que l'on retrouve actuellement montrent le même pendage que la stratification, soit 7°. Des poches paléokarstiques dans le flanc des canyons montrent le même phénomène.

2. Phase de régénération

Pendant le Néogène se produit l'orogenèse du Kugitangtau.

Le remplissage argileux est en partie évacué par des infiltrations d'eau du plateau à la faveur de grandes failles méridionales, on remarque que les écoulements se situent préférentiellement à l'ouest de ces failles, zones où l'on trouve les cavités actuellement accessibles.

Cette phase mi-quaternaire semble relativement brève : on passe rapidement de conditions phréatiques à un régime vadose, puis sec ; le calcaire n'a pratiquement pas été érodé lors de cette période.

Finalement, des eaux thermales empruntant les failles méridionales envahissent les galeries nettoyées d'une partie de leurs sédiments ; ces eaux altèrent le calcaire et les remplissages tout en déposant des minéralisations particulières : calcite, fluorite et sulfures métalliques.

Ces cavités se distinguent d'autres cavernes aux minéralisations extravagantes, telles Carlsbad ou Lechuguilla, par des eaux thermales en phase évolutive terminale : elles ont perdu leur pouvoir corrosif et montrent une concentration élevée en éléments rares (A Lechuguilla, les eaux thermales ont pris une part prépondérante dans le creusement de la cavité).

3. Phase moderne

Les parois des cavités se corrodent essentiellement par condensation : l'air souterrain contient des gaz tels CO_2, H_2S, SO_2 et HF (!!!) qui sont dissouts dans l'eau de condensation ; le matériel soluble s'en va et les insolubles forment des croûtes oranges.

Les crues irrégulières amènent des sédiments de la surface et perturbent les remplissages des cavités.

De grandes quantités de gypse et de calcite précipitent.

MINERALOGIE

La minéralogie souterraine de cette région est certainement des plus fascinantes. V.A.Maltsev recense plus de 100 espèces minérales différentes qui ont pu être classées génétiquement en 3 phases :

1. Phase thermale

On trouve de la calcite cristallisée entre 100 et 150°C à inclusions de galène métacinnabre et oxyde de manganèse, de la fluorite en croûte pourpre cristallisée vers 80°C. Le calcaire

Le plateau incliné du Kugitang avec au second plan un canyon et au fond le sommet du massif (3137 m). Photo Rémy Wenger

Cristallisation de gypse se développant à partir du sol (hauteur: environ 30 cm). Promeszutochnaya (photo Rémy Wenger)

des parois a été corrodé sur environ 1 m et le résultat de cette corrosion a recristallisé partiellement en calcite, en sulfures et en silicates (plagioclase).

2. Phase post-thermale

Les argiles provenant de l'altération des parois calcaires montrent de l'illite, de l'hématite, de la goethite, de la kaolinite et du sable de gypse.

Des produits de la phase thermale sont «retravaillés» en spéléothèmes : on note des paragenèses à cérusite-aragonite, de la sauconite nickelifère, de la fraipontite (!), des «excroissances» de célestine sur calcite ainsi que de la tyuyamunite (minéral radioactif...) déterminée visuellement (douteux!).

3. Phase moderne

On assiste à une croissance classique de spéléothèmes : les dépôts de type calcite englobent la mangano-calcite, la calcite magnésienne, la dolomite, l'ankérite, la sidérite, l'aragonite et l'hydromagnésite.

On observe de grandes quantités de gypse sous toutes ses formes : en croûtes, en stalactites, en chandeliers, en stalagmites creuses, en cheveux, en aiguilles...

Le gypse a deux origines distinctes : on a d'une part le gypse qui provient des formations rocheuses superficielles et d'autre part le gypse créé par l'H_2S attaquant le calcaire.

On peut trouver dans les parties les plus sèches l'halite, l'epsomite, la mirabilite et... le salpètre qui trouve son origine profonde dans le guano de chauve-souris !

SPÉLÉOLOGIE

Parlons tout d'abord du climat souterrain. Toutes les grottes de la région bénéficient d'un climat particulièrement agréable: il y fait entre 18 et 22°C. On s'y sent donc très bien en short et T-shirt !

Ensuite, la morphologie des galeries est principalement de type grande galerie avec plusieurs mètres, voire dizaines de mètres de diamètre. Rares sont les endroits où il faut ramper, mais ils sont également fort craints car c'est un véritable supplice que d'enfiler une combinaison ou un pull dans cette atmosphère pour progresser.

Les galeries sont aussi fréquemment labyrinthiques, ce qui donna lieu à plusieurs visites "prolongées".

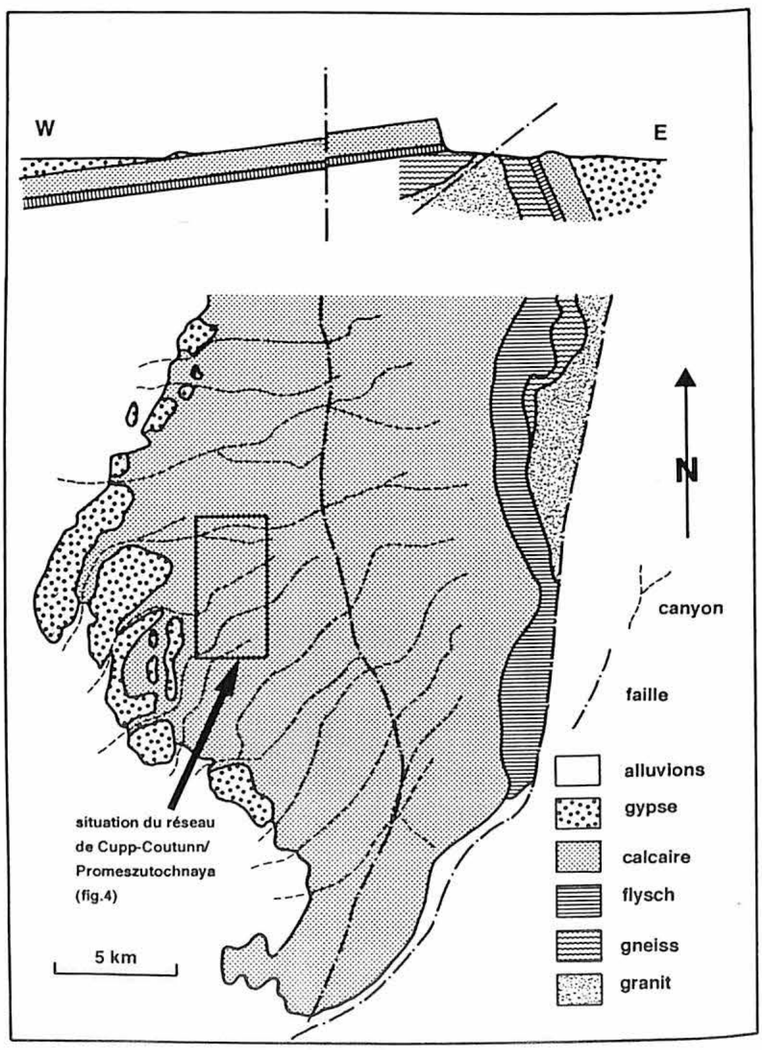


Fig. 3 : Géologie du massif du Kugitang

Nous avons visité plusieurs grottes, à savoir Cupp-Coutunn, Promeszutochnaya, Geophyzicheskaya, Tush-Yurruck et Hushm-Oyeek (voir fig. 4). Nous allons tenter de décrire brièvement chacune d'elles.

Cupp-Coutunn - Promeszutochnaya

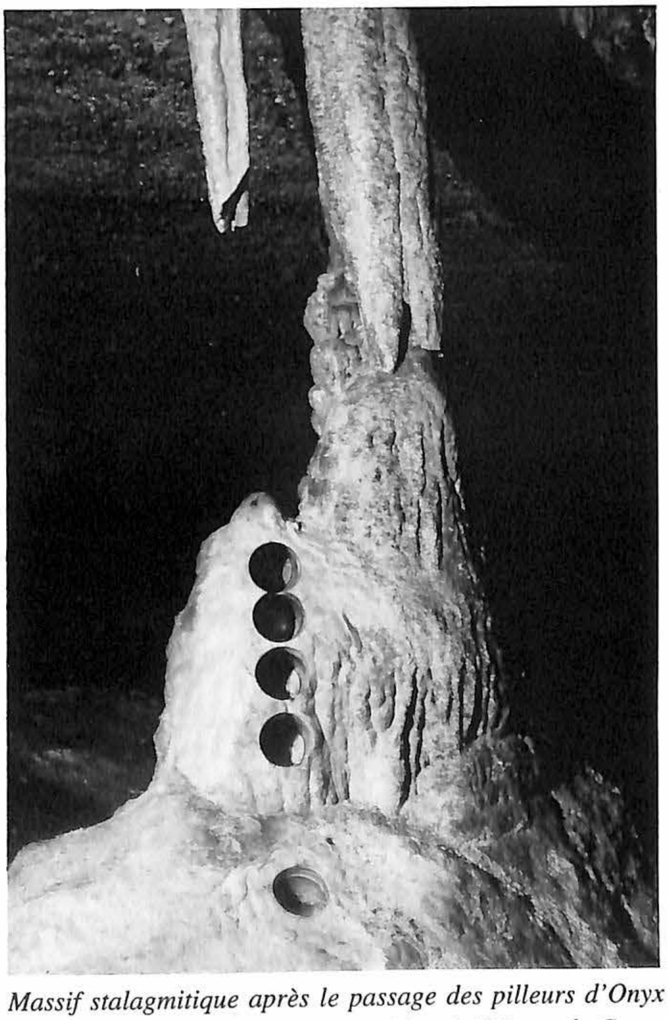
Cupp-Coutunn : 27 km

Promeszutochnaya : 25,5 km

Cupp-Coutunn et Promeszutochnaya sont maintenant jonctionnées et forment un seul réseau, le plus grand de la région. Cependant, comme la liaison souterraine est très pénible, nous les avons visitées séparément.

Cupp-Coutunn ("la bergerie", en Turkmen) est la grotte dans laquelle nous avons élu domicile (avec 3 autres groupes, notons-le !). Elle possède de superbes galeries par leur taille et leur forme, et le sol de la cavité est fréquemment couvert d'un sable argileux très fin.

Cupp-Coutunn a des caractéristiques qui la rendent malheureusement fort attrayante pour les gens locaux : d'accès facile, elle possède une grande quantité d'onyx calcique. C'est pourquoi, en plus de l'entrée naturelle, un tunnel a été creusé pour permettre la sortie massive du (semi-) précieux matériau.



Massif stalagmitique après le passage des pilleurs d'Onyx calcitique... (diamètre des trous : 13 cm). Réseau de Cupp-Coutunn (photo Rémy Wenger)

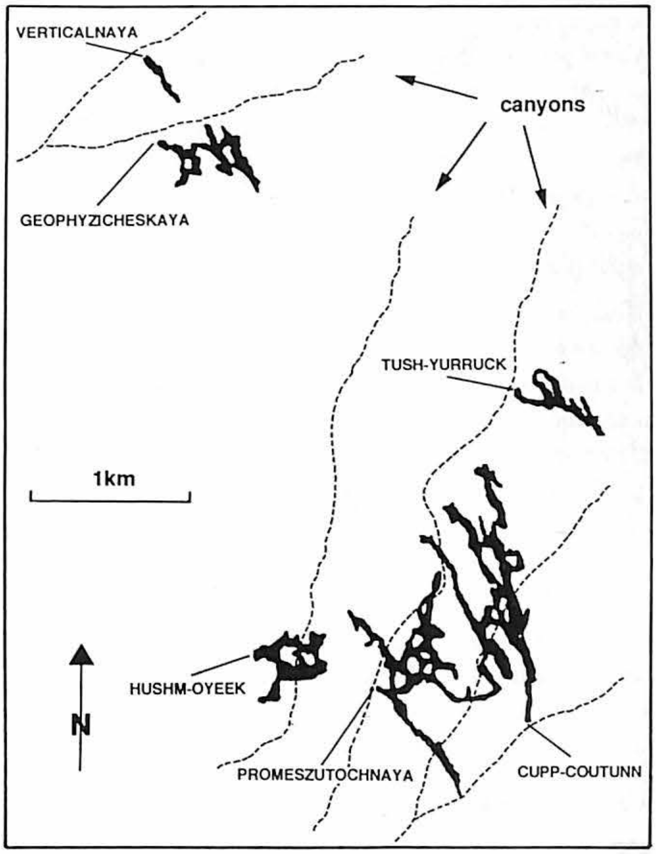


Fig. 4 : Situation des cavités du massif du Kugitang. Les réseaux souterrains se développent souvent sous des canyons profonds de 200 à 300 m.

C'est donc en grande partie une grotte saccagée qui s'offrit à nous: concrétions sales, trouées ou cassées pour l'exploitation d'onyx ... et passons sur les latrines !

Elle recèle cependant, dans ses parties les plus éloignées, un cachet qui sut nous charmer, avec d'immenses galeries et de superbes remplissages.

Promeszutochnaya, elle, est bien mieux préservée puisque, après une centaine de mètres de progression facile, il faut se pencher (les "chasseurs" d'onyx ne semblent pas pousser la témérité jusque là !). En plus, comme la plupart des grottes de la région, son aspect labyrinthique rebute tout visiteur inexpérimenté.

Le sol et les parois sont couverts d'une argile rouge très semblable, à ce que me dirent certains, à la "merde de gorille" de Lechuguilla.

Certains endroits sont bien préservés et l'on peut y admirer des concrétions étonnantes. Le gypse est l'espèce minéralogique la mieux représentée et ses concrétions ont, selon V.A. Maltsev, une genèse intéressante.

Parmi celles-ci, citons des stalagmites de gypse qui s'élèvent à quelques centimètres au-dessus du sol. Elles sont creuses et ne possèdent qu'une mince paroi de gypse.

Cet aspect particulier serait lié au degré d'humidité qui varie avec les saisons : lorsque l'humidité est grande dans la concrétion, le gypse est dissous et traverse sous cette forme la paroi, pour précipiter à l'extérieur lorsque le degré d'humidité a diminué, accroissant ainsi le diamètre de la concrétion et évidant son centre. Ceci ne nous explique évidemment pas encore comment une stalagmite de gypse peut s'élever audessus du sol, car le modèle "classique" de la stalagmite de calcite n'est pas applicable ici (ne serait-ce que parce qu'il n'y a pas d'arrivée d'eau au-dessus).

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Disons encore de Promeszutochnaya qu'elle recèle en son sein un minéral parfaitement inconnu, mesurant environ un centimètre de long et que personne ne veut prélever pour analyse puisqu'il est unique ! Avis aux amateurs...

Geophyzicheskaya

Dév. : 4,5 km

Geophyzicheskaya, la grotte des "géophysiciens", est probablement la plus sublime et mieux conservée de toutes celles qu'il nous à été donné de voir.

Ce sont les concrétions de cette grotte qui la rendent si belle.

Le gypse y est omniprésent: grands chandeliers, monocristaux, croûte épaisse de plusieurs dizaines de centimètres tapissant sol et parois, stalagmites...

Mais la forme la plus étonnante qu'il nous à été donné d'y voir reste probablement ce tapis de fines aiguilles de gypse longues de plusieurs centimètres et s'élevant du sol, défiant à la fois gravité et logique. Nul ne peut expliquer leur développement : ce ne peut être par capillarité que l'eau monte et fait pousser la concrétion, l'aiguille n'a pas de canal central !

Geophyzicheskaya possède aussi une bonne quantité d'aragonite sous forme de buissons hélicoïdaux.

En plus, nous avons observé dans cette grotte exceptionnelle de la fluorine, de la célestine et de l'hydromagnésite, tous trois des minéraux fort rares sous terre.

Tush-Yurruck

Dév. : 3,2 km

C'est par un sentier de porcs-épics que l'on parvient aux parties profondes de cette grotte. Là encore, il y a profusion de concrétions de gypse, comme des stalactites, quelques colonnes et de très beaux cristaux tapissant les parois.

Hushm-Oyeek

Dév. : 7 km ; **dén. :** 170 m

Hushm-Oyeek, la dernière grotte que nous ayons visitée, n'est cependant pas la moindre.

D'abord, parce que c'est la seule qui présente une dénivellation digne de ce nom. La grotte débute en pente d'éboulis assez raide, et, là encore, les proportions des galeries sont plus qu'honorables : plusieurs dizaines de mètres de diamètre. A la base de l'éboulis, vous vous trouvez environ à la cote -100.

Ensuite, parce que la grotte s'ouvre au beau milieu d'une petite plaine et non dans un canyon. S'il y a une chose qui ressemble le plus à une doline, c'est bien l'entrée d'Hushm-Oyeek.

Enfin, les concrétions, bien que de gypse, une fois de plus, sont à proprement parler sidérantes.

Il y a profusion de colonnes de gypse creuses, souvent ouvertes à certains endroits, ce qui nous a permis de nous glisser à l'intérieur et de faire des photos en "lumière intérieure". Si vous cherchez des orgues de gypse dans une salle aux dimensions de cathédrale, je vous recommande cette grotte.

En plus de ces formes "classiques" (on finit par être blasé de tout !), Hushm-Oyeek nous réservait une petite surprise : un tronc de concrétion de gypse, évidé par dissolution, large de quelques trois mètres de diamètre, s'enfonçait dans le sol et nous offrit la splendeur des cristaux qui tapissaient sa surface.

Malheureusement, la blancheur immaculée du gypse était troublée par des slogans, qui bien qu'en cyrillique, n'en étaient pas pour autant esthétiques. Mais certains (rares) endroits conservaient leur beauté virginale.

CONCLUSIONS

Les grottes du Kugitang sont sans conteste d'un très grand intérêt, tant scientifique que spéléologique.

Scientifique par leur minéralogie étonnante, leur genèse hydrothermale et leur équilibre chimique unique.

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fell to the floor of cave lakes when a frequent drip destroyed their surface tension support. The cave system is also known for its finds of cultural material left by the prehistoric inhabitants of Cuba, including the engravings in Cueva de Mesa and a human skeleton dated to 3000 years in Cueva de la Incógnita. The upper levels of the cave also have extensive accumulations of Pleistocene animal bones. For its multiple geological, paleontological, prehistorical, and historical values, the Gran Caverna de Santo Tomás was recognized as a national monument of Cuba in 1989.

Several caves in the Pinar del Rio, La Habana, and Matanzas provinces have been developed as tourist sites. These include Cuevas de Bellamar and Cueva Grande de Santa Catalina, both located in raised terraces in Matanzas. Both caves are also important for their speleothems, particularly for very large calcite crystals as well as large cones and mushrooms of fallen cave rafts.

ANDRZEJ TYC

See also **Caribbean Islands**

Further Reading

Nuevo Atlas Nacional de Cuba. 1988. La Habana: Instituto de Geografía de la Academia de Ciencias de Cuba

Núñez Jiménez, A. (editor) 1984. *Cuevas y carsos*, La Habana: Editoria Científico-Técnica; 2nd edition, 1990

Núñez Jiménez, A. 1990. *La Gran Caverna de Santo Tomás: Monumento Nacional*, La Habana: Ediciones Plaja Vieja

Panos, V. & Stelcl, O. 1968. Physiographic and geologic control in development of Cuban mogotes. *Zeitschrift für Geomorphologie*, 12(2):117–73

Pulina, M. & Fagundo, J.R. 1992. Tropical karst and chemical denudation of Western Cuba. *Geographia Polonica*, 60:195–216

Schenck, J.E., Porter, Ch. & Coons, D. 1999. NSS expedition to Cuba. *NSS News*, October 1999

CUPP-COUTUNN CAVE, TURKMENISTAN

Cupp-Coutunn, the longest limestone cave in the former Soviet Union, is located in the Kugitang region of eastern Turkmenistan, close to the borders with Uzbekistan and Afghanistan. The cave is internationally famous for its mineralogy, both in the number of mineral species and in the great variety of its speleothem forms. In 1991, Cupp-Coutunn and its associated caves were placed on the Global Indicative List of Geological Sites (GILGES) by a working group of the World Heritage Convention.

The Cupp-Coutunn cave system (Figure 1; Maltsev & Self, 1992) is located on the southwestern flank of the Kugitangtau ridge, which runs north-south for some 50 km and attains an altitude of 3137 m. Low hills to the north connect the Kugitangtau ridge to the southwestern end of the Tien Shan mountain chain, from which it appears topographically as an outlier. The Kugitangtau is an anticlinal dome with a granite batholith intruded into its core. A major fault, the Eastern Kugitang Upthrust, along the north—south major axis of the anticline, separates the uplifted Kugitangtau from the Uzbek plain to the east. The Kugitangtau cuesta presents a scarp face over 1 km high, topped with a near-vertical wall of upper Jurassic limestone. The dip slope to the west is a gentle 7° to 15°, deeply dissected by canyons. This dip slope is cut by a second major fault, subparallel and of opposite throw to the Eastern Kugitang Upthrust, leaving the central spine of the ridge as a horst block.

The caves of southern Kugitangtau show a complex history. They developed as an extensive phreatic maze, following the then horizontal bedding in the limestone on several levels, probably in late Cretaceous times. These passages were subsequently abandoned as conduits for groundwater flow and infilled with argillaceous sediments. Neogene uplift and tilting of the strata rejuvenated the caves. Detrital deposits were locally eroded by groundwater introduced via a north—south fault set, though in places the consolidated remains of this ancient filling are retained as the walls or roof of the cave. New passage development was restricted to invasive tubes in the immediate vicinity of these faults. The air-filled passages were then invaded by thermal water entering from another (Chilgas) fault set, with chemical alteration of the cave wall rocks and sediments. Alteration effects include recrystallization of the limestone and replacement of carbonates by other minerals, mostly silicates and sulfides. Small amounts of hydrothermal calcite and fluorite were locally deposited within the cave, the calcite sometimes containing microscopic inclusions of metal sulfides. The thermal fluids do not appear to have been particularly aggressive, as no significant passage enlargement has been noted. Stable isotope analysis of rock and mineral samples suggests that the thermal water was an evolved basinal brine (Bottrell, Crowley & Self, 2001).

During the mid-Quaternary, there was some movement of the Chilgas faults. This caused the displacement of cave passages crossed by these faults, and collapse in some of the larger airfilled passages. The modern phase of development is marked by condensation corrosion of the cave walls and roof, the reworking of material from the thermal phase, and the deposition of speleothems. For the most part, the caves are independent of drainage from the surface, though some canyons have cut their beds deep enough to intersect the caves. However, the Kugitang region is semi-arid and significant quantities of water enter the caves about once per decade, locally introducing alluvium or reworking the older sediments.

The international importance of the Cupp-Coutunn cave system is in its speleothem mineralogy, which has been entirely deposited during the post-thermal phase of the caves' development. Some very rare minerals have been formed by the reworking of material from the thermal phase, whether this material was deposited in the cave itself or as vein minerals in fractures crossing the cave. Particularly interesting are zinc alumino-silicates, which are coloured green by trace quantities of nickel. Sauconite was the first to be identified, and then the very rare fraipontite (with only a few occurrences known worldwide, this is its first report as a cave mineral). Si and Al mobility is due to acidic gases released from a red, clay-like coating (ochre) on hydrothermally altered wall rock. Ochre is a variable but stratified material, with sulfate-reducing bacteria in the lower layers and oxidizing bacteria in the outer layers. It is more like a soil than a classic corrosion residue and various secondary oxide and silicate minerals have been identified within it (Maltsev, Korshunov & Semikolennykh, 1997). Hydrogen sulfide produced within the ocker is oxidized to sulfuric acid, which in turn attacks crystals of thermal phase fluorite. Gaseous hydrogen fluoride is released into the cave air, the evidence for this being tiny dark purple crystals of fluorite that have been found growing on calcite helictites and on euhedral gypsum crystals (Maltsev & Korshunov, 1998).

Cupp-Coutunn has spectacular displays of speleothems of the more common cave minerals. Where surface water infiltrates from canyon floors or from north—south faults, there are calcite stalactites, stalagmites, and even shields. A particularly beautiful banded flowstone (marble onyx) was commercially mined from 1970 until 1982, with three mine adits cut into the cave to provide easier access. The mining was finally halted following a campaign led by Moscow and Ashkhabad cavers. Aragonite is a main speleothem mineral in some parts of the cave, often in association with calcite. This association produces some of the most photogenic speleothems, such as quill anthodite bushes and multi-corallite splays (Figure 2). Helictites are abundant, sometimes with euhedral crystals of clear gypsum or blue celestite growing on their sides. Gypsum is found in most parts of the cave, as beards, flowers, crusts, chandeliers, and as large hollow stalagmites. Rare speleothem forms include solid crystalline stalagmites of gypsum, aragonite pseudo-stalactites, and macro-crystalline calcite stalactites.

Cupp-Coutunn/Promeszutochnaya (combined length 56 km) is part of a more extensive karst system that is still largely filled with ancient sediments. Nearby, and recognized as part of the Cupp-Coutunn system, is Geophyzicheskaya (length 4.5 km, with spectacular gypsum chandeliers) and Hashm-Oyeek (length 7 km, first reported by Diodorus Siculus *c.* 40 BC). Dozens of other cave fragments have been found in neighbouring canyons throughout southern Kugitangtau. The area was once very popular with Russian cavers, but there have been few expeditions since Turkmenistan became an independent country.

Vladimir Maltsev's team (Moscow) was pre-eminent in both the exploration and the scientific study of the caves during the late Soviet period. Much of our modern understanding of ontogeny is based on speleothem observations made in these caves.

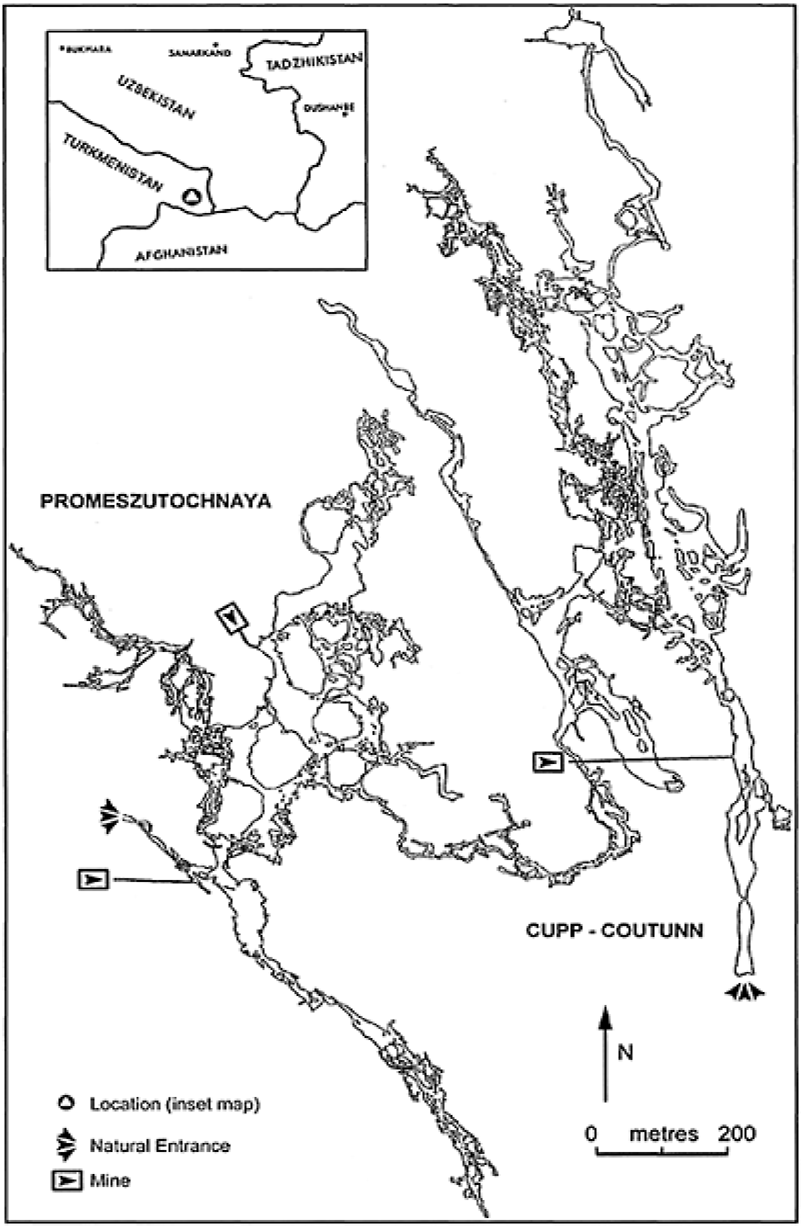
CHARLES ANTHONY SELF

Works Cited

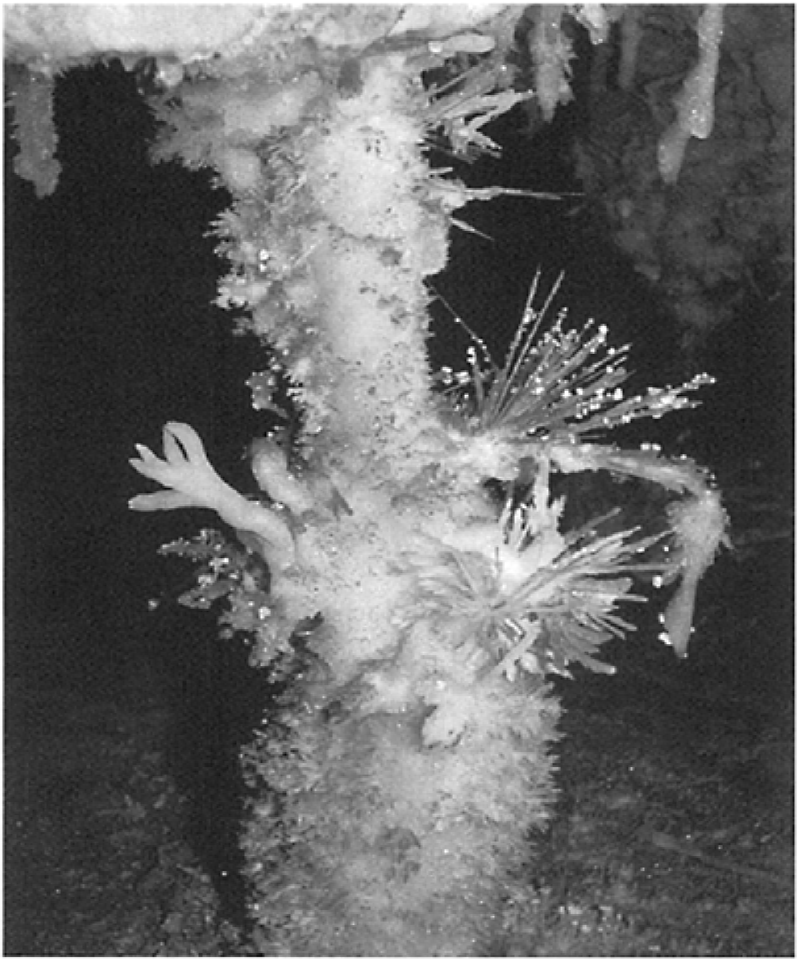
Bottrell, S.H., Crowley, S. & Self, C.A. 2001. Invasion of a karst aquifer by hydrothermal fluids: evidence from stable isotopic compositions of cave mineralization. *Geofluids,* 1:103–21

Maltsev, V.A. & Korshunov, V.A. 1998. Geochemistry of fluorite and related features of the Kugitangtou ridge caves, Turkmenistan. *Journal of Cave and Karst Studies,* 60(3):151–55

Maltsev, V.A., Korshunov, V.A. & Semikolennykh, A.A. 1997. Cave chemolithotrophic soils.



Cupp-Coutunn Cave, Turkmenistan: Figure 1. Cave survey (plan) and area map.



Cupp-Coutunn Cave, Turkmenistan: Figure 2. A calcite column has been overgrown by corallites (calcite), multi-corallites (calcite, aragonite, hydromagnesite), a branching helictite (aragonite), and a multi-corallite/spathite hybrid (the bent arm-like protrusion on the right). Aragonite spathites grow independently from the cave roof. (Photo by Charles Self)

Proceedings of the 12th International Congress of Speleology, vol. 1, Basel, Switzerland: Speleo Projects: 29–32

Maltsev, V.A. & Self, C.A. 1992. Cupp-Coutunn cave system, Turkmenia, Central Asia. *Proceedings of the University of Bristol Spelaeological Society,* 19(2):117–49

Further Reading

Maltsev, V.A. 1993. Minerals of the Cupp Coutann karst cave system, Southeast Turkmenistan. *World of Stones,* 1:5–30

A detailed description in English with many colour photographs.

Maltsev, V.A. 1997. Cupp-Coutunn Cave, Turkmenistan. In *Cave Minerals of the World,* 2nd edition, C.A.Hill & P.Forti, Huntsville, Alabama: National Speleological Society

This book contains more than fifty other references to the cave in the main text.

http://fadr.msu.ru/~wkor/maltsev/kugitang-caves.htm

A very well-constructed site with many photographs.

On a Plateau in Turkestan

Jim Birchall continues his survey of the major caving regions of the USSR with an account of a visit to Soviet Central Asia. The area's vast caving potential, which has already seen several British expeditions, is described.

IT'S 'say goodbye time' as you enter Soviet Central Asia. Say goodbye to your last decent cup of tea, your last decent sit-down toilet, of being in control of the events in your daily life, of knowing what's going on or what's going to happen. It was almost say goodbye to Ben Lyon, as we left him behind in a toilet in Samarkand.

On a typical Anglo Soviet Expedition it usually takes about 24 hours to find out what's gone wrong. Are we going to the right location, has the advanced equipment arrived, do we have donkeys, has somebody found a water supply, are there any other foreign caving groups in the area, and have the locals got the message that we don't want millet? Actually, the really serious problems are the ones you don't get told about, such as that our return flight is from Tashkent but our visas are only valid for Samarkand. Or, although we have a truck and donkeys to get us onto the plateau, we have nothing arranged to get us down as it coincides with market day in Dushanbe and all the trucks and donkeys are going there. On this occasion, all our advanced equipment and food was on the wrong side of the plateau and they had, indeed, brought bags of millet.

Eventually, it's lorry time. You always end up bouncing in an open lorry that's an MOT nightmare, hanging on for dear life as it drives up goat tracks or washed out mining roads that just about cling to the side of some cliff. Just the sort of thrill that some people would pay a lot of money for at Blackpool funfair.

As Bob Dylan says, 'It was in the Darkness of the Night' that it all eventually came together on the top of the Kirktau Plateau, just east of Samarkand in Uzbekistan. We had eleven British, two Swiss, and six Russian cavers, plus three Uzbeki donkey drivers, one translator from Magnitogorsk, and all our advanced equipment, on a flat campsite next to a waterhole. We crashed out to be ready for the next day, but John Gunn set about his science regime. Up at 6am for breakfast and all out of the camp by 7am. Main meal at 6pm, and everybody to log in what they had done that day, John to assess the data. Our first job was to survey the plateau and find the virgin territory.

For calculating the survey data we had a British owned, Japanese calculator, programmed by a Swiss caver with data input by Lancashire lads. That, plus all the first day classical mistakes of reading the percentage scale instead of the clino scale, of double inputting the magnetic declination, and of getting the XY, north/south, east/west axis back to front, led to an internationally confusing situation. You could hear John Gunn's science tent getting more and more upset that night, but it was soon sorted out and John proceeded to plot a detailed survey of the plateau.

The surface of the Kirktau Plateau is covered with well-developed classic karst features such as dolines, karren and dry valleys. In places it is littered with cave debris, calcite formations, and truncated cave passages. Nearly all the remaining caves are vertical potholes with little horizontal development.

The obvious holes had already been explored and tagged by previous Russian exploration teams, so we proceeded to garden at the bottom of unexplored dolines. Eleven new caves were found. One night Karl Lunt wandered back into camp.

'I think I've found something new - it's a shakehole with a 10 second drop.'

Anne Hodgson logged the subsequent exploration of Moon Hole as 'a most surprising find. A huge earthy shakehole about 40m in diameter funnelled down to a black hole roughly oval in shape (4m by 3m).' Stones thrown down the shaft seemed to suggest a long drop. The area around the shakehole was almost devoid of belay points, and the funnel proved to be full of loose rocks. Eventually, a descent was made by bolting down the shaft as rocks whistled past the explorers, the theory being that to stay near the wall was safer and shorter spaces between rebelays meant more chance of surviving a cut rope. The bottom was reached at -73m. Another shaft seemed to run parallel, but it was not explored. There were two chambers, but no way on.

The shakehole entrance to Moon Hole that funnels down to a 73m shaft on the Kirktau Plateau. _Photos: Jim Birchall_

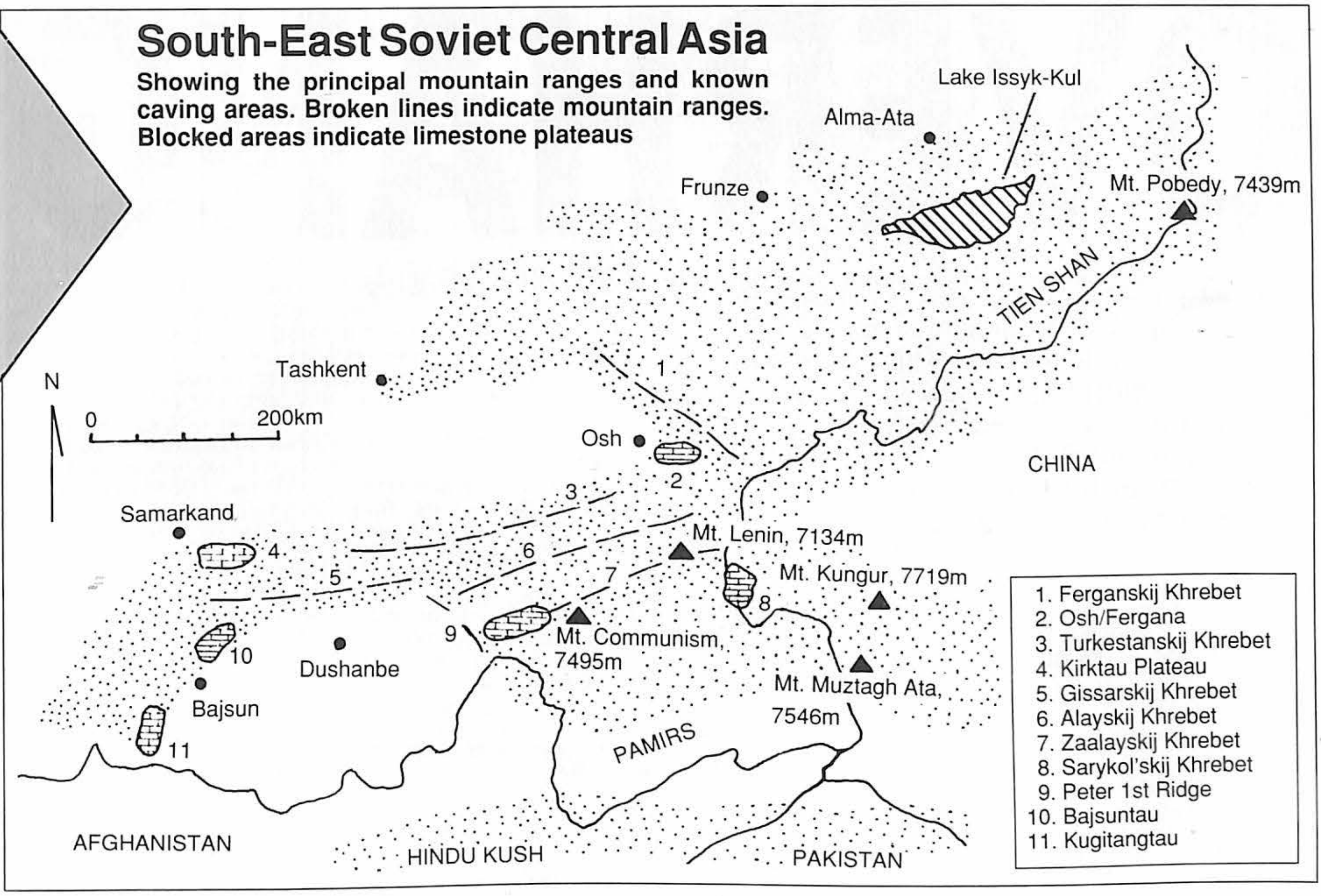
Fridge Pot was first explored by Russian cavers. We found it snow-plugged at about -15m, but a way down one side was located using a Russian titanium ice screw for a belay. The cave dropped through a series of pitches to -56m, ending in an impressive snow-filled chamber: The Ice King's Hall. There were no obvious ways on.

The cave of Kievskaja is situated at the far end of the plateau, about an hour's walk from the camp. It is some 3km long, but of indeterminate depth, having been surveyed on several occasions, resulting in conflicting data. The 'official' depth is 990m. The entrance is via a tight passage between collapsed blocks, leading to the first of a series of pitches that end in sumps. We descended it to -700m, which was as far as we could go with the tackle we had available, not having intended to bottom it.

By the end of the expedition we had decided that the only thing that moved fast in Uzbekistan was Jim Birchall when a snake got in his tent. Ben Lyon sorted it out with an aluminium teapot. During our last days there, Ben stood on the eastern edge of the plateau and looked across to the distant snow-capped mountains of the western edge of the Pamirs and pontificated 'There's caves out there and I want to get into those mountains.'

'Is not possible,' said Misha. 'The area is closed and we do not know about it.'

Much later, in Samarkand, we met two Russian climbers who had sneaked out of Uzbekistan into the mountain area we had been fondly gazing at. We bought them a beer in the Intourist Bar, and proceeded to chat them up. In return, they recounted the cave entrances they had seen. We applied for and received permits and visas to explore in this region, and an Anglo Soviet Caving Expedition to the Peter 1st Ridge should have been completed by the time this report appears.



Soviet Central Asia

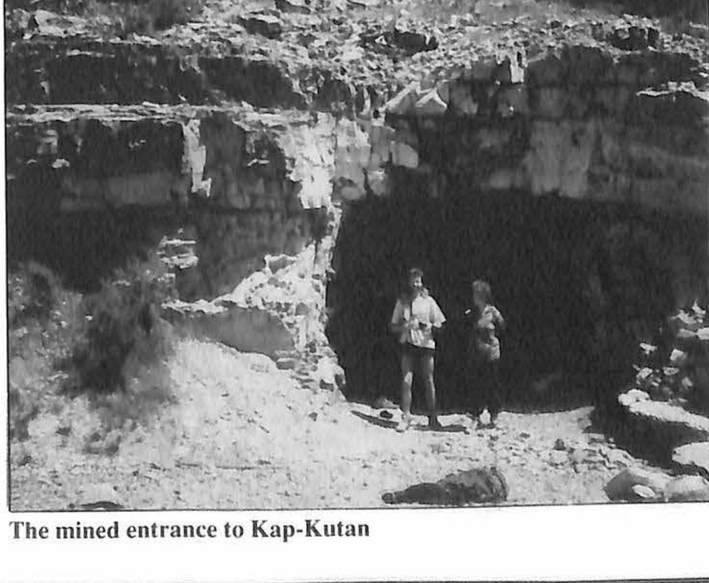
Culture

Soviet Central Asia, or Soviet Turkestan as it used to be called, is a land apart from the rest of the Soviet Union. Basically, it is hot, dry, and mainly a lowland desert with a high mountain region in the south-east. It is in the mountain regions that caves are found. The area contains most of five soviet republics: Turkmenistan, Uzbekistan, Kirghizia, Tadzhikistan, and Kazakhstan. Ethnically, it is a mixture of Turkmens, Uzbeks, Kazakhs, Kirghizes with a traditional Islamic background, along with Russian and Ukranian settlers, and large wandering groups of Latvians, Lithuanians and Estonians, all of which makes for a confusing culture.

Ecology

Ecologically, it is becoming a disaster area. The Aral Sea is almost dead, having lost 60 per cent of its water, and its main fishing port is now 60km from the coast. Too much water was extracted from the two main rivers that flowed into the sea. The reduced sea is beginning to have a knock-on effect on the rest of Asia; it could affect the snowfall in the Himalaya, and the run-offs into the Indus and Ganges rivers. A potential ecological crisis will occur if the region turns to extracting water from Siberia in the north, as this in turn will affect the Arctic ice cap in northern Siberia.

As if that is not enough, in the north-east of the region there is an atomic weapons testing site, and in the science city of Ust'-Kamenogorsk there has been a nuclear fuel plant explosion leading to widespread radioactive contamination.



The mined entrance to Kap-Kutan

The caves

Soviet Central Asia covers a range of extreme caving conditions including the nature of the cave, its altitude and temperature. Kap-Kutan/Promezhutochnaja (54km) is mainly horizontal, while Boj Bulok (-1,368m) is sloping and Kievskaja (-990m) is vertical. Beneath the desert plain at about 600m asl, Provull is totally sumped while the rift cave of Rangkul (-350m) is high on a Pamirs mountain slope at 4,400m asl. Temperature extremes exist from the hot and dry Kap-Kutan/Promezhutochnaja to the ice-locked Baysun and Pamirs alpine caves. Add to this, the caves themselves range from limestone, through gypsum, to salt.

The regions

Bajsuntau: There are several limestone ridges and plateaus some 25km north of Bajsun. The Khetmen Chapty Plateau has the single Uralskaja cave (-580m), consisting of a series of deep shafts to -317m, then a long, meandering active streamway 2,200m long. The Hodja Gur Gur Ata Plateau has a 35km long/300m high limestone wall, riddled with cave entrances such as Festivalnaja (12km/-620m) and the recent British find of Dark Star (4km/-168m). Chul-Bair Plateau contains the narrow, meandering Boj Bulok (-1,368m).

Khodjha Mumyn: A salt dome in Tadzhikistan containing several salt caves such as Dnepropetrovskaja (2.5km), Soljenoc Chudo (870m) and the Vershynnaja Shaft (-121m).

Kirktau Plateau: A well explored plateau some 50km south-east of Samarkand with over 100 logged vertical caves, the deepest of which is Kievskaja (-990m). There are some spectacular karst features, with summits up to 2,500m asl.

Kugitangtau: This region consists of a gentle mountain ridge some 50km long, dissected by deep, long, meandering canyons with several mainly horizontal gypsum and limestone systems. These are hot, dry, and stunningly decorative with unique mineral formations. The main caves are the Kap-Kutan/Promezhutochnaja system (54km), Geophyzicheskaya (4.5km) and Verticalnaja (1.6km).

Beneath the desert plains to the south of the mountain ridge is an associated, entirely water-filled, phreatic system which can be accessed through open pots such as Provull (dived to -58m).

Osh/Fergana: The Chil-Ustun, Chil-Mairam and Tuya-Muyun ranges between Osh and the Fergansky Khrebet range is an area of small caves containing sites such as the Tash-Ata cave, Sasik-Unkur cave, and the Chil-Ustun cave (380m). Many of the caves of the region have been exploited for their minerals.

Peter 1st Ridge: This is a newly opened mountain area on the north-western edge of the Pamirs. Little is known about the area at the moment, except that some climbers have reported sighting some cave entrances.

Sarykol'skij Khrebet: This is a little-explored, high mountain region east of Lake Karakul in the eastern Pamirs, on the Sino-Soviet border, with the noted Rangkul'skaja cave (-350m). This is a rift cave on a mountainside at an altitude of 4,400m asl, the highest known cave in the USSR. Further exploration in this area is hampered by the fact that the cave entrances are almost permanently blocked by ice and snow.

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Geology and geomorphology of Turkmenistan: A review

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Abstract

This article provides a background for scientists interested in a general overview of the geology and geomorphology of Turkmenistan, a subject covered only sparsely in the international geological literature despite the very attractive features of this important Central Asian country. The basement of Turkmenistan is a complex amalgamation of arc–related terranes developed in the Asiatic and northern Paleotethys oceanic domains during Late Paleozoic to Triassic times. A major part of the country coincides with the Turan Platform, where a thick sedimentary succession accumulated between Late Paleozoic and Cenozoic. Sedimentation rates culminated during Middle Jurassic times, being more eminent in the Kopeh–Dagh Province to the south due to backarc extension in remote regions of the Neotethys subduction zone. Closure of the Neotethys ocean and collisional events in the Iranian, Afghan and Indian regions to the south resulted in inversion of the tectonic regime into a compressional setting in Early Cenozoic. The Caspian Province in western Turkmenistan recorded a geological and tectonic history very similar to that of the South Caspian Basin in Cenozoic times. Major gas and oil fields have developed in different petroleum systems of the Turan and Caspian Provinces. Dynamics of the Karakum desert and evolving drainages across it have a major bearing on the geomorphology and environment of Turkmenistan. Major structural features of the country are described, and attractive geological features are introduced.

Keywords: *Turkmenistan, Turan Platform, Karakum Desert, Amu–Darya River, Kopeh–Dagh, South Caspian Basin, Geology, Hydrocarbon Potential.*

"Either thou shalt renounce thy vaunt and yield,
Or else thy bones shall strew this sand, till winds
Bleach them, or Oxus with his summer-floods,
Oxus in summer wash them all away".
Sohrab and Rustum by Matthew Arnold

Introduction

Located in the transition zone of the Cimmerian terranes in the south, and the stable Eurasian plate in the north, Turkmenistan is a very interesting country from the geological point of view, yet it has been studied in a very limited capacity. A major attractive aspect of the geology of Turkmenistan lies in its vast petroleum potential (The reader is addressed to the oil and gas reserve map of Turkmenistan by Crude Accountability, 2011). Turkmenistan is surmised as the second gas reserve of Eurasia and Europe after the Russian Federation. The proved natural gas reserves in the country is estimated at 17.5 trillion m^3 (Olcott, 2013).

Most geological studies in Turkmenistan were carried out by the former Soviet Union geologists (e.g., Kalugin, 1957; Volvovsky *et al.*, 1966; Rastsvetaev, 1966; Krymus & Lykov, 1969; Amursky, 1971), many of which are in Russian language, and are scarcely accessible to an international audience. More recent geological studies, dedicated specifically to this region include those by Lyberis *et al.* (1998), Lyberis and Manby (1999), and Garzanti and Gaetani (2002), whereas others have considered Turkmenistan in the wider framework of the regional geology of the "Turan Platform" and of Central Asia in general. The term "Turan platform" (sometimes used in conjunction with "South Kazakh platform") is applied for description of a large area between the Kopeh–Dagh and Caspian Sea in the west and the western Tien Shan/Pamir ranges in the east, which is mainly covered by upper Permian to Quaternary deposits, and is considered roughly stable since the Triassic times (Kazmin, 1990; Maksimov, 1992; Lordkipanidze, 1991; Sheikh–Zade, 1996; Thomas *et al.*, 1999; Natal'in & Sengör, 2005). According to Natal'in and Sengör (2005) the boundaries of Scythian and Turan platforms are defined by the extent of their Jurassic to Cenozoic cover, which, in the Turan case, oversteps onto the southwestern part of the Altaids. Compared to the rather sedimentological and physiographical concept of the "Turan platform", the term "Turan plate" is generally used for the tectonic realm situated between the Iranian plate to the south, and Altaids, Uralides and Ust–Yurt domains to the north. The Paleotethys suture and the Skytho–Turanian fault respectively delineate the southern and northern boundaries of the Turan plate. Thomas *et al.* (1999) provided structure–contour and isopach maps for five main stratigraphic intervals, Late Permian to Cenozoic in age, to reconstruct the paleogeographic and paleotectonic evolution of the southern margin of Eurasia. Natal'in and Sengör (2005) analyzed borehole and geophysical data, and distinguished different geological units within the Turan domain, including Bukhara, Chardjou, Karakum–Mangyshlak, Tuarkyr, and Karabogaz units. They suggested that the basement of these terranes, extending from northern Afghanistan and Turkmenistan to the Caucasus and the northern Black Sea, consists of a number of *en échelon* array of southwest–facing arc fragments of Paleozoic to Jurassic ages which were stacked into their present places by large–scale, right–lateral strike–slip transport in the Triassic and middle Jurassic, simultaneous with the subduction and elimination of the Paleotethys ocean.

Detailed studies by Lyberis *et al.* (1998) and Lyberis and Manby (1999) investigated the stratigraphic and structural evolution of the Turan continental block, suggesting that post–Triassic sediments were folded and uplifted in the Kopeh–Dagh mountains in response to the convergence between the Iranian and Turan plates. They inferred ca. 75 km of north–south shortening in the western part of the Kopeh–Dagh–Greater–Balkhan area, accommodated by oblique movement along the major Ashk–Abad fault zone and east–west structures south of it.

Sedimentologic and petrographic analysis of the Upper Paleozoic to Triassic Kizilkaya sedimentary succession in western Turkmenistan led Garzanti and Gaetani (2002) to conclude that the Turan Plate consists of an amalgamation of Upper Paleozoic to Triassic continental microblocks separated by oceanic sutures. In their reconstruction of the southern margin of Eurasia, Zanchetta *et al.* (2013) showed that this tectonically active region recorded several episodes of continental accretion and opening of arc–related basins associated with magmatic activity. Brunet *et al.* (2017) used geological and geophysical data to reconstruct the Late Paleozoic and Mesozoic evolution of the Amu–Darya basin in Turkmenistan and Uzbekistan.

This article reviews geological and geomorphological information from the Iranian Kopeh–Dagh and Gorgan plain, as well as the available regional geological maps, and combines them with ETM and Google Earth™ satellite images to illustrate and extrapolate major geological units and tectonic structures within the territory of Turkmenistan. A new general geological map of the region is compiled (see sections 2 and 3), and the geological evolution of the country is discussed also based on the mapping and surface features observed with the help of remote sensing data. Spectacular and enigmatic geological and geomorphological features of the country are described and discussed, and a comparison is made between Turkmenistan and the neighboring regions.

Basement, regional geology and geomorphology

The basement of the Turan platform in Turkmenistan is an assemblage of amalgamated magmatic arcs and forearc–accretionary wedge complexes (Fig. 1), suggested by Natal'in and Sengör (2005) to have resulted from strike–slip stacking of the “Silk Road Arc” in Late Paleozoic to Triassic times. The basement then developed into several extensional basins between Lower Jurassic and Paleogene (Lyberis & Manby, 1999). Basement of the western Turkmenistan, near the coasts of the South Caspian Basin (SCB) is suggested to be an extension of the oceanic–type crust which underlies the thick sedimentary cover of the SCB (Shikalibeily & Grigoriants, 1980; Brunet *et al.*, 2003; Golonka, 2007). Because of extensive Neogene to Quaternary cover, bedrock geology is limited to ca. 25% of the area of the country (Fig. 2). The cover materials include mostly the Karakum sand veneer, recent Caspian Sea deposits, and regoliths in alluvial fans and flood plains, as well regoliths produced by weathering of Neogene deposits. Bedrock crops out in three main regions, including the Kopeh–Dagh range in south, the Karabogaz (Balkhan) to Kharazm region in north (the Turan Province), and the Gowurdag in east (the Pamir Province).

We used geological evolution histories to distinguish regions within the Turkmenistan territory, and described here below their geology, petroleum potential, and peculiar geomorphological features; they include: 1) Kopeh–Dagh Province, 2) Caspian Province, 3) Turan Province, and 4) Pamir Province. Three hydrocarbon provinces also can be identified in Turkmenistan: a) the Amu–Darya basin, b) the Gograndag–Okarem Zone, and c) the Kopeh–Dagh basin. Except for the northern Kopeh–Dagh range to the south, and the western Pamir range to the east, Turkmenistan is dominated by low–lying, low–relief landforms. In southeast, large alluvial fans of Murghab and Harirud (Tejen in Turkmenistan) rivers form the Mary (Merv) and Tejen oases respectively. The Karakum desert covers a vast central part of the territory with an average elevation of ca. 100 m asl.

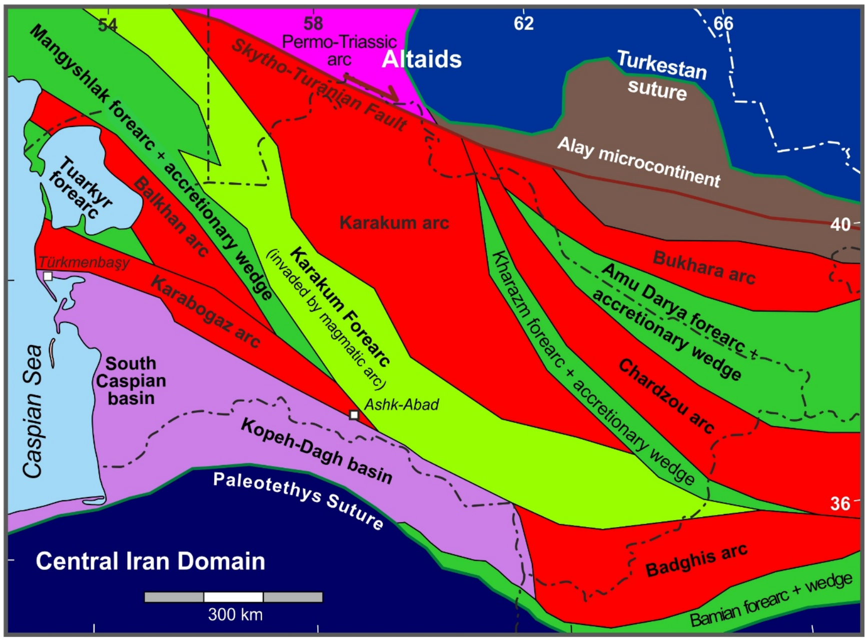

Figure 1. The Paleozoic–Triassic basement of Turkmenistan. Modified after Natal'in and Sengör (2005) and Zanchetta *et al.* (2013). International boundaries are indicated.

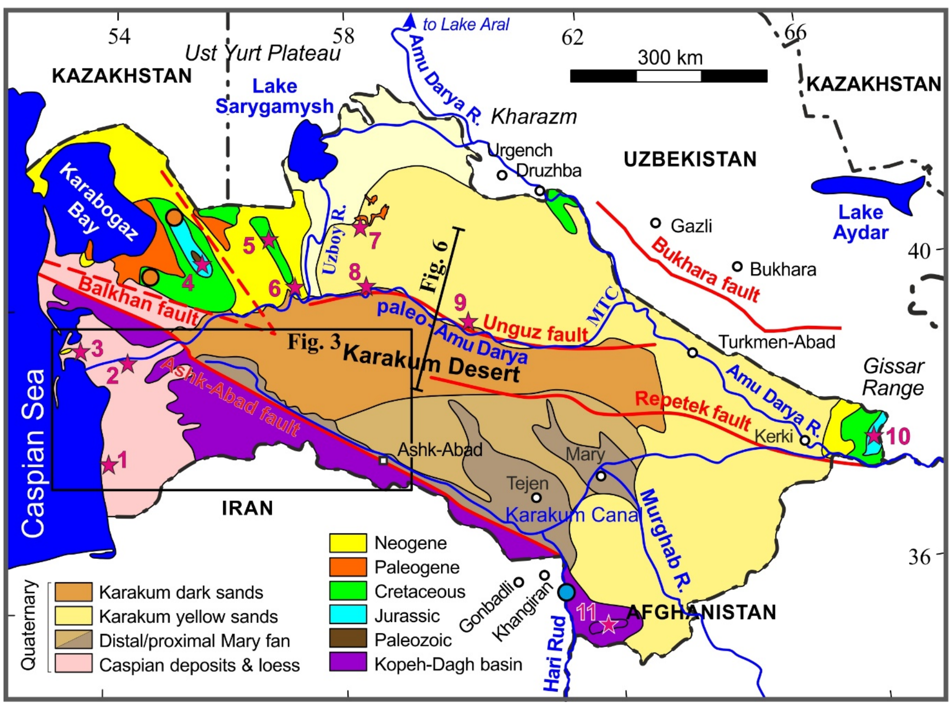

Figure 2. General geological map of Turkmenistan, compiled from small–scale maps provided by the Russian Geological Research Institute (VSEGEI) and available at One Geology Portal, integrated with geological data in Iran and ETM and Google EarthTM satellite images. Stars indicate features discussed in the text: 1: Gyeok Patlavuk mud volcano; 2: Monzhukly diapiric structure; 3: Cheleken Peninsula; 4: Kizilkaya erosional window; 5: Altyn Asyr Lake; 6: Uzboy River deflection; 7: lowest point in Turkmenistan (81 m b.s.l.); 8: Darvaza; 9: Neogene strata N of the Unguz fault; 10: dinosaur plateau; 11: Yeroylanduz depression. MCT: Main Turkmen Collector.

The highest elevations in Turkmenistan belong to the Gowurdak zone, where Pamir mountains on the border with Uzbekistan have a peak of 3138 m height. In the central Kopeh–Dagh zone, elevation reaches to ca. 2770 m on the border with Iran. The highest elevation in the Balkhan zone is ca. 435 m, close to the lowest elevations near the Caspian coast with an elevation of ca. –27 m. The lowest point in the country is –92 m in the Akhchakaya Depression – southeast of the Sargamysh Lake and the northwestern part of the Trans–Unguz Karakum (Babaev, 1994).

Kopeh–Dagh Province

Southern part of Turkmenistan coincides with the Kopeh–Dagh (Kopet–Dag) Province, which is separated from the Turan Province along the major Ashk–Abad fault zone. The word "kopeh" means "pile", "heap" or "ridge" in Persian, and the word "dagh" means "mountain" in Turkic. Therefore "Kopeh–Dagh" may refer to gentle ridges which are produced by long anticlines in this province. A vast part of this geological province is located within the Iranian territory, evolution of which is described here as an inverted extensional basin.

The inverted basin

The Kopeh–Dagh mountains are the result of folding and faulting of a Mesozoic extensional basin in the northeastern part of the Iranian Plateau. Nature of the basement in the Kopeh–Dagh basin is not well–understood. The oldest rocks are revealed in an erosional window in easternmost part of the mountain belt in Iran (the Aghdarband window), where a Lower–Middle Triassic basin, consisted of deformed arc–related marine succession were deposited along the southern margin of Eurasia (Ruttner, 1991; Baud *et al.*, 1991; Zanchi *et al.*, 2016). Deformed and moderately metamorphosed Upper Paleozoic carbonate and siliciclastic rocks, in fault contact with abovementioned Mesozoic rocks, appear to form a basement to the basin fill. An extensional tectonic event in the backarc setting of the remote Neotethys subduction zone incepted the Kopeh–Dagh sedimentary basin in Middle Jurassic times. Sedimentation continued without magmatic activity (Afshar–Harb, 1979) and ca. 7 km (data from the Iranian side of the basin) of carbonate and siliciclastic deposits accumulated by the Late Eocene, when marine deposition ceased and compressional inversion of the basin began (Robert *et al.*, 2014). Lyberis and Manby (1999) suggest that the post–Triassic succession of the Kopeh–Dagh appears to become even thicker in Turkmenistan, and reaches to ca. 17 km. The extensional stresses gradually diminished, and the first signs of inversion of the basin into a compressional setting appeared in Late Eocene (Robert *et al.*, 2014). Major shortening of the basin, incepted in Oligocene to Miocene times, stopped the marine sedimentation, and folded and faulted the inverted basin sequence. A simplified map of the Kopeh–Dagh basin, produced by use of remote sensing data and extrapolation of the geological units in Iran across the border with Turkmenistan is shown in Fig. 3.

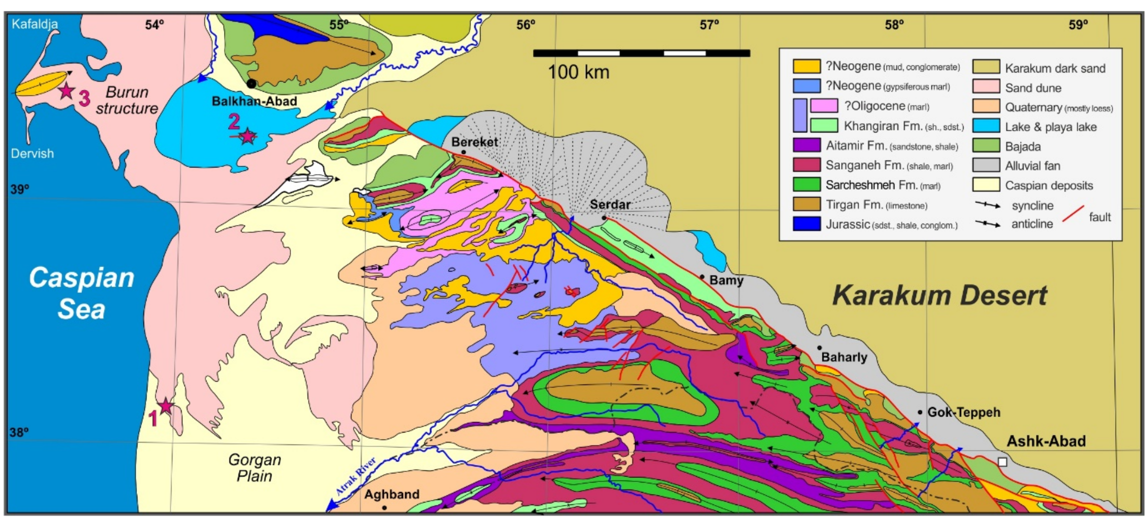

Figure 3. Geological map of the Kopeh–Dagh province (compiled from geological maps of northeastern Iran and extrapolated by satellite imagery to southern Turkmenistan). Formation names and lithologies are after the Iranian stratigraphic nomenclature. Stars are numbered as in Fig. 2.

Folds and thrust faults in northern Kopeh–Dagh province show a vergence towards north (Lyberis & Manby, 1999). The southern margin of the Turan Platform is bent downward along the front of the Kopeh–Dagh belt, as shown by increasing basement depth and thickness of cover strata as well as by gravity anomalies (Thomas *et al.*, 1999; Jackson, 2002). The southern margin of the Turan Platform therefore represents the northern foreland of the Kopeh–Dagh fold–and–thrust belt, whereas south–verging folds and faults in southern part of the belt face towards the southern foreland in the Iranian territory.

Hydrocarbon potential

The petroleum potential of the Kopeh–Dagh basin in Turkmenistan is poorly known; however some major gas fields occurring in the easternmost Kopeh–Dagh region of northeastern Iran, notably the Khangiran and Gonbadli fields, probably extend eastward into Turkmenistan. The reservoir rocks in these fields, located in anticlinal traps (Moussavi–Harami & Brenner, 1992), are Upper Jurassic carbonates (Mozduran Formation) and Lower Cretaceous siliciclastic (Shurijeh Formation; Afshar–Harb, 1979; Aghanabati, 2004; Kavoosi *et al.*, 2009). The main source rocks for the gas are considered the Middle Jurassic shales and carbonates of the Chaman–Bid Formation and the Upper Bajocian to Bathonian shales of the Kashafrud Formation (Robert *et al.*, 2014).

The Yeroylanduz depression

The 38 km–long and ca. 10 km–wide Yeroylanduz depression, a most spectacular geomorphological feature carved into Cenozoic strata of the easternmost continuation of the Iranian Kopeh–Dagh, is located in southernmost Turkmenistan near the border with Iran and Afghanistan (star 11 in Fig. 2). Yeroylanduz in Turkmen language means "*the salt that has ornamented the land*", referring to the small salt lakes formed by evaporation of internally drained water (Fig. 4A).

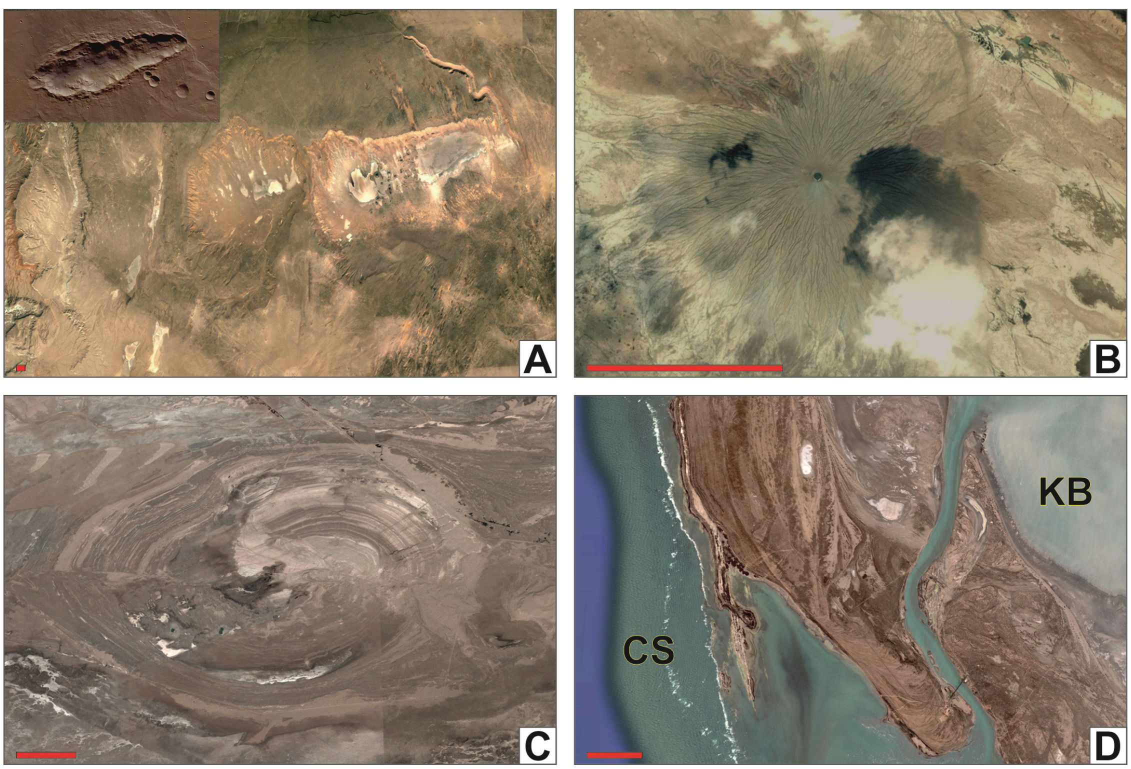

Figure 4. Geomorphological features of the Kopeh–Dagh and Caspian provinces. A) Yeroylanduz depression in southernmost Turkmenistan (N 35°40' E 61°46'). Inset figure is example of an oblique impact crater on Mars (European Space Agency, 2011). Drainage at the eastern end of the Yeroylanduz depression also recalls channel on Mars. B) Gyeok Patlavuk mud volcano close to the east coast of the Caspian Sea (N 38°09' E 53°58'). C) Monzhukly diapiric structure in the Akchagyl and Apsheron Formations along the Burun structure (N 39°17' E 54°21'). D) Very narrow channel connecting the Karabogaz Bay (KB) to the Caspian Sea (CS) (N 41°05' E 52°54'). Scale: red bar = 1 km.

The three parts of this east–west–trending depression, which includes a long trough in the east and a smaller pit in the west, are given the local names of Kagazly, Tekeduz, and Nemeksar. The depression, reaching a maximum depth of ca. 450 m in its central part, is closed on all sides, therefore precipitation water in it is internally drained. A partial exception is an 18 km long relatively young ravine with steep walls which drains seasonal water into the depression form the eastern end. Hillocks within the eastern trough are topped by what appear to be volcanic or other igneous rocks. Because volcanism is not recorded in the area, and neither the occurrence of subsurface salt nor related diapiric structures have been reported – which may explain development of such depression via extrusion of a salt dome, we suggest here that the depression might have been developed as an oblique meteorite impact crater, and that the supposed volcanic rocks inside the depression may represent instead the meteorite remnants.

Caspian Province

Western Turkmenistan represents eastern margin of the South Caspian Basin (SCB), a rapidly subsiding basin which has accumulated up to 25 km of sediments with a major contribution in Late Cenozoic times (Brunet *et al.*, 2003). This part is therefore named as “Caspian Province”, and shares many of the geological features of the SCB.

Cenozoic sedimentation history

A regional retreat of the sea from the Turan Platform at the end of the Cretaceous was followed by a marine transgression during the Danian, when shallow–marine carbonates were deposited in subsiding regions within the Turan domain, including the Kopeh–Dagh and Amu–Darya basins (Maksimov, 1992; Thomas *et al.*, 1999). In the western regions of the Turan Platform, Oligocene and Miocene sediments exposed along the Caspian Sea coast and north of the Karabogaz, are largely marls and clays – surmised to be equivalents of the Maykop Series in Azerbaijan – deposited in lagoonal to shallow–marine environments (Thomas *et al.*, 1999).

The Caspian Sea was completely isolated from the major Paratethys Sea by Early Pliocene time (late Pontian in Russian literature or early Zanclean in standard Stages). The Pliocene Productive Series, known as “Red Beds” or “Cheleken Series” in Turkmenistan, were deposited in this period, and include fluviodeltaic to lacustrine cyclothems of interbedded sandstone, siltstone, and shale including layers with reworked Paleogene and Neogene foraminifera and ostracods (Reynolds *et al.*, 1998; Devlin *et al.*, 1999; Smith–Rouch, 2006). This unit testifies to the rapid accumulation of large volumes of sediments supplied by major fluviodeltaic systems, including the Amu–Darya paleodelta (Smith–Rouch, 2006).

The Akchagyl Formation marks the last major transgression of the Caspian Sea in the Paratethys domain during which the sea occupied a much larger basin, which extended between the northern Greater Caucasus region in the west and the Amu–Darya–Aral region in the east. Paleogeographic reconstruction of the Paratethys basin during middle Late Pliocene (see Popove *et al.*, 2006; van Bak *et al.*, 2013) indicates that the sea covered the whole Karakum area, and was connected to the Aral Sea through a N–S corridor. A major part of Turkmenistan, including the entire Karakum Desert, is thus suggested to be floored by the Akchagyl Formation. Magnetostratigraphic studies by van Bak *et al.* (2013) dated the Akchagylian, Apsheronian and Bakunian transgressions of the Caspian Sea as ca. 3.2 Ma, ca. 2.0 Ma and 0.85–0.89 Ma respectively.

Hydrocarbon potential

The first discovery of oil in western Turkmenistan occurred on the Cheleken Peninsula in 1876 (Smith–Rouch, 2006). The Gograndag–Okarem hydrocarbon Zone in the Caspian Province of Turkmenistan is easternmost extension of the South Caspian Basin (SCB). Gas and oil fields in this zone are developed in anticlines cored by shale diapirs. The main source rocks for hydrocarbons are Oligo–Miocene mudrocks equivalent to the Maykop Series in Azerbaijan, whereas the major reservoirs and seals are mostly found in the upper part of the lower to middle Pliocene “Red Bed” Series. Reservoir facies are fluviodeltaic, slope, and turbidite sandstones interbedded with siltstones and shales (Smith–Rouch, 2006). The relatively cool temperature gradient in the southeastern part of the SCB places the Maykop and Diatom Suites source rocks in the oil–generating window at greater depths as compared to other parts of the basin.

Mud diapirism

Mud diapirism is a widespread feature both offshore and onshore of the SCB. Within the

Caspian Province of Turkmenistan, the diapirism is well documented by exploration seismic data, and is manifested as mud volcanoes at the surface, locally associated with sand intrusions (Oppo & Capozzi, 2015). Best–known examples reported from the oil fields in Azerbaijan (Huseynov & Guliyev, 2004) suggest that mud diapirism in the SCB began in Early Miocene times. Mud diapirs may originate from as deep as 14 km (Cooper, 2001), as testified by fragments of Mesozoic and Paleogene rocks contained in the mud breccia generated in larger mud volcanoes during catastrophic events (Kholodov, 1987; Inan *et al.*, 1997). Most of the erupted mud, however, is derived from the pelitic parts of the Oligocene–Miocene Maykop Series, the major petroleum source rock in the SCB (Inan *et al.*, 1997; Kireeva & Babayan, 1985; Fowler *et al.*, 2000; Planke *et al.*, 2003). Mud volcanoes in the Gograndag–Okarem province commonly pierce anticlines hosting hydrocarbon accumulations, allowing the partial leakage of the fluids (Oppo & Capozzi, 2015). More than twenty mud volcanoes are located in the eastern onshore area of the SCB in Turkmenistan, some of which are associated with seepage of oil and gas (see Fig. 1 in Oppo *et al.*, 2014). They display a variety of morphological and geological features, including inactive centers subjected to erosion, cones associated with gryphons (gryphon – gas–mud vent generally occurring at the flanks of a main dome or crater) and salsa lakes, and negative caldera–like morphologies filled with saline water (Oppo *et al.*, 2014). The most spectacular one is the Gyeok Patlavuk, with a cone very similar to magmatic volcanoes, rising ca. 73 m above the nearby coastal plain located at –20 m (star 1 in Fig. 2; Fig. 4B).

Mud diapirism has induced doming of the Plio–Pleistocene Akchagyl and Apsheron Formations in the Monzhukly area (star 2 in Fig. 2; Fig. 4C), where the structure is cut by several faults as in salt diapirs of north central Iran (compare with Fig. 1.10 in Jackson *et al.*, 1990). A few mud volcanoes occur along the southwestern rim of the diapiric structure, which is part of the so–called Burun structure, a set of *en échelon* folds hosting a major gas field and extending from the Cheleken peninsula in the west to the Nebit–Dagh in the east. The Burun structure is the eastern continuation of the Apsheron–Balkhan sill, a shallow structure linked kinematically to the Ashk–Abad fault system and separating the South Caspian from the Middle Caspian basin (Jackson *et al.*, 2002).

Cheleken peninsula

The Cheleken peninsula is located at the western end of an *en échelon* array of folds named as Burun structure, and at the eastern end of the Apsheron–Balkhan sill. The backbone of the peninsula is the Cheleken anticline, formed by Pliocene Red Beds and by the Pleistocene Apsheron Formation pierced by several mud volcanoes. The Cheleken peninsula – marked as “Chereken Island” on a map by A. Bekovich–Cherkassky in 1715 – used to be an island in historical time, and becomes an island again from time to time when Caspian waters rise (star 3 in Fig. 2). The peninsula was linked to the mainland in 1937, when sea–level dropped and the shallow area between the island and the mainland dried out (Zonn *et al.*, 2010). The two nearly symmetrical spits in the west, the northern Kafaldja Peninsula and the southern Dervish Peninsula pointing towards Ogurja Ada 17 km farther south, make it very similar to the Ebro river delta in Spain.

Karabogaz Bay

The Karabogaz Bay (area ca. 18,000 km^2, average depth 8–10 m) is the saltiest water body on Earth and hosts the world's largest deposit of marine salt. Its water surface lies several meters below that of the Caspian Sea, to which the Bay is connected by a 7 km–long and only 200–350 m–wide strait (Fig. 4D). There is a great contrast in salinity between the Caspian Sea (12 g/l) and the Bay (350 g/l), which acts as a regional regulator of both water level and salinity (Zonn *et al.*, 2010). The water level of the Caspian Sea reached – 29 m in 1977, the lowest level in the last 400 years. To reduce water loss, the strait was dammed in March 1980. In response to damming, however, the Bay dried up completely by November 1983, and the dam was destroyed in 1992. Until 1996 the Karabogaz bay filled up with Caspian water at a rate of 1.7 m/yr, and evolved in a similar way as the Sea since then (Kosarev & Kostianoy, 2005).

Turan Province

Exposed in the Balkhan zone of the western Turan Province are Jurassic to Neogene strata displaying major open NW–SE–trending folds. Upper Paleozoic to Triassic rocks are exposed only in the central Balkhan zone, in the small Kizilkaya dome–like structure surrounded by younger rocks (star 4 in Fig. 2; Fig. 5A; Garzanti & Gaetani, 2002). Sub–horizontal Cenozoic strata crop out southeast of Lake Sarygamish (star 9 in Fig. 2), where the lowest elevations in the country occur. Cretaceous and Paleogene sedimentary rocks are exposed in a NW–trending, SE–plunging anticline in the Druzhba area of northeasternmost Turkmenistan, near the Uzbekistan border. A NW–plunging syncline and a SE–plunging anticline floor the Karabogaz and Karakum lakes, respectively.

Hydrocarbon potential

The Amu–Darya basin of central and eastern Turkmenistan, underlying the Karakum Desert and straddling the Uzbekistan border, is a hydrocarbon province with great productive potential and discovered gas reserves. Modeling of the reserves indicate that the total undiscovered resources in the Amu–Darya basin are about 3.31 billion t, in which gas accounts for more than 98 percent (Clarke, 1994; Yixin *et al.*, 2015). Discovered gas reserves are estimated between 6.5 and 7.9 trillion cubic feet. The basement, consisting of Paleozoic rocks deformed and metamorphosed during the Variscan orogeny, is overlain by an Upper Permian–Triassic rift–graben fill followed in turn by thick coal–bearing continental rocks of Early to Middle Jurassic age. The late Middle Jurassic carbonates are overlain by the thick Late Jurassic evaporites of the Gaurdak Formation (Osichkina, 2006), followed in turn by Cretaceous to Paleogene largely marine clastic and carbonate rocks. Old faults were reactivated and new faults and structural traps formed during the Alpine orogeny (Ulmishek, 2004), when continental clastic rocks were deposited along the basin's margins.

The main source rocks for gas are Lower Jurassic coal and black shales interbedded within clastics, whereas gas reservoirs mostly occur in mid–Jurassic carbonates and Neocomian clastics. Seals include the Upper Jurassic Gaurdak evaporites and subordinately Lower Cretaceous marl and shale. Traps may be structural, paleogeomorphic, stratigraphic, or a combination of these types (Ulmishek, 2004).

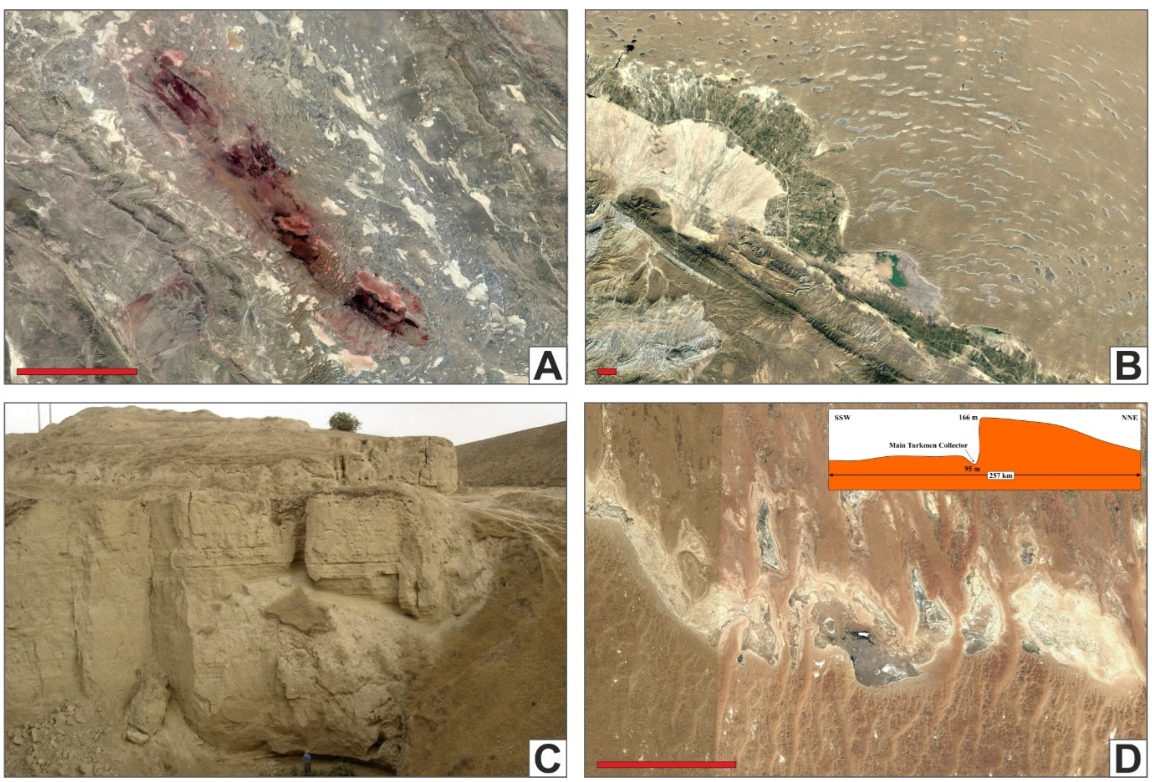

Figure 5. Geological and sedimentological features of Turkmenistan. A) Kizilkaya domal structure exposing Upper Paleozoic volcaniclastic red beds (N 40°36' E 55°28'). B) Salt pans within the sand dunes of the southern Karakum Desert near Serdar. The pans are filled seasonally with water leaking from the irrigated fields in the lower–left corner of the picture (N 39°07' E 56°46'). C) Loess deposits in the northwestern Kopeh–Dagh region of Iran, near the Turkmenistan border. D) Salt marshes formed along the Unguz fault (N 39°45' E 59°28'); inset shows E–W scarp–like topography associated to the active Unguz fault. Neogene strata exposed to the north may be upthrown by several tens of meters. Location of the profile, which has very strong vertical exaggeration, is shown in Fig. 2. Scale: red bar = 5 km in A, B, and C; man at the base of picture in D.

In the middle of the Amu–Darya hydrocarbon province, there is a 30 m–deep pit of fire called Darvaza (or "door to hell"; in Persian darvaza = gate; star 8 in Fig. 2). It is said that a Soviet oilrig fell into the crater in 1971, and a geologist decided to get rid of the rig by setting the pit on fire. The resulting gas–fed flames are still burning.

Pamir Province

The Gowurdag (Koytendag) zone in easternmost Turkmenistan represents the western termination of the Pamir mountains in Tajikistan and Uzbekistan. Jurassic to Neogene sedimentary rocks are exposed in a NE–trending folded structure, cored in Uzbekistan by Proterozoic and Paleozoic rocks thrusted over Neogene strata towards the SE. Jurassic strata host the world’s longest dinosaur trackways, hence the Koytendag is called "dinosaur plateau" (star 10 in Fig. 2).

Wind, water and earth

Being covered by the vast Karakum desert, a major part of Turkmenistan’s surface geology and geomorphology is sculpted by action of wind and drift of sand and dust in an arid environment. Turkmenistan also has a long history of major natural and human modifications of rivers and drainage systems which is discussed under this section.

Karakum desert

As the most important geomorphologic feature of Turkmenistan, the Karakum (black sand) desert occupies ca. 70% of the country's area. The entire territory of Turkmenistan is divided into different deserts, including sand, clay, loess, stony and salt types (see Fig. 2 in Babaev, 1994). The neighboring mountains, including Kopeh–Dagh, Hindu–Kush and Pamir, may be considered as the sources for sands within these deserts, however prevailing wind systems of the region suggest that the major source area may be in the Kazakhstan steppe and beyond. For a more detailed account of provenance of the Karakum desert sands see Garzanti *et al.* (2019).

The Karakum desert has a general low elevation with a maximum of ca. 220 m in the eastern part which reduces to ca. 0 m amsl in the west near the Caspian Sea; it drops to ca. –92 m in a small depression to the southeast of the Sarygamish lake (star 7 in Fig. 2). Abundant desert pans occupy the southern part of the Karakum desert in vicinity of Kopeh–Dagh mountains, some of which appear to be seasonally filled by water leaking from the Karakum canal and farms which are irrigated by the canal (Fig. 5B). Most of the onshore oil and gas fields of the country are hosted in central and eastern parts of the Karakum desert.

Turkmenistan records the highest frequency dust storms in Central Asia. Dust storms exceed 40 per year in the Karakum desert and near the Caspian Sea. The largest source area for these storms is the Karakum desert, however there is a large dust belt that extends from west to east, lying north of the Caspian Sea, south of Lake Balkhash and in the Aral Sea region (Indoitu *et al.*, 2012). The real dark sands of Karakum occur in a central belt of the desert, which extends between Turkmen–Abad in the east and Serdar in the west. Other parts of the desert are covered with lighter–colored sands. The Amu–Darya river separates Karakum sands in its southwest from the Kyzyl–Kum (red sand) sands in its northeast within the Uzbekistan and southern Kazakhstan.

Results of the study by Maman *et al.* (2011) suggest that the ergs in the Karakum are mostly stabilized. They also argue that a low wind power environment and sufficient rainfall (>100 mm) support vegetation over the ergs. A sample from the northern margin of the Karakum desert near Kharazam yielded an Optically–Stimulated Luminescence (OSL) age of 7.3 ± 0.8 ka (Maman *et al.*, 2011).

It is suggested that the parallel extension of the dune ridges does not correspond to the prevailing wind direction. On the other hand some researchers believe that the major part of sand material in the Lower Karakum have never been affected by aeolian processes, and even attribute relief of the longitudinal valleys and ridges to activity of fluvial processes (Shahgedanova, 2002). Longitudinal N–S–trending sand dunes are specially visible in southern Karakum resting over the Mary fan with a maximum relief of ca. 30 m, and an average spacing of ca. 2.5 km. The Murghab river fan hosts the Merv (Mary) oasis. Distal parts of this fan is composed of fine–grained fluvial silt and clay material, interspersed with planes of muck. These fine–grained materials are sculpted by yardangs (yardang – a long, irregular, sharp–crested, undercut ridge between two round–bottomed troughs, carved on a plateau or unsheltered plain in a desert region by wind erosion; has a Turkic origin) and lie below the mobile dunes of the southern Karakum desert (Stoppato *et al.*, 2003).

Loess

Loess in Turkmenistan is part of the Eurasian loess belt which extends between the Pacific to Atlantic coasts in mid–latitudes. The formation of continuous loess–paleosol sequences by dust deposition began 22 My ago (Guo *et al.*, 2002), however a major volume of the loess was deposited in Pleistocene times. Most of the studies (e.g. Sun, 2002) suggest that the Chinese loess deposits have their provenance from the Gobi (stony) desert of northern China. Equivalent of Gobi desert in Turkmenistan may be the stony deserts, which are mostly located in the northwestern part of the country. The Loess deposits of northern Iran close to the border with Turkmenistan is composed of a large fraction of silt size material (more than 80%) and smaller fractions of clay and sand size grains (Frechen *et al.*, 2009) (Fig. 5D). These are homogeneous windblown geological materials interspersed with some paleosol horizons. The sequence in general records an alternation of comparatively dry and cool climate phases with increased dust accumulation including loess formation, and moist and warm phases with soil formation, respectively (Kehl *et al.*, 2006). Different horizons of loess deposits in Aghband section of northern Iran near the border with Turkmenistan were dated between 145 and 9.5 ka (Frechen *et al.*, 2009).

Amu–Darya River, Karakum Canal and MTC

The Amu–Darya River (Oxus in Latin) is a major river (the largest river basin in Central Asia) formed by the junction of Vakhsh, Panj and Kunduz rivers which originate in the Pamir mountains. Flowing for ca. 2400 km towards northwest, the river drains into the previous Aral Sea at an elevation of ca. 30 m.

It is believed that the precursor of the Amu–Darya River ran into the Caspian Sea instead of the Aral Sea. The junction to the Caspian Sea was located in the south of the present Karabogaz Bay. The river drastically changed its course in Pleistocene or early Holocene times into the Aral Sea, leaving the old course in the Uzboy valley (Zavialov, 2005). Similar changes in historical periods have also been reported. According to Ptolemy (in the 2nd century A.D.) and Biruni, the river flowed towards west from modern Kerki (a city in Lebap Province of Turkmenistan) – not northwesterly as in present time – and evaporated in the Karakum desert. It is also suggested that the Amu–Darya had flowed through the Uzboy into the Caspian Sea at the time of the Mongol conquest of Gorganj (later Urgench) in 618–1221 AD, and had turned back towards Lake Aral only about 1575 AD (Encyclopedia Iranica). Possible old courses of the Amu–Darya River are shown in Fig. 2.

The Karakum canal was designed by the Soviet Union government, and was built between 1954 and 1988 to transfer water from Amu–Darya into western Turkmenistan. The canal is among the largest water supply and irrigation canals of the world. It is navigable over much of its 1375 km length, and carries 13 km^3 of water annually from the Amu–Darya River across the Karakum desert. The canal opened up huge new tracts of land to agriculture, especially to cotton monoculture heavily promoted by the Soviet Union, and supplying Ashk–Abad with a major source of water. Unfortunately, the primitive construction of the canal allows almost 50 percent of the water to escape en route, creating lakes and ponds along the canal, and a rise in groundwater leading to widespread soil salinization problems. The canal is also a major factor leading to the Aral Sea environmental disaster (Wikipedia; Kharin, 2002).

Northern part of the Karakum desert is separated from the rest of it along the so–called Main Turkmen Collector (MTC). The MTC was planned in 1970s as a 720 km long drainage to be built from Turkmen–Abad through the center of the Karakum Desert along the ancient river bed of the Amu–Darya (along the Unguz salt marshes) (Zonn & Kostianoy, 2014). The collector occupies the lowest elevations in the middle of the Karakum desert.

Structure and seismotectonics

Structural features in the basement rocks of Turkmenistan and in the Caspian Province are mostly documented by geophysical data, whereas surface structures are best displayed in the Kopeh–Dagh Province and partly in the northern Turan Province.

In the Kopeh–Dagh zone, spectacular E–W trending folds of Mesozoic to Paleogene strata form an orocline convex towards the north (Fig. 3). The folds developed since the early Neogene in response to N–S shortening of the sedimentary basin located between the Central Iran and Turan blocks. Fold wavelength decreases from 25–30 km in the central part of the zone to ≤ 12 km towards its margins. In the northern Kopeh–Dagh, fold–trends become parallel to the Ashk–Abad fault zone, indicating that fold geometry is controlled by the fault (Lyberis & Manby, 1999). Right–lateral strike–slip motion at depth along the western end of the Ashk–Abad fault zone is suggested by the right–stepping *en échelon* pattern of anticline axes in the Pliocene Red Series and younger sediments (Jackson *et al.*, 2002).

The presence of folded structures beneath onshore areas of the eastern South Caspian Basin (Gograndag–Okarem petroleum province) was highlighted by hydrocarbon exploration during the Soviet Union period. Folds are parallel to the coastline and have thus a different trend than in the adjacent Kopeh–Dagh basin where shortening is N–S (Fig. 1 in Oppo *et al.*, 2014). Such a 90° difference in shortening direction needs an explanation. One possible mechanism is the westward extrusion of the Kopeh–Dagh (Hollingsworth *et al.*, 2008), which may have induced fold–thrust deformation in Neogene sediments of the easternmost SCB. An alternative mechanism is large–scale gravitational collapse of cover strata, as observed in the Gulf of Mexico (Worrall & Snelson, 1989). The offshore region, called Turkmen Block or Turkmen Step, is a relatively shallow region compared to the rest of the SCB, and is characterized by slumps and growth faulting (Smith–Rouch, 2006).

In northern Turkmenistan, including the Balkhan zone, NW–trending folds indicate NE–SW shortening. This regional structural trend continues northwards into Kazakhstan abutting against the Skytho–Turanian fault (Fig. 1).

Major Faults

The ca. 845 km–long, NW–SE–striking (N62W) Ashk–Abad fault system, the largest in Turkmenistan, separates the Kopeh–Dagh mountains in the south from the Karakum Desert in the north (Fig. 3). Its linear surface signature, and the notable change in elevation across the fault, indicate a steep structure with a major strike–slip component but with a large dip–slip component as well. Several moderate–size earthquakes of both right–lateral strike–slip and thrust mechanisms (Vannucci *et al.*, 2004) confirm that oblique shortening across the Ashk–Abad fault zone is partitioned between thrusts and strike–slip faults. Considering a N–S shortening of ca. 75 km in the western Kopeh–Dagh, starting at the Miocene–Pliocene boundary, Lyberis and Manby (1999) calculated a convergence rate of 13–15 mm/yr between the Iran and Turan plates. If such a shortening is applied to the Ashk–Abad fault zone, representing the boundary between the two plates, and resolved into components parallel and perpendicular to the fault, these authors concluded that shortening orthogonal to the eastern Kopeh–Dagh is twice as large as the right–lateral strike–slip movement. Rather than purely N–S shortening, more recent geodetic estimates (Tavakoli, 2007) suggest maximum velocities relative to Eurasia of ca. 11 mm/yr in northwestern direction, which is consistent with NE–trending folds in the western Kopeh–Dagh (Fig. 3). Such a velocity field implies that strike–slip motion on the Ashk–Abad fault prevails over its thrust component, with rates of 5 ± 2 mm/yr and 2.5 ± 2 mm/yr, respectively (Tavakoli, 2007). Other estimates of slip rate on the fault zone range between 1.5 and 12 mm/yr (see Mousavi *et al.*, 2013).

Some folds in the Kopeh–Dagh zone are probably cored by thrusts, and many are cut and displaced by relatively small NW– and NE–trending strike–slip faults. Similar structures accommodate part of the shortening in the Iranian Kopeh–Dagh (Hollingsworth *et al.*, 2006).

Faults parallel to NW–trending folds are mapped by the Russian Geological Research Institute (VSEGEI) in the Balkhan zone. A ca. 670 km–long, WNW–striking fault across the central Karakum Desert is shown in geophysical maps produced for hydrocarbon research (Ulmishek, 2004). Another 560 km–long and WNW–striking fault is inferred to exist along the Unguz salt marshes based on topographic features and surface geology (Fig. 5B). A 380 km–long, WNW–striking fault runs along the southern margin of the Balkhan zone. The NNW–trending structure occupied by Lake Altyn–Asyr in northwestern Turkmenistan (star 5 in Fig. 2) is cored by Cretaceous to Paleogene strata and interpreted as a right–lateral strike–slip fault that diverted the Uzboy River around its southern tip (star 6 in Fig. 2). The gradient of uplift is estimated as greater than 0.03–0.04 mm km^{-1} yr^{-1} (Jaboyedoff *et al.*, 2005).

Seismicity

Central part of the Turkmenistan shows very rare instrumental seismic activity, and most of the earthquakes inside the country occur along the northern margin of the Kopeh–Dagh region (Fig. 6). The Ashk–Abad earthquake of 6th October 1948 had a magnitude of 7.3, and claimed ca. 110,000 lives, most in Ashk–Abad city (Tchalenko, 1975).

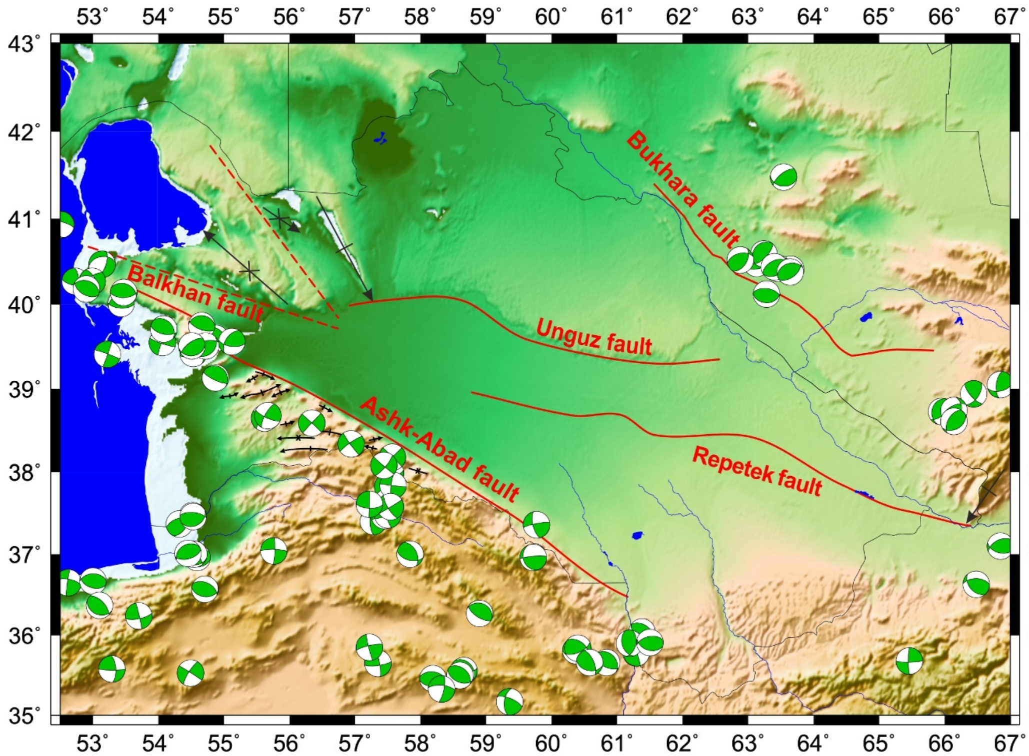

Figure 6. Seismotectonic map of Turkmenistan. Note dominance of strike–slip and thrust earthquake focal mechanisms in the hanging–wall of the Ashk–Abad fault and near the central part of the Bukhara fault respectively.

The rupture did not occur along the surface trace of the main fault, but on the nearby faults (Berberian & Yeats, 2001). The poorly constrained hypocenter was located at a depth of ca. 15 km (Engdahl catalogue). The focal mechanism (Earthquake Mechanisms of the Mediterranean Area database) and local geology suggest a shallow–dipping thrust movement by 20° to the SW. The epicenter of the 1895 Krasnovodsk (Ms 7.4) and 1946 Kazandzhik earthquakes (M 7.0) was located at the northwestern end of the Ashk–Abad fault system near the Caspian Sea (Ambraseys, 1997; Balakina & Moskvina, 2007). Another major source of hazard for eastern Turkmenistan is the Bukhara–Gazli seismic zone (BGSZ)located to the northeast of the Bukhara (Bukhara–Gissar) fault in southern Uzbekistan, which has generated earthquakes of magnitude ≥ 7 in historical and recent times (Artikov *et al.*, 2015). The Bukhara fault is a major NW–striking normal fault of Permo–Mesozoic age which shows evidence of Tertiary reactivation (Thomas *et al.*, 1995, 1999), while the BGSZ occupies a relatively small area in the central vicinity of the earlier fault, and is associated with earthquakes of thrust mechanism on fault planes which are highly oblique to the Bukhara fault (Fig. 6).

Conclusions

The geology and geomorphology of Turkmenistan is still underexplored. Basement units were assembled during the Variscan and Cimmerian orogenies in Late Paleozoic to Triassic times by subduction of oceanic domains and collision of magmatic arcs and accretionary complexes within the Paleotethys and northern Asiatic oceanic realms. After closure of the Paleotethyan seaways and amalgamation of peri–Gondwanan microblocks with the Turan platform, thick sedimentary successions accumulated in extensional basins that started to subside rapidly in the backarc region of the Neotethys ocean during Middle Jurassic. Based on the Mesozoic–Cenozoic evolution, the four Kopeh–Dagh, Caspian, Turan, and Pamir geological provinces are identified, hosting the three Kopeh–Dagh, Gograndag–Okarem (South Caspian), and Amu–Darya hydrocarbon–prone basins.

Up to 17 km of Middle Jurassic to Neogene carbonate and siliciclastic rocks accumulated in the Kopeh–Dagh extensional basin, supplied with sediments derived from magmatic arcs in the Asiatic–Paleotethys oceanic realms. Compressional inversion induced by collisional events underway in Neotethyan realms to the south took place in

Cenozoic. Hydrocarbon potential appears limited to the easternmost part of the Kopeh–Dagh basin.

The Caspian province of Turkmenistan shares the rapid Cenozoic subsidence of the South Caspian Basin. The Caspian Sea encroached onto most of Turkmenistan as far as the Aral Sea in the Upper Pliocene, when the Akchagyl Formation was deposited. The temperature gradient of the southeastern SCB, cooler than in Azerbaijan, places the Oligo–Miocene Maykop and Diatom Suites source rocks in the oil–generating window at greater depths. North–south structural trends in the Gograndag–Okarem Zone may have resulted either from westward extrusion of the western Kopeh–Dagh or from gravitational collapse of young cover strata. Mud diapirism started in the early Miocene, and is still forming spectacular mud volcanoes mostly sourced in the Oligo–Miocene Maykop Series along the Caspian shores. The Cheleken peninsula lies at the western end of a series of *en échelon* folds related to dextral strike–slip motion along the western Ashk–Abad fault system. These structures represent the eastern continuation of the Apsheron–Balkhan sill separating the South Caspian from the Middle Caspian basin. The Karabogaz Bay, the saltiest water body on Earth, acts as a regional regulator of both water level and salinity in the Caspian Sea.

The Turan Province is characterized by NW–SE–trending folds affecting Jurassic to Neogene cover strata. Upper Paleozoic to Triassic siliciclastic rocks are exposed only in the Kizilkaya dome–like structure. Towards the east, the basement is buried under the Upper Permian to Neogene, marine to continental succession of the Amu–Darya basin, which hosts major hydrocarbon reserves in Upper Jurassic carbonates and Neocomian clastic rocks. Folded Jurassic to Neogene strata occur in the westernmost Pamir mountains.

Vast sands in the Karakum desert covers ca. 70% of the Turkmenistan territory mostly in central and eastern parts, and conceals the underlying Amu–Darya basin which is very important in terms of hydrocarbon reserves. Sands within the desert probably source from the steppe in Kazakhstan and beyond, and generate frequent dust storms within the country. Sediments in loess deposits located in southern part of Turkmenistan are finer–grained and older as compared to the sands in Karakum. Amu–Darya, the largest river in Central Asia, has experienced major changes in historical and modern times. The Turkmen Canal and Main Turkmen Collector are two major projects of Soviet Union period aimed at reorganization of drainage in this arid region.

The most prominent tectonic feature and major source of seismic hazard in Turkmenistan is the Ashk–Abad fault system, which accommodates oblique shortening between the Kopeh–Dagh province and the Turan platform.

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References

Afshar–Harb, A., 1979. The stratigraphy, tectonics and petroleum geology of the Kopet Dagh region, northern Iran, PhD thesis, Imperial College of Science and Technology, London.

Aghanabati, A., 2004. Geology of Iran. Geological Survey of Iran Publication, 558 p.

Ambraseys, N.N., 1997. The Krasnovodsk (Turkmenistan) earthquake of 8 July 1895, J. Earthquake Eng., 1: 293–317.

Amursky, G.I., 1971. The deep structure of Kopetdag. Geotectonics, 1: 34–40. (Engl. transl.)

Artikov T.U., Ibragimov R.S., Ibragimova T.L., Mirzaev M.A., Artikov M.T., 2015. Revealing the seismicity increase in interrelationships in various seismic zones in Uzbekistan as a case study. Geodesy and Geodynamics, 6(5): 351–360.

Babaev, A.G., 1994. Landscapes of Turkmenistan. In Biogeography and ecology of Turkmenistan. eds. Fet, V., Atamuradov., K.I., Springer–Science+Business Media, B.V., 5–22.

Balakina, L.M., Moskvina, A.G., 2007. Seismogenic zones of the Transcaspian Region: Characteristics of sources of the largest Earthquakes. II. The Krasnovodsk and Kazandzhik Earthquakes. Izvestiya, Physics of the Solid Earth, 43(5): 378–403.

Berberian, M., Yeats, R.S., 2001. Contribution of archaeological data to studies of earthquake history in the Iranian Plateau. Journal of Structural Geology, 23(2): 563–584.

Brunet, M.F., Ershov, A.V., Korotaev, M.V., Melikhov, V.N., Barrier, E., Mordvintsev, D.O., Sidorova, I.P., 2017. Late Palaeozoic and Mesozoic evolution of the Amu–Darya Basin (Turkmenistan, Uzbekistan). In: Brunet, M.–F., McCann, T. & Sobel, E.R. (eds) Geological Evolution of Central Asian Basins and the Western Tien Shan Range. Geological Society, London, Special Publications, 427.

Brunet, M.–F., Korotaev, M.V., Ershov, A.V., Nikishin, A.M., 2003. The South Caspian Basin: a review of its evolution from subsidence modelling. Sediment. Geol., 156: 119–148.
Cooper, C., 2001. Mud volcanoes of Azerbaijan visualized using 3D seismic depth cubes: the importance of overpressured fluid and gas instead of non extant diapirs. In: Abstracts Volume Subsurface Sediment Mobilization Conference. 10–13 September, Ghent, Belgium, 71.
Crude Accountability, 2011. Turkmenistan Oil and Gas Map. https://crudeaccountability.org.
Devlin, W.J., Cogswell, J.M., Gaskins, G.M., Isaksen, G.H., Pitcher, D.M., Puls, D.P., Stanley, K.O., Wall, G.R.T., 1999. South Caspian Basin – Young, cool, and full of promise: GSA Today, 9(7): 1–9.
European Space Agency, 2011. http://www.esa.int/spaceinimages/Images/2011.
Fowler, S., Mildenhall, J., Zalova, S., Riley, G., Elsley, G., Desplanques, A., Guliev, F., 2000. Mud volcanoes and structural development on Shah Deniz. J. Petrol. Sci. Eng., 28: 189–206.
Frechen, M., Kehl, M., Rolf, C., Sarvati, R., Skowronek, A., 2009. Loess chronology of the Caspian Lowland in Northern Iran. Quaternary International, 198: 220–233.
Garzanti, E., Gaetani, M., 2002. Unroofing history of Late Palaeozoic magmatic arcs within the "TuranPlate" (TuarkyrTurkmenistan). Sedimentary Geology, 151: 67–87.
Garzanti, E., Ghassemi, M.R., Limonta, M., Resentini, A., 2019. Provenance of Karakum Desert sand (Turkmenistan): Lithic–rich orogenic signature of central Asian dune fields. Rivista Italiana di Paleontologia e Stratigrafia, in press.
Golonka, J., 2007, Geodynamic evolution of the South Caspian Basin, in P. O. Yilmaz, G. H. Isaksen, editors, Oil and gas of the Greater Caspian area: AAPG Studies in Geology 55: 17–41.
Guo Z.T., Ruddiman W.F., Hao Q.Z., Wu H.B., Qiao Y.S., Zhu R.X., Peng S.Z., Wei J.J., Yuan B.Y., Liu T.S., 2002. Onset of Asian desertification by 22 Myr ago inferred from loess deposits in China. Nature, 416: 159–163.
Hollingsworth, J., Jackson, J., Walker, R., Gheitanchi, M., Bolourchi, M., 2006. Strike–slip faulting, rotation, and along–strike elongation in the Kopeh Dagh mountains, NE Iran. Geophys. J. Int. 166: 1161–1177.
Hollingsworth, J., Jackson, J., Walker, R., Nazari, H., 2008. Extrusion tectonics and subduction in the eastern South Caspian region since 10 Ma. Geology, 36(10): 763–766.
Huseynov, D.A., Guliyev, I.S., 2004. Mud volcanic natural phenomena in the South Caspian Basin: geology, fluid dynamics and environmental impact. Environ. Geol., 46: 1012–1023.
Inan, S., Namik Yalcin, M., Guliev, I., Kuliev, K., Feizullayev, A., 1997. Deep petroleum occurrences in the Lower Kura Depression, South Caspian Basin, Azerbaijan: an organic geochemical and basin modeling study. Mar. Pet. Geol., 14: 731–762.
Indoitu, R., Orlovsky, L., Orlovsky, N., 2012. Dust storms in Central Asia: Spatial and temporal variations. Journal of Arid Environments, 85: 62–70.
Jaboyedoff1, M., Derron, M.–H., Manby, G.M., 2005. Note on seismic hazard assessment using gradient of uplift velocities in the Turan block (Central Asia). Natural Hazards and Earth System Sciences, 5: 43–47.
Jackson, J., 2002, Strength of the continental lithosphere: Time to abandon the jelly sandwich?: GSA Today, 12: 4–10.
Jackson, J.A., Priestley, K., Allen, M.B., Berberian, M., 2002. Active tectonics of the South Caspian Basin. Geophysical Journal International, 148: 214–254.
Kalugin, P.I., 1957. Zona vnutrennikh skladok Kopet–Daga. In Geologya S.S.S.R., 22: 403–407.
Kavoosi, M., Lasemi, Y., Sherkati, S., Moussavi–Harami, R., 2009. Facies analysis and depositional sequences of the Upper Jurassic Mozduran Formation, a reservoir in the Kopet Dagh Basin, NE iran. J. Pet. Geol., 32(3): 235–260.
Kazmin, V.G., 1990. Early Mesozoic reconstruction of the Black Sea–Caucasus region. In: Evolution of the northern margin of the Tethys. Mémoires de la Société géologique de France. Nouvelle Series 54: 147–158.
Kehl, M., Sarvati, R., Ahmadi, H., Frechen, M., Skowronek, A., 2006. Loess/paleosolsequences along a climatic gradient in Northern Iran. Eiszeitalter und Gegenwart 55: 149–173.
Kharin, N., 2002. Vegetation degradation in Central Asia under the impact of human activities. Springer Science+Business Media New York, Originally published by Kluwer Academic Publishers. 182 p.
Kholodov, V., 1987. The role of sand Diapirism in the genesis of mud volcanoes. Litol. Polezn. Iskop., 4: 12–28. (in Russian).
Kireeva, L., Babayan, D., 1985. Genetic analysis of oil and gas accumulations of Middle Pliocene deposits of southwestern Turkmenistan. Ylym Publisher House, Ashgabat, Turkmenistan (in Russian), Geologiya e naftegazonosnost Turkmenistana.
Kosarev, A.N., Kostianoy, A.G., 2005. Kara–Bogaz–Gol Bay, In: The Caspian Sea Environment, (Eds.) A.G. Kostianoy, A.N. Kosarev, Springer–Verlag, Berlin, Heidelberg, New York, 211–221.
Krimus, V.N., Lykov, V.I. 1969. The character of the junction of the epi–Hercynian platform and the Alpine folded belt, South Turkmenia. Geotectonics, 6: 391–396 (Engl. transl.)
Lordkipanidze, L.N., 1991. Platforms, 256 p., Nauka, Tashkent, Uzbekistan.
Lyberis, N., Manby, G., 1999. Oblique to orthogonal convergence across the Turan block in the post–Miocene, Am.

Assoc. Petrol.Geol. Bull., 83(7): 1135–1160.
Lyberis, N., Manby, G., Poli, J.T., Kalugin, V., Yousouphocaev, H., Ashirov, T., 1998, Post–triassic evolution of the southern margin of the Turan plate: Comptes Rendus de l'Académie des Sciences, Paris, 326: 137–143.
Maksimov, S.E, 1992. Geological Structure and Economic Minerals of the USSR, 6. Kazakhstan and Middle Asia, Book 3. Platform Cover of the Epi–Paleozoic Plates and Depressions of Middle Asia and Kazakhstan (Turanian Plate and Adjacent Areas). Nedra, Moscow.
Maman, S., Blumberg, D.G., Tsoar, H., Mamedov, B., Porat, N., 2011. The Central Asian ergs: A study by remote sensing and geographic information systems. Aeolian Research, 353–366.
Mousavi, Z., Walpersdorf, A., Walker, R.T., Tavakoli, F., Pathier, E., Nankali, H., Nilfouroushan, F., Djamour, Y., 2013. Global Positioning System constraints on the active tectonics of NE Iran and the South Caspian region. Earth and Planetary Science Letters, 377: 287–298.
Moussavi–Harami, R., Brenner, R.L., 1992. Geohistory analysis and petroleum reservoir characteristics of Lower Cretaceous (Neocomian) sandstones, eastern Kopet–Dagh basin, northeastern Iran: AAPG Bulletin, 76: 1200–1208.
Natal'in, B.A., Sengör, A.M.C., 2005. Late Palaeozoic to Triasic evolution of the Turan and Scythian platforms: The pre–history of the Palaeo–Tethyan closure. Tectonophysics, 404: 175–202.
Olcott, M.B., 2013. The Geopolitics of Natural Gas; Turkmenistan: real energy giant or eternal potential? Harvard University's Belfer Center and Rice University's Baker Institute Center for Energy Studies. 31 p.
Oppo, D., Capozzi, R., 2015. Spatial association ofmud volcano and sandstone intrusions, Boyadag anticline, western Turkmenistan. Basin Research, 1–13, doi: 10.1111/bre.12136.
Oppo, D., Capozzi, R., Nigarov, A., Paltamet, E., 2014. Mud volcanism and fluid geochemistry in the Cheleken Peninsula, western Turkmenistan. Mar. Pet. Geol., 57: 122–134.
Planke, S., Svensen, H., Hovland, M., Banks, D.A., Jamtveit, B., 2003. Mud and fluid migration in active mud volcanoes in Azerbaijan. Geo–Mar. Lett., 23: 258–268.
Popov, S.V., Shcherba, I.G., Ilyina, L.B., Nevesskaya, L.A., Paramonova, N.P., Khondkarian, S.O., Magyar, I., 2006. Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranean. Palaeogeography, Palaeoclimatology, Palaeoecology, 238: 91–106.
Rastsvetaev, L.M., 1966. Razryvy Kopet–Daga i ikh sviaz' po skladchatoi structuroi. Geotektonica, 3: 93–107.
Reynolds, A.D., Simmons, M.D., Bowman, M.B.J., Henton, J., Brayshaw, A.C., Ali–Zade, A.A., Guliyev, I.S., Suleymanova, S.F., Ateava, E.Z., Mamedova, D.N., Koshkarly, R.O., 1998., Implications of outcrop geology for reservoirs in the Neogene Productive Series, Apsheron Peninsula, Azerbaijan: American Association of Petroleum Geologists Bulletin, 82(1): 25–49.
Robert, A.M.M., Letouzey, J., Kavoosi, M.A., Sherkati, S., Müller, C., Vergés, J., Aghababei, A., 2014. Structural evolution of the Kopeh Dagh fold–and–thrust–belt (NE Iran) and interactions with the South Caspian Sea Basin and Amu–Darya Basin. Marine and Petroleum Geology, 57: 68–87.
Ruttner, A.W., 1993. Southern borderland of Triassic Laurasia in north–east Iran. Geologische Rundschau, 82: 110–120.
Shahgedanova, M., 2002. The physical geography of northern Eurasia. Oxford University Press, 571 p.
Sheikh–Zade, E.R., 1996. Results of seismic reflection profiling in the Turanian Platform. Tectonophysics, 264: 123–135.
Shikalibeily, E.Sh., Grigoriants, B.V., 1980. Principal features of the crustal structure of the south–Caspian basin and the conditions of its formation, Tectonophysics, 69: 113–121.
Smith–Rouch, L.S., 2006. Oligocene–Miocene Maykop/Diatom Total Petroleum System of the South Caspian Basin Province, Azerbaijan, Iran, and Turkmenistan. U.S. Geological Survey Bulletin 2201–I.
Stoppato, M., Bini, A., Eklund, L.M., 2003. Deserts. Firefly Books, Nature, 256 p.
Sun, J., 2002. Source regions and formation of the loess sediments on the High Mountain regions of Northwestern China. Quaternary Research, 58 (3): 341–351.
Tavakoli, F., 2007. Present–day Deformation and Kinematics of the active faults observed by GPS in the Zagros and East of Iran (Ph.D. thesis). Université Joseph Fourier, Grenoble I.
Tchalenko, J.S., 1975. Seismicity and structure of the Kopet Dagh (Iran, USSR), Phil. Trans. R. Soc. Lond., A., 278(1275): 1–28.
Thomas J.C., Cobbold, P.R., Shein, V.S., Le Douaran, S., 1995. Late Paleozoic to recent development of sedimentary basins on the Turan and south Kazakh platforms, central Asia (abs.): AAPG Bulletin, 79(8): 1252.
Thomas J.C., Grasso, J.R., Bossu, R., Martinod, J., Nurtaev, B., 1999. Recent deformation in the Turan and South Kazakh platforms, western central Asia, and its relation to Arabia–Asia and India–Asia collisions. Tectonics, 18(2): 201–214.
Ulmishek, G.F., 2004. Petroleum geology and resources of the Amu–Darya Basin, Turkmenistan, Uzbekistan, Afghanistan, and Iran. U.S. Geol. Surv. Bull. 2201–4, 32 p.
Van Baak, C.G.C., Vasiliev, I., Stoica, M., Kuiper, K.F., Forte, A.M., Aliyeva, E., Krijgsman, W., 2013. A

magnetostratigraphic time frame for Plio–Pleistocene transgressions in the South Caspian Basin, Azerbaijan. Global and Planetary Change, 103: 119–134.

Vannucci, G., Pondrelli, S., Argnani, A., Morelli, A., Gasperini, P., Boschi, E., 2004. An atlas of Mediterranean seismicity. Annals of Geophysics, supplement to vol. 47 N. 1: 247–306.

Volvovsky, I.S., Garetzky, R.G., Shlezinger, A.E., Shreibman, V.I., 1966, Tectonics of the Turan plate (in Russian): Geologitcheskiy Institut Akademii Nauk, U.S.S.R., 165, 287 p.

Worrall, D.M., Snelson, S., 1989. Evolution of the northern Gulf of Mexico, with emphasis on Cenozoic growth faulting and the role of salt. In, A.W. Bally, A.R. Palmer (Eds.), The Geology of North America – An Overview. Geological Society of America, A: 97–138.

Zanchetta, S., Berra, F., Zanchi, A., Bergomi, M., Caridroit, M., Nicora, M., Heidarzadeh, G., 2013. The record of the Late Palaeozoic active margin of the Palaeotethys in NE Iran: Constraints on the Cimmerian orogeny. Gondwana Research, 24: 1237–1266.

Zanchi, A., Zanchetta, S., Balini, M., Ghassemi, M.R., 2016. Oblique convergence during the Cimmerian collision: Evidence from the Triassic Aghdarband Basin, NE Iran. Gondwana Research, 38: 149–170.

Zavialov, P., 2005. Physical Oceanography of the dying Aral Sea. Springer–Verlag Berlin Heidelberg New York. 146 p.

Zonn, I., Kostianoy, A., Kosarev, A., Glantz, M., 2010. The Caspian Sea encyclopedia, ebook, Springer Heidelberg Dordrecht London New York, 537 p.

Zonn, I.S., Kostianoy, A.G., 2014. The Turkmen Lake Altyn Asyr and water resources in Turkmenistan. Springer. 323 p.

Coleoptera (Insecta) from Ashgabat City and Köýtendag Nature Reserve, with nine first records for Turkmenistan

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Coleoptera (Insecta) from Ashgabat City and Köýtendag Nature Reserve, with nine first records for Turkmenistan

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Abstract: A list of 60 species group taxa of 15 families of the order Coleoptera collected at Ashgabat City and in Lebap Province (Turkmenistan) is presented. Nine species are reported for the first time for the country: *Bembidion aeneum* Germar, 1823, *Chlaenius extensus* Mannerheim, 1825, *Gyrinus distinctus* Aubé, 1838, *Bisnius piochardi* (Fauvel, 1875), *Gabrius hissaricus* Schillhammer, 2003, *Quedius novus* Eppelsheim, 1892, *Thinodromus behnei* Gildenkov, 2000, *Trichophya pilicornis* (Gyllenhal, 1810) and *Galeruca jucunda* (Faldermann, 1836).

Keywords: Coleoptera, Turkmenistan, new records, first records

Introduction

We give a list of beetles collected from two regions of Turkmenistan in May 2015. The first site is the Botanic Gardens in the Ashgabat City and the second one is the Köýtendag Nature Reserve, Köýtendag Mts., south-eastern Turkmenistan. All material was collected by Prof. Pavel Stoev from the National Museum of Natural History, Bulgarian Academy of Sciences, Sofia, during a Rapid Environmental Assessment survey carried out by an international team of zoologists in the Köýtendag Mts.

The new faunistic information is presented concerning the recent data for the distribution of the Palaearctic beetles (see the sources in part "Material and methods"), thus previous faunistic studies in the region are not considered.

Material and methods

The present study is based on the identification of 245 specimens belonging to 15 families of the order Coleoptera. The arrangement of the families and statuses of the taxa follow the recent editions of the catalogues of the Palaearctic Coleoptera (volumes 4–8, Löbl & Smetana, 2007–2013 and volumes 1 and 3, Löbl & Löbl, 2016–2017). The names of authors who identified the species are given with their shortened first name and full surname at each family (in the part "List of taxa").

Description of the localities

– № 01: Ashgabat City, Botanic Gardens, 37.954N 58.346E, under stones, leaf litter, dense, mostly dry mixed forest, 22.V.2015.

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Figures 1–2 (photos courtesy of Pavel Stoev). Locality № 07: the passage Gyrkgyz dere, a collecting site for *Chlaenius extensus*, *Quedius novus*, *Q. scintillans* and *Cyphogenia aurita aurita*.

Figure 3 (photo courtesy of Pavel Stoev). Locality № 10: the canyon Umbar dere, a collecting site for three species first reported from Turkmenistan: *Chlaenius extensus, Quedius novus,* and *Galeruca jucunda*.

– № 02: Lebap Province, Köýtendag District, Köýtendag Town, 37.508N 65.993E, in close proximity to the river, dry, under stones, 24.V.2015.
– № 03: Lebap Province, Köýtendag District, approx. 10 km from Köýtendag Town towards Garlyk Village, desert, in close proximity to the road, dry, 24.V.2015.
– № 04: Lebap Province, Köýtendag District, Gurshun Magdanly Village (= Svintsovoy rudnik), around Kaptarhana Cave (Pigeon Cave), 37.828N 66.410E, grassland, 24.V.2015.
– № 05: Lebap Province, Köýtendag District, Bazardepe Village, Köýtendag Nature Reserve Headquarter, 37.762N 66.369E, grassland, 24.V.2015.
– № 06: Lebap Province, Köýtendag District, Köýtendag Mts., from Köýten Village towards Gyrkgyz dere, some 8–9 km from, close to the road, approx. 950 m a.s.l., under stones, 25.V.2015.
– № 07: Lebap Province, Köýtendag District, Köýtendag Mts., Gyrkgyz dere, along the track, 37.936N 66.595E, under stones, 25.V.2015 (Figs 1–2).
– № 08: Lebap Province, Köýtendag District, Köýtendag Mts., Gyrkgyz dere, Kyrkgyz grotto, 37.938N 66.584E, humid, 25.V.2015.
– № 09: Lebap Province, Köýtendag District, Köýtendag Mts., Hojapil Village, around the Dinosaurs tracks Site, 37.941N 66.627E, under stones, 25.V.2015.
– № 10: Lebap Province, Köýtendag District, Köýtendag Mts., Hojapil Village, Umbar dere (the canyon with the waterfall), along the track, 37.936N 66.653E, under stones, 25.V.2015 (Fig. 3).
– № 11: Lebap Province, Köýtendag District, Köýtendag Mts., Hojapil Village, Bash Bulak 2 source, collected from the source and around it, 37.940N 66.554E, 25.V.2015.
– № 12: Lebap Province, Köýtendag District, Köýtendag Mts., Daray dere, track from the water tank to the source, 37.781N 66.452E, under stones, 26.V.2015.
– № 13: Lebap Province, Köýtendag District, Köýtendag Mts., Daray dere, disused mine galleries close to the source, 37.778N 66.465E, 26.V.2015.

Figures 4–5 (photos courtesy of Pavel Stoev). Localities № 5, № 15 and № 19: grasslands surrounding the Köýtendag Nature Reserve Headquarter, a collecting site for some widely distributed species, such as *Apotomus rufithorax, Syntomus fusco-maculatus, Hybosorus illigeri, Augyles turanicus, Cheirodes brevicollis, Gonocephalum rusticum, G. setulosum setulosum, Chaetocnema hortensis,* and *Sharpia rubida*.

– № 14: Lebap Province, Köýtendag District, Köýtendag Mts., Garlyk Village, Gap Gotan Cave, 37.642N 66.408E, collected mostly in the artificial mine gallery, 27.V.2015.
– № 15: Lebap Province, Köýtendag District, Bazardepe Village, Köýtendag Nature Reserve Headquarter, 37.762N 66.369E, attracted by light at night, 27–28.V.2015.
– № 16: Lebap Province, Köýtendag District, Köýtendag Mts., Garlyk Village, around Gulshirin Cave (= Geofizicheskaya), on shrubs, grass and under stones, 37.673N 66.395E, 28.V.2015.
– № 17: Lebap Province, Köýtendag District, Köýtendag Mts., Garlyk Village, Suuv Oyuk Sinkhole (the sinkhole with the blind loaches), around the sinkhole and in the water, 37.597N 66.406E, 29.V.2015.
– № 18: Lebap Province, Köýtendag District, Köýtendag Mts., Garlyk Village, Khashim Oyuk Cave, 37.642N 66.383E, dry, collected mostly in the entrance hall, 29.V.2015.
– № 19: Lebap Province, Köýtendag District, Bazardepe Village, Köýtendag Nature Reserve Headquarter, 37.762N 66.369E, attracted by light at night, 29.V.2015.
– № 20: Lebap Province, Köýtendag District, Gurshun Magdanly Village (= Svintsovoy rudnik), disused mine gallery "Kette-Kamov", 37.862N 66.489E, humid, 30.V.2015.
– № 21: Lebap Province, Köýtendag District, Bazardepe Village, Köýtendag Nature Reserve Headquarter, near Sauk Kamar Cave, 37.758N 66.348E, 30.V.2015.

Note: Entries № 5, № 15 and № 19 refer to the same locality (Figs 4–5), but to different dates and collecting methods.

Abbreviations for specimen depositories

CHF	Hans Fery collection, Berlin, Germany (property of the Naturhistorisches Museum Wien, Vienna, Austria)
DKCP	David Král collection, Prague, Czech Republic (deposited in NMPC)
HNHM	Hungarian Natural History Museum, Budapest, Hungary (Ottó Merkl)
NMNHS	National Museum of Natural History, Sofia, Bulgaria (Borislav Guéorguiev)
NMPC	Prague National Museum, Prague, Czech Republic (Jiří Hájek)
SCH	Michael Schülke collection, Berlin, Germany (property of the Museum für Naturkunde, Berlin, Germany)
ZKDC	Zbyněk Kejval collection, Domažlice, Czech Republic

List of the taxa

Family Carabidae (det. B. Guéorguiev)

Acinopus (*Acinopus*) *laevigatus* Ménétriés, 1832. Material examined: № 06 (1 ♀, NMNHS). Distribution: Balkan Peninsula (Croatia, Bulgaria, Greece), Romania, Moldova, Ukraine, southern part of European Russia, Transcaucasia (Armenia, Azerbaijan), northern Levant (Turkey, Israel), Iran, Iraq, Central Asia (from Turkmenistan and Kazakhstan to Gansu, Xizang and northernmost parts of Pakistan and India).

Apotomus rufithorax Pecchioli, 1837. Material examined: № 15 (2 ♂♂, 1 ♀, NMNHS). Distribution: Mediterranean region (southern Europe, north-western Africa, Levant), Transcaucasia (Armenia, Azerbaijan), Iran, Iraq, Turkmenistan, Uzbekistan, Afghanistan.

Asaphidion transcaspicum (Semenov, 1889). Material examined: № 10 (1 ♂, NMNHS). Distribution: Bulgaria, Georgia, Azerbaijan, Iran, Central Asia (from Turkmenistan to Xinjiang), eastern Siberia.

Bembidion (*Ocyturanes*) *dyscheres* Netolitzky, 1943. Material examined: № 14 (2 ♂♂, 1 ♀, NMNHS). Distribution: Iran, Central Asia (from Turkmenistan to Tajikistan and Pakistan).

Bembidion (*Peryphus*) *obscurellum turanicum* Csiki, 1928. Material examined: № 10 (1 ♀, NMNHS). Distribution: Turkey, Iran, Central Asia (from Turkmenistan to Mongolia and Kashmir), eastern Siberia, northern China.

Bembidion (*Philochthus*) *aeneum athalassicum* De Monte, 1953. Material examined: № 15 (1 ♂, 3 ♀♀, NMNHS). Distribution: Ukraine, Azerbaijan, Uzbekistan (Neri & Gudenzi, 2013). Notes: The record from the Köýtendag Nature Reserve is the first one of the halobiont *B. aeneum* (s.l.) Germar, 1823 from Turkmenistan. According to Paolo Neri (pers. comm.), the ssp. *athalassicum* occurs in environments with clays containing high percentage of NaCl.

Broscus punctatus (Dejean, 1828). Material examined: № 01 (1 ♂, NMNHS). Distribution: southern Levant (Egypt, Sinai), Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (Uzbekistan, Kyrgyzstan, Tajikistan, Afghanistan), Nepal, northern India, south China.

Calathus (*Neocalathus*) *ambiguus ambiguus* (Paykull, 1790). Material examined: № 10 (2 ♂♂, 6 ♀♀, NMNHS). Distribution: Europe, western Siberia, Transcaucasia, northern Levant (Turkey, Syria, Israel), Iran, Central Asia (from Turkmenistan and Kazakhstan to Afghanistan).

Calosoma (*Caminaria*) *maderae dsungaricum* Gebler, 1833. Material examined: № 01 (1 ♀, NMNHS). Distribution: eastern Mediterranean region (Greece, Turkey, Cyprus, Syria), Romania, Ukraine, southern part of European Russia, Caucasus, Transcaucasia (Armenia, Azerbaijan), Middle East (Iran, Iraq, Kuwait), Central Asia (from Turkmenistan and Kazakhstan to Mongolia, Gansu, Xizang and Pakistan).

Chlaenius (*Chlaeniellus*) *extensus* Mannerheim, 1825. Material examined: № 07 (1 ♀, NMNHS); № 10 (1 ♀, NMNHS; Fig. 6). Distribution: Iran, Uzbekistan, Kyrgyzstan, Tajikistan, southern Siberia. Recently, Schnitter (2016) reported "*Chlaenius* (*Chlaeniellus*) near *extensus*" as a new taxon for Mongolia. Notes: First record from Turkmenistan. Mandl (1983) stated that this species and *Chl*. *vestitus* (Paykull, 1790) are morphologically very similar and differ only in body size. The same author (ibid.) suggested that the former could be a subspecies of the latter. This needs verification because both species co-occur in Iran and Kopet Dagh (a mountain range situated in north-eastern Iran and south-western Turkmenistan; ibid.; Azadbakhsh & Nozari, 2015). These territories, as well as the south part of Kazakhstan are perhaps the areas where these two taxa interbreed.

Cymindis (*Paracymindis*) *asiabadense kryzhanovskii* Emetz, 1972. Material examined: № 14 (5 ♂♂, 1 ♀, NMNHS). Distribution: Turkmenistan, Tajikistan.

Eremosphodrus (*Rugisphodrus*) *dvorshaki* Casale & Vereschagina, 1986. Material examined: № 14 (1 ♂, 1 ♀, NMNHS). Distribution: Kazakhstan, Kyrgyzstan, Uzbekistan, Turkmenistan.

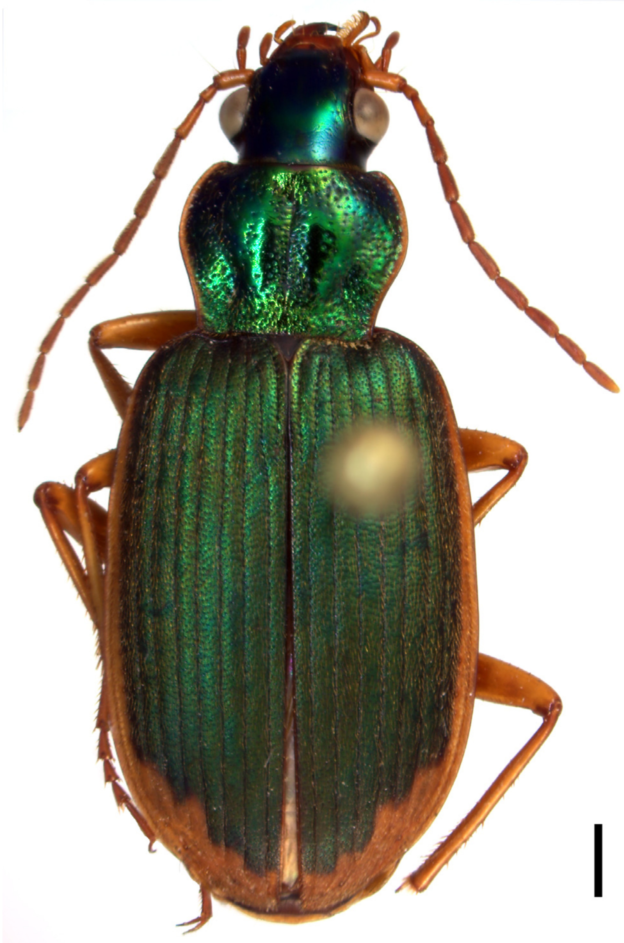

Figure 6. *Chlaenius extensus*. Scale line = 1 mm.

Parophonus (*Ophonomimus*) *interstitialis* (Reitter, 1889). Material examined: № 15 (1 ♀, NMNHS). Distribution: Armenia, Iran, Iraq, Central Asia (from Kazakhstan and Turkmenistan to Pakistan).

Poecilus (*Ancholeus*) *dissors* (Tschitschérine, 1893). Material examined: № 15 (1 ♂, NMNHS). Distribution: Turkmenistan, Kyrgyzstan, Afghanistan.

Syntomus fuscomaculatus Motschulsky, 1844. Material examined: № 15 (2 ♀♀, NMNHS); № 21 (1 ♀, NMNHS). Distribution: Mediterranean region, southern part of European Russia, Caucasus, Transcaucasia, Levant, Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (from Turkmenistan and Kazakhstan to Mongolia and Pakistan), Bhutan, India.

Trechus (*Trechus*) *quadristriatus* (Schrank, 1781). Material examined: № 10 (1 ♂, 2 ♀♀, NMNHS). Distribution: Europe, north-western Africa, Caucasus, Transcaucasia, Levant, Middle East, Central Asia (from Turkmenistan to Xinjiang).

Family Gyrinidae (det. H. Fery)

Gyrinus (*Gyrinus*) *distinctus* Aubé, 1838. Material examined: № 11 (1 ♂, 1 ♀, CHF; 2 ♂♂, NMNHS). Distribution: Europe (except for the northern parts); in Africa: Egypt, Libya and parts of the Afrotropical Region; in Asia: northern Levant (Turkey, Cyprus, Syria, Lebanon), Middle East (Iran, Iraq, United Arab Emirates), Central Asia (Kazakhstan, Uzbekistan, Kyrgyzstan, Mongolia, Afghanistan), China (northern and western regions), Kashmir. Notes: First record from Turkmenistan.

Family Dytiscidae (det. H. Fery)

Hydaticus (*Prodaticus*) cf. *pictus* (Sharp, 1882). Material examined: № 17 (2 ♂♂, CHF; 1 ♂, 1 ♀, NMNHS). Distribution: Syria, Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (Kazakhstan and Turkmenistan to Pakistan) (Temreshev, 2015).

Hydroporus planus (Fabricius, 1782). Material examined: № 11 (1 ♀, NMNHS). Distribution: Europe, Morocco, Algeria, Turkey, Lebanon, Iran, Iraq, Turkmenistan, Kazakhstan, Kirgizstan, western Siberia.

Nebrioporus airumlus (Kolenati, 1845). Material examined: № 11 (1 ♂, 1 ♀, CHF; 1 ♂, 2 ♀♀, NMNHS). Distribution: Poland, Ukraine, southern part of Russia, Caucasus, Transcaucasia, Turkey, Israel, Iran, Central Asia (Kazakhstan and Turkmenistan to Mongolia and Pakistan), eastern Siberia, large parts of China, Kashmir, northern India.

Family Staphylinidae (det. M. Schülke)

Achenium quadriceps Eppelsheim, 1889. Material examined: № 15 (7 specimens, NMNHS, 3 specimens SCH); № 19 (1 specimen, SCH). Distribution: southern Russia, Caucasus and Transcaucasia (Armenia, Azerbaijan), Iran, Middle Asia (Afghanistan, Kyrgyzstan, Kazakhstan, Turkmenistan, Tajikistan, Uzbekistan, China: Xinjian Uygur Zizhiqu) (Assing, 2010).

Bisnius piochardi (Fauvel, 1875). Material examined: № 01 (1 ♂, SCH). Distribution: from east Turkey to Israel, Syria and Iran (Schülke & Smetana, 2015). Notes: First record from Turkmenistan. The collected specimen was compared with a male from eastern Turkey.

Gabrius hissaricus Schillhammer, 2003. Material examined: № 13 (2 ♂♂, NMNHS, 1 ♂, SCH); № 20 (1 ♂, SCH). Distribution: Tajikistan, Turkey (?). Notes: First record from Turkmenistan. The species was described from the Gissar range in Tajikistan. It was later recorded from Erzincan province of Turkey by Özgen & Khachikov (2013). Since a highly similar species, *Gabrius armeniacus* Coiffait, 1966, has been recorded from Armenia, this record requires confirmation.

Quedius (*Raphirus*) *novus* Eppelsheim, 1892. Material examined: № 07 (1 specimen, NMNHS); № 08 (1 specimen, SCH); № 10 (3 specimens, NMNHS, 2 specimens SCH); № 13 (1 specimen, SCH). Distribution: recorded from Tajikistan and Uzbekistan (Schülke & Smetana, 2015). Notes: First record from Turkmenistan.

Quedius (*Raphirus*) *scintillans* (Gravenhorst, 1806). Material examined: № 07 (1 specimen, SCH). Distribution: western Palaearctic, from North Africa across Europe to the Middle East (Iran, Israel, Lebanon, Syria, Turkey) and Middle Asia (Afghanistan, Turkmenistan, Uzbekistan) (Schülke & Smetana, 2015).

Sepedophilus rufulus (Hochhuth, 1849). Material examined: № 13 (2 specimens, NMNHS, 1 specimen SCH); № 14 (6 specimens, NMNHS, 4 specimens SCH). Distribution: whole Caucasus and Transcaucasia (Russia, Georgia, Azerbaijan, Armenia, northeastern Turkey), Middle East (Iran, Iraq), Middle Asia (Afghanistan, Turkmenistan, Uzbekistan), northern Pakistan, India (Kashmir) (Schülke & Smetana, 2015).

Thinodromus behnei Gildenkov, 2000. Material examined: № 14 (1 specimen, NMNHS, 1 specimen SCH). Distribution: western part of Tajikistan (Gissar Alai and Zarafshan Mountain ranges) (Gildenkov, 2001). Notes: First record from Turkmenistan.

Trichophya pilicornis (Gyllenhal, 1810). Material examined: № 13 (2 specimens, NMNHS, 1 specimen SCH). Distribution: whole Palaearctic region (Canary Islands and Spain in the west to east Siberia and the Russian Far East), also adventive in the Nearctic region (Schülke & Smetana, 2015). Records from the eastern part of the Palaearctic and from the Himalaya (Uttarakhand, Himachal Pradesh) require confirmation. The species lives in leaf litter and under bark. It has also been reported from old mines, where it was probably transported with pit wood. Notes: First record from Turkmenistan.

Family Hybosoridae (det. D. Král & B. Guéorguiev)

Hybosorus illigeri Reiche, 1853. Material examined: № 15 (1 ♀, NMNHS). Distribution: Subcosmopolitan (species with an extremely wide distribution, extending from south parts of Europe to India and South Africa including Madagascar; it has been also introduced to large parts of the Nearctic and Neotropical Regions. Widely distributed in Turkmenistan (Nikolajev, 1987).

Family Scarabaeidae (det. D. Král)

Phaeadoretus comptus (Ménétriés, 1849). Material examined: № 15 (2 specimens, DKCP; 2 specimens, NMNHS); № 19 (1 specimen, NMNHS). Distribution: known from whole Middle Asia, Azerbaijan, Iran and Afghanistan. Widely distributed in Turkmenistan (Nikolajev, 1987).

Pleurophorus apicipennis Reitter, 1892. Material examined: № 15 (1 specimen, DKCP; 9 specimens, NMNHS). Distribution: widely distributed in western Asia (from Turkey and Turkmenistan in the west to the Xinjiang in China in the east).

Family Heteroceridae (det. B. Guéorguiev)

Augyles turanicus (Reitter, 1887). Material examined: № 19 (1 ♀, NMNHS; Fig. 7). Distribution: Algeria, Georgia, Levant (Turkey, Syria, Israel), Middle East

Figure 7. *Augyles turanicus*, a typical shore beetle. Scale line = 1 mm.

(Iraq, Iran, Saudi Arabia, United Arab Emirates), Kazakhstan, Turkmenistan, Uzbekistan (Mascagni et al., 2016). Extensive bibliographical data about Turanian species were represented by Sazhnev (2017).

Family Elateridae (det. T. Németh)

Aeoloides figuratus (Germar, 1844). Material examined: № 15 (1 specimen, NMNHS); № 19 (1 specimen, HNHM; 3 specimens, NMNHS). Distribution: Caucasus, Transcaucasia, Arabian Peninsula, Central Asia to Pakistan.

Agriotes (*Agriotes*) *meticulosus* Candèze, 1863. Material examined: № 15 (2 specimens, NMNHS). Distribution: Caucasus, Transcaucasia, Arabian Peninsula, Iran to Pakistan.

Family Ptinidae (det. B. Guéorguiev)

Niptus hololeucus (Faldermann, 1835). Material examined: № 14 (29 specimens, NMNHS). Distribution: Cosmopolitan.

Figure 8. *Dichillus seminitidus*, a typical nocturnal beetle. Scale line = 1 mm.

Family Coccinellidae (det. O. Merkl & B. Guéorguiev)

Coccinella (*Coccinella*) *septempunctata* Linnaeus, 1758. Material examined: № 02 (1 specimen, NMNHS); № 09 (1 specimen, NMNHS); № 12 (1 specimen, NMNHS). Distribution: whole Palaearctic region (south to northern Vietnam); deliberately introduced to North America.

Family Tenebrionidae (det. O. Merkl)

Adesmia (*Adesmia*) *planidorsis* Reitter, 1916. Material examined: № 16 (1 specimen, NMNHS); № 17 (1 specimen, NMNHS). Distribution: Tajikistan, Turkmenistan, Uzbekistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Cheirodes (*Pseudanemia*) *brevicollis* (Wollaston, 1864). Material examined: № 15 (1 specimen, NMNHS). Distribution: Mediterranean region (southern Europe, Canary Islands, North Africa, Turkey, Levant), Transcaucasia (Armenia, Azerbaijan), Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (from Turkmenistan to Mongolia, Xinjiang and Pakistan), Sahelian and Saharan parts of Africa (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Cyphogenia (*Cyphogenia*) *aurita aurita* (Pallas, 1781). Material examined: № 07 (1 specimen, NMNHS). Distribution: southern part of European Russia, Afghanistan, Iran, Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan, China (Xinjiang) (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Dailognatha nasuta (Ménétriés, 1849). Material examined: № 04 (1 specimen, HNHM); № 05 (1 specimen, NMNHS); № 16 (1 specimen, NMNHS). Distribution: Afghanistan, Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Dichillus (*Dichillus*) *seminitidus* Solsky, 1881. Material examined: № 15 (1 specimen, NMNHS; Fig. 8). Distribution: Afghanistan, Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Gonocephalum (*Gonocephalum*) *rusticum* (A. G. Olivier, 1811). Material examined: № 05 (1 specimen, NMNHS); № 15 (5 specimens, NMNHS). Distribution: Mediterranean region (southern Europe, Canary Islands, North Africa, Turkey, Levant), Transcaucasia (Armenia, Azerbaijan), Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (from Turkmenistan to Mongolia and China) (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Gonocephalum (*Gonocephalum*) *setulosum setulosum* (Faldermann, 1837). Material examined: № 15 (1 specimen, NMNHS). Distribution: Mediterranean region (southern Europe, Canary Islands, North Africa, Turkey, Levant), southern part of European Russia, Caucasus, Transcaucasia, Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (from Turkmenistan to Afghanistan), Sahelian and Saharan parts of Africa (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Leptodes (*Paraleptodes*) *terminassianae* G. Medvedev, 1970. Material examined: № 18 (11 fragmented specimens NMNHS, 1 fragmented specimen, HNHM). Distribution: Turkmenistan, Uzbekistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Neopachypterus serrulatus (Reitter, 1904). Material examined: № 12 (1 specimen, NMNHS). Distribution: Afghanistan, Armenia, Azerbaijan, Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Pimeliocnera gebieni Reitter, 1909. Material examined: № 16 (1 specimen, NMNHS). Distribution: Tajikistan, Turkmenistan, Uzbekistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Pimelipachys laevicollis laevicollis (Reitter, 1893). Material examined: № 04 (1 specimen, HNHM; 2 specimens, NMNHS). Distribution: Kazakhstan, Turkmenistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Omophlus sp. Material examined: № 09 (1 specimen, NMNHS).

Opatroides punctulatus parvulus (Faldermann, 1837). Material examined: № 15 (2 specimens, NMNHS). Distribution: Afghanistan, Armenia, Azerbaijan, Iran, Tajikistan, Turkmenistan, Turkey, Pakistan, Uzbekistan, western India (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Thriptera longipilis Reitter, 1895. Material examined: № 03 (1 specimen, NMNHS); № 04 (1 specimen, NMNHS). Distribution: Afghanistan, Tajikistan, Turkmenistan (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Zophosis (*Oculosis*) *punctata punctata* Brullé, 1832. Material examined: № 09 (1 specimen, NMNHS). Distribution: Mediterranean region (southern Europe, North Africa, Turkey, Levant), Transcaucasia (Armenia, Azerbaijan), Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (from Turkmenistan to Xinjiang and Pakistan) (Löbl et al., 2008; Medvedev & Nepesova, 1985).

Family Meloidae (det. D. Szalóki)

Ctenopus sinuatipennis (Fairmaire, 1892). Material examined: № 17 (1 specimen, HNHM). Distribution: Turkmenistan, Uzbekistan, China (Xinjiang).

Family Anthicidae (det. Z. Kejval)

Cordicomus margelanicus (Pic, 1893). Material examined: № 15 (1 ♂, 1 ♀, NMNHS; 1 ♂, 1 ♀, ZKDC). Distribution: Ukraine, southern Russia, Turkey, Syria, Azerbaijan, Iran, Iraq, Central Asia (from Turkmenistan to Mongolia and Afghanistan) (Chandler et al., 2008). Notes: In the Palaearctic catalogue (Chandler et al. 2008), the species is listed under *Cordicollis* Marseul, 1879 but is to be treated as *Cordicomus* Pic, 1894 (ICZN 2016, Opinion 2377).

Cyclodinus reitteri (Pic, 1892). Material examined: № 15 (5 ♂♂, 4 ♀♀, NMNHS; 5 ♂♂, 3 ♀♀, ZKDC); № 19 (8 ♂♂, 4 ♀♀, NMNHS; 2 ♂♂, 2 ♀♀, ZKDC). Distribution: southern Russia, Azerbaijan, Syria, Turkmenistan, Uzbekistan, Afghanistan (Chandler et al., 2008).

Family Chrysomelidae (det. B. Guéorguiev)

Chaetocnema (*Chaetocnema*) *hortensis* (Geoffroy, 1785). Material examined: № 19 (1 ♀, NMNHS). Distribution: Europe, Macaronesia (Azores, Madeira), Morocco, Tunisia, Levant, Georgia, Azerbaijan, Middle East (Iran, Iraq, Arabian Peninsula), Central Asia (from Turkmenistan to Mongolia), eastern Siberia, Russian Far East, China (Jiangsu).

Galeruca (*Galeruca*) *jucunda* (Faldermann, 1837). Material examined: № 10 (1 ♂, NMNHS; Fig. 9). Distribution: Europe (excluding the northern and eastern parts), Caucasus, southern Siberia, Turkey, Azerbaijan, Syria, N Iran, Afghanistan, Mongolia, China (Inner Mongolia, Xizang) (Beenen, 2010; Mirzaei & Nozari, 2016). Notes: First record from Turkmenistan.

Family Curculionidae (det. V. Szénási)

Corigetus sp. Material examined: № 09 (1 specimen, NMNHS).

Figure 9. *Galeruca jucunda*. Scale line = 1 mm.

Hypera (*Hypera*) *postica* (Gyllenhal, 1813). Material examined: № 10 (2 specimens, NMNHS). Distribution: whole Europe (including Caucasus and Transcaucasia), North Africa, Turkey to Xinjiang; accidentally introduced to Japan and North America.

Phacephorus nebulosus (Fåhraeus, 1840). Material examined: № 10 (1 specimen, HNHM); № 15 (3 specimens, HNHM; 2 specimens, NMNHS). Distribution: southern part of European Russia, Ukraine, Central Asia to China and eastern Siberia.

Sharpia rubida (Rosenhauer, 1856). Material examined: № 15 (3 specimens, NMNHS); № 19 (2 specimens, NMNHS). Distribution: Mediterranean region (southern Europe, North Africa, Levant), Transcaucasia (Armenia, Azerbaijan), Central Asia (from Turkmenistan, Uzbekistan).

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References

Assing V. 2010 A revision of *Achenium* (Coleoptera: Staphylinidae: Paederinae). Nova Supplementa Entomologica 21: 1–190.

Azadbakhsh S., Nozari J. 2015 Checklist of the Iranian Ground Beetles (Coleoptera; Carabidae). Zootaxa 4024 (1): 1–108.

Beenen R. 2010 Galerucinae. In: Löbl I, Smetana A. (eds) Catalogue of Palaearctic Coleoptera. Vol. 6. Apollo Books, Stenstrup, pp. 443–491.

Chandler D.S., Uhmann G., Nardi G., Telnov D. 2008 Anthicidae Latreille, 1819. In: Löbl I., Smetana A. (eds) Catalogue of Palaearctic Coleoptera. Vol. 5. Tenebrionoidea. Apollo Books, Stenstrup, pp. 421–455.

Gildenkov M.Y. 2001 Phylogenetic relations in the Oxytelinae subfamily. The Palaearctic *Thinodromus* fauna (Coleoptera: Staphylinidae: Oxytelinae). Publishing House SSPU, Smolensk, 201 pp. (In Russian).

ICZN 2016: Opinion 2377 (Case 3624) A proposal for the rejection of 38 names in anthicidae (Coleoptera): approved. Bulletin of Zoological Nomenclature 73: 65–69.

Löbl I., Löbl D. (eds) 2016 Catalogue of Palaearctic Coleoptera. Vol. 3. Scarabaeoidea – Scirtoidea – Dascilloidea – Buprestoidea – Byrrhoidea. Revised and Updated Edition. Brill, Leiden, Boston, xxviii + 984 pp.

Löbl I., Löbl D. (eds) 2017 Catalogue of Palaearctic Coleoptera. Vol. 1. Revised and updated edition. Archostemata – Myxophaga – Adephaga. Brill, Leiden, Boston, xxxiv + 1443 pp.

Löbl I., Smetana A. (eds) 2007 Catalogue of Palaearctic Coleoptera, Vol. 4. Elateroidea – Derodontoidea – Bostrichoidea – Lymexyloidea – Cleroidea – Cucujoidea. Apollo Books, Stenstrup, 935 pp.

Löbl I., Smetana A. (eds) 2008 Catalogue of Palaearctic Coleoptera. Vol. 5. Tenebrionoidea. Apollo Books, Stenstrup, 670 pp.

Löbl I., Smetana A. (eds) 2010 Catalogue of Palaearctic Coleoptera. Vol. 6. Chrysomeloidea. Apollo Books, Stenstrup, 924 pp.

Löbl I., Smetana A. (eds) 2011 Catalogue of Palaearctic Coleoptera. Vol. 7. Curculionoidea 1. Apollo Books, Stenstrup, 373 pp.

Löbl I., Smetana A. (eds) 2013 Catalogue of Palaearctic Coleoptera. Vol. 8. Curculionoidea 2. Apollo Books, Stenstrup, 700 pp.

Löbl I., Merkl O., Ando K., Bouchard P., Lillig M., Masumoto K., Schawaller W., Soldati F. 2008 Tenebrionidae. In: Löbl I., Smetana A. (eds) Catalogue of Palaearctic Coleoptera, Volume 5. Tenebrionoidea. Apollo Books, Stenstrup, pp. 105–352.

Mandl K. 1983 Ein Beitrag zur Kenntnis einiger Chlaeniinae-(Callistinae-) Formen aus der paläarktischen und der orientalischen Region. (Zugleich erste Auswertung der vom Naturhistorischen Museum in Wien erworbenen Chlaeniinae-Spezialsammlung Ernst Grundmanns). (Carabidae, Col.). 1. Teil. Annalen des Naturhistorischen Museums in Wien (B) 84: 401–447.

Mascagni A., Jäch M., Ostovan H., Ghahari H. 2016 Annotated checklist of Dryopidae and Heteroceridae (Coleoptera: Byrrhoidea) of Iran. Zootaxa, 4144 (3): 354–364. http://doi.org/10.11646/zootaxa.4144.3.4

Medvedev G.S., Nepesova M.G. 1985 Key to Tenebrionidae of Turkmenistan. Ylym, Ashkhabad, 178 pp. (In Russian).

Mirzaei M., Nozari J. 2016 Catalogue of Iranian subfamily Galerucinae s. str. (Coleoptera: Chrysomelidae). Iranian Journal of Animal Biosystematics 12 (2): 167–180.

Neri P., Gudenzi I. 2013 Note sul genere *Bembidion* Latreille, 1802, sottogenere *Philochthus* Stephens, 1828 e descrizione di cinque nuove specie (Insecta Coleoptera Carabidae). Quaderno di Studi e Notizie di Storia Naturale della Romagna 38: 97–179.

Nikolajev G.V. 1987 Scarabaeoidea (Coleoptera) of Kazakhstan and Middle Asia. Izdatelstvo Nauka KazSSR, Alma-Ata, 232 pp. (In Russian).

Özgen I., Khachikov E.A. 2013 New and additional records of *Gabrius* Stephens, 1829 (Coleoptera: Staphylinidae: Staphylininae) from Turkey and Cyprus. Archives of Biological Sciences 65 (2): 681–683.

Temreshev I.I. 2015 First records of *Hydaticus* (*Prodaticus*) *pictus* Sharp, 1882 (Coleoptera, Dytiscidae) in Kazakhstan. Euroasian Entomological Journal 14 (6): 554.

Sazhnev A.S. 2017 The variegated mud-loving beetles (Coleoptera: Heteroceridae) of the World. Bibliographic Index. (ver. 1.5).

Schnitter P. 2016 Vorläufige Checkliste der Laufkäfer (Coleoptera: Carabidae) der Mongolei 3. Beitrag zur Carabidenfauna der Mongolei. Erforschung biologischer Ressourcen der Mongolei 13: 197–220.

Schülke M., Smetana A. 2015 Staphylinidae. In: Löbl I., Löbl D. (eds) Catalogue of Palaearctic Coleoptera. Volume 2. Hydrophiloidea – Staphylinoidea. Revised and updated edition. Brill, Leiden, Boston, pp. 304–1134.

A report of RSPB-supported scientific research at Koytendag State Nature Reserve, East Turkmenistan

Compiled by Geoff Welch
Edited by Geoff Welch, Pavel Stoev

giving nature a home

Cover photograph: Koytendag massif from Tamcy. Photo credit: Jeremy Holden (RSPB).

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All of the work in Turkmenistan detailed in this report was carried out under the Memorandum of Understanding between the Ministry of Agriculture and Environment Protection of Turkmenistan and the Royal Society for Protection of Birds, within the Project on “Improvement of the status of birds and other biodiversity in Turkmenistan”.

Fig. 1. Camera trap training. Photo credit: Jeremy Holden (RSPB).
Fig. 2. Bird survey training. Photo credit: Jeremy Holden (RSPB).
Fig. 3. Survey team at sinkhole near Garlyk. Photo credit: Jeremy Holden (RSPB).

Table of contents

Introduction

Situated in the extreme south-east of Turkmenistan, on the international border with Uzbekistan and close to the border with Afghanistan, Koytendag[1] presents one of the most distinctive landscapes in Central Asia – *see maps 1 and 2*. The state nature reserve and wildlife sanctuaries that form the site extend from the hot, dry semi-desert plains of the Amudarya valley to the snow-capped peaks of Airy-baba. Rising to 3,137 m, this is the highest mountain in Turkmenistan. The Koytendag ridge (former Kugitang or Kugitangtaw) is a continuation of the Gissar ridge, itself the south-western end of the Pamir-Alay mountain range - a mountain chain that extends for over 800 kms from the Pamirs to the Tien-Shan with more than thirty-five peaks over 5,000 m.

Based on Udvardy's biogeographic classification (Udvardy 1975) Koytendag is situated in the Palaearctic Realm, Pamir-Tian-Shan Highlands Province, in a transition area between mixed mountains and highland systems with complex zonation and cold-winter (continental) deserts and semi-deserts. The site lies close to the borders of three other Udvardy Provinces: the Turanian, the Hindu Kush Highlands and the Anatolian-Iranian Desert and contains elements of the flora and fauna of each of these Provinces. The site is also one of 50 Important Bird and Biodiversity Areas (IBAs) in Turkmenistan, with biome-restricted bird communities from three biomes, and lies within the Central Asian Mountain Forests and Steppes WWF Global 200 Ecoregion and the IUCN/WWF Mountains of Central Asia Centre of Plant Diversity.

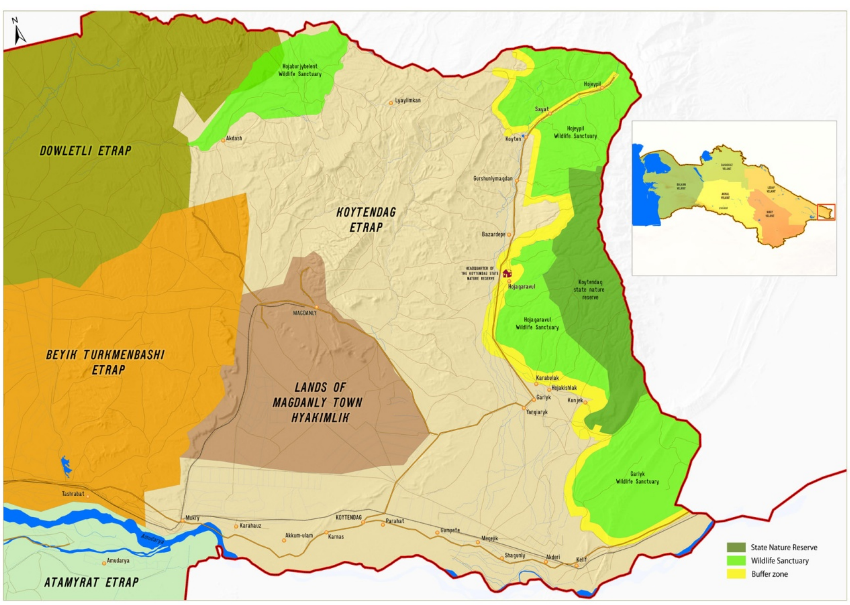
The Koytendag region is characterized by high mountain ridges dissected by deep canyons, many over 100 m deep. Each canyon has a distinct flora and features resulting in the region having great aesthetic, scientific, recreational and touristic importance. In the lower parts of the western slopes of the Koytendag ridge, the landscape is dominated by steep escarpments and cliffs. In the central section, there is an extensive area of very steep-sided, winding valleys bordered by a dramatic karst landscape. Erosion of the Jurassic limestone has created a complex of more than 300 caves, shafts and sinkholes, considered to be among the most important cave systems in Eurasia. These caves contain an extremely diverse array of geological formations and support a unique cave fauna. Along the south-eastern slope of the Koytendag ridge are several alluvial fans, some still with running water but many are permanently dry.

The plains are dominated by low wormwood scrub and patches of tamarisk but as altitude increases these give way to grazed pastures, extensive areas of juniper woodland, with a rich carpet of tulips and primulas in spring, finally becoming a rocky, but equally striking, alpine zone with low cushions of prickly thrift. The numerous, seasonal springs and streams provide important patches of more diverse and lush vegetation – *see figures 4 to 8*.

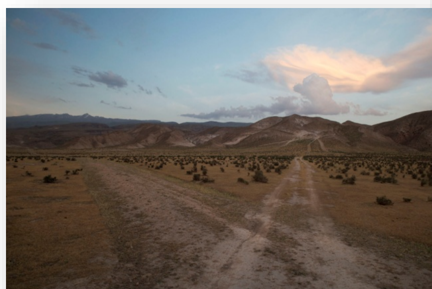
[1] Unless otherwise stated, for example by the addition of 'ridge', 'region' etc, the term Koytendag is used to refer to the complex of Koytendag State Nature Reserve and Hojapil, Garlyk, Hojaburjybelent and Hojagaravul State Sanctuaries.

Map 1. Location of Koytendag. Map by Atamyrat Veyisov.

Map 2. Boundaries of Koytendag. Map by Atamyrat Veyisov.



Figures 4-8. Habitats at Koytendag.



From top to bottom:
Fig. 4. From Airy-baba looking south-west.
Fig. 5. Juniper woodland at Maydan.
Fig. 6. Daraydere river.
Fig. 7. *Artemesia* scrub in the Koyten valley.
Fig. 8. Dry landscape of the Koytendarya valley.
Photos: Jeremy Holden (RSPB).

History

(i) Protection

Koytendag State Nature Reserve and three Wildlife Sanctuaries – Hojapil, Garlyk and Hojaburjybelent – were established between 1986 and 1990 to protect and preserve the mountain ecosystem of the Koytendag region and to maintain the ecological balance between the environment and increasing economic activities. Together these covered an area of 116,366 ha. Of particular importance was the protection of rare species such as markhor, important habitats such as pistachio and juniper forests, and the impressive dinosaur trackways at Hojapil. In 1990 the area under protection was increased to 122,377 ha with the establishment of a fourth Wildlife Sanctuary, Hojagarvul. In 2014, minor revisions were made to the boundaries of Hojapil, Garlyk and Hojagaravul Wildlife Sanctuaries and a 18,112 ha buffer zone was added so that currently a total of 129,047 ha is under protection and management.

(ii) Scientific research

The natural wonders of Koytendag have been studied for many years but much of the research has focussed on the paleontological and geological features of the site, with the result that many aspects of the site's biodiversity are still comparatively poorly known and documented. In 2012, at the instigation of the President of Turkmenistan, Gurbanguly Berdymukhamedov, the Turkmen Government decided to nominate Koytendag as the country's first UNESCO Natural World Heritage Site. The first stage in this process was the organisation of a major scientific expedition and conference in spring 2012. With the participation of experts from over 20 countries this provided an opportunity to highlight and review the international importance of the site. A major outcome of this expedition and conference was the signing of a Memorandum of Understanding (MoU) between the Ministry of Nature Protection of Turkmenistan (now the Ministry of Agriculture and Environment Protection of Turkmenistan) and the RSPB. Under this MoU the RSPB has provided, and continues to provide, technical support to Koytendag to assist with the preparation of the World Heritage nomination dossier, production of an up to date site management plan, and resources and training for key reserve staff. The MoU also covers Bathyz State Nature Reserve in south-east Turkmenistan which is another potential UNESCO Natural World Heritage Site.

Coordinated and funded by the RSPB, three teams of international biodiversity experts visited Koytendag between 2013 and 2015, plus separate technical visits to develop the management plan and run training courses, and the results of these visits are presented in this report.

In addition to these dedicated surveys, reserve staff implement an annual monitoring programme – *see table 1* – which covers selected biological, geological and environmental factors and provides a basis on which the dedicated surveys can build.

Table 1. Regular annual monitoring and research at Koytendag State Nature Reserve.

Factor		Periodicity	Location of records
Biological resources			
Plants	Phenology	1-2 times/month during spring and summer	The headquarters administration of Koytendag State Nature Reserve in Bazardepe village and Ministry of Agriculture and Environment Protection of Turkmenistan in Ashgabat
	Distribution – Red Data Book species only	1-2 times/month during spring and summer	
Birds (limited range of species at present)	Species, numbers and general distribution	1-2 times/month during spring, summer and winter	
Markhor and Urial	Number of males/females/ young and general distribution	Spring and autumn (10-15 day survey periods)	
Fauna - general	Camera trapping in 2013 and 2014	Throughout the year	
Geological objects			
State of geological Nature Monuments	Visual assessment of condition	Throughout the year	The headquarters administration of Koytendag State Nature Reserve in Bazardepe village and Ministry of Agriculture and Environment Protection of Turkmenistan in Ashgabat
Caves (by specialists of the Koytendag Geology Research expedition)	Air temperature, humidity and radioactivity outside and inside cave entrances plus 3-4 sampling points deep within the caves	Monthly	
Environmental			
Meteorological data (from Etrap meteorological station in Koytendag town)	Air and soil temperature, precipitation, wind speed and direction, humidity	Daily	The headquarters administration of Koytendag State Nature Reserve in Bazardepe village and Ministry of Agriculture and Environment Protection of Turkmenistan in Ashgabat
Water resources - General	Dynamics of seasonal watercourses	Seasonal	
Kaynarbaba lake and Aksuw (by specialists of the Koytendag Geology Research expedition)	Air and water temperature, and levels of radioactivity (U and Ra) and hydrogen sulphide H_2S	Monthly	

Scientific research
Hydrogeology

Fig. 9. Entrance to new underground lake (Photo credit: Mikhail Pereladov).

Hydrogeology
Aleksandr Degtyarev and *Mikhail Pereladov*

Whilst the majority of research has concentrated on the biodiversity of the site, limited work has also been carried out on the hydrogeology of the site because it has played, and continues to play, a key role in the development of the site; it supports a unique cave fauna; and it provides an essential resource for local communities.

1.1 Background

The characteristic features of the hydrological regime of the Koytendag ridge can be attributed to the high rate of precipitation filtration by the soil, the presence in the mountain ridge of several aquifers and the abundance of gypsum rock, which has formed large underground cavities with varying degrees of flooding – *see 1.4 Discussion regarding the karstic nature of the site for more details*. Together these have led to the formation of several hundred water sources of various types including springs, wells, sinkholes, cave lakes etc. As well as physical differences, water bodies vary in relation to chemical composition, temperature, inter/intra-annual fluctuations in volume etc. These variations have, in turn, influenced the development of different cave fauna complexes.

1.2 Methodology

A total of 13 water bodies were visited – *see table 2 and map 3* – with locations being representative of the valley of the Koytendarya throughout its length and in transverse section. At each location information was collected on water temperature, flow rate, chemical composition and presence of biota.

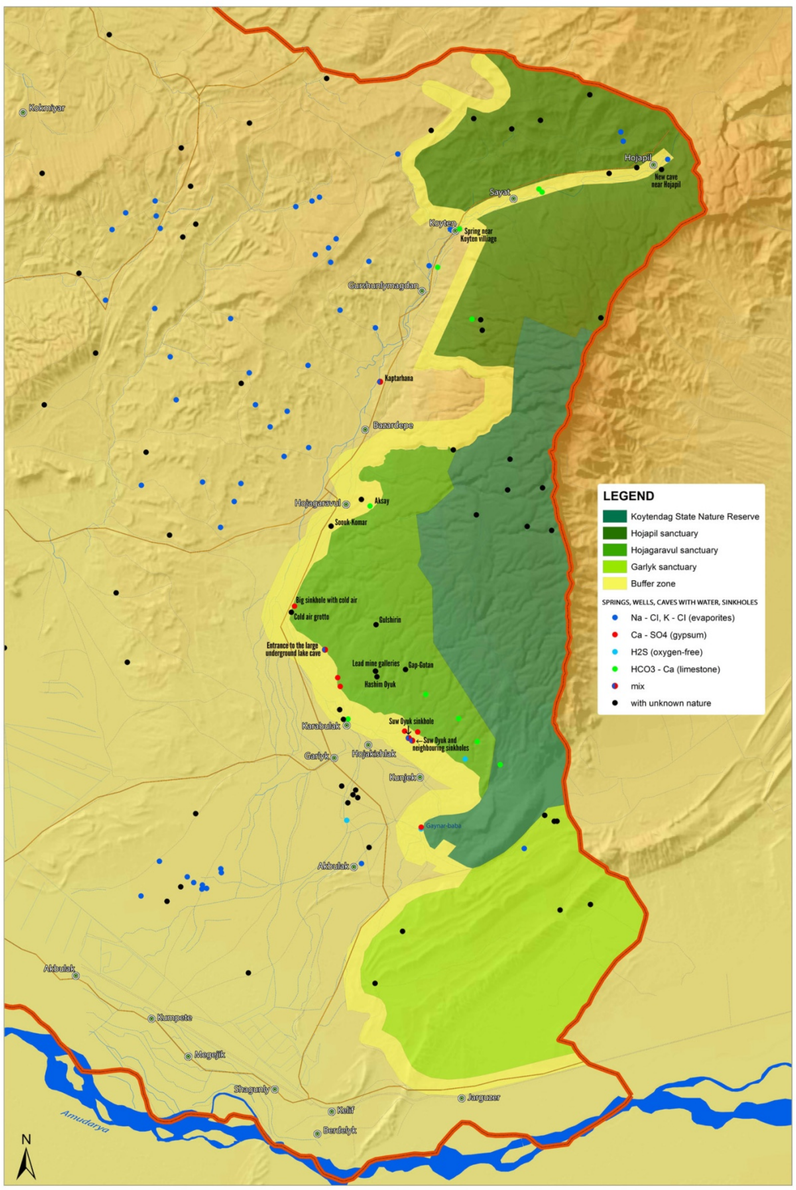
Due to time limitations, many water sources such as those on the western side of the valley remain unexplored. Similarly, it was not possible to collect information on hydrogeological dynamics such as intra-annual and long-term fluctuations. Field data was complemented with information from the literature. Recommendations for future work to address these limitations are given in section 1.5.

Table 2. Water bodies surveyed in May 2015.

Date	Site name	GPS coordinates
24/05	Kaptarhana	N 37º 49.686’ E 066º 24.627’
25/05	New cave near Hojapil	N 37º 56.750’ E 066º 39.245’
25/05	Spring near Koyten village	N 37º 55.172’ E 066º 29.242’
26/05	Suw Oyuk sinkhole	N 37º 35.806’ E 066º 24.322’
27/05	Suw Oyuk and neighbouring sinkholes	N 37º 35.806’ E 066º 24.322’
28/05	Gulshirin	N 37 º 40.345’ E 066 º 23.218’
29/05	Hashim-Oyik	N 37 º 38.545’ E 066 º 22.967’
30/05	Lead mine galleries	N 37 º 38.553’ E 066 º 22.958’
30/05	Soouk-Komar	N 37º 44.328’ E 066º 21.512’
31/05	Aksay	N 37º 44.938’ E 066º 23.558’
31/05	Big sinkhole with cold air	N 37º 41.368’ E 066º 19.284’
31/05	Cold air grotto	N 37º 41.155’ E 066º 19.159’

31/05	Entrance to large underground lake cave	N 37° 39.330' E 066° 20.801'
01/06	Gap-Gotan	N 37° 38.497' E 066° 24.428'

Map 3. Caves and springs at Koytendag. Map by Atamyrat Veyisov.



1.3 Results

1. New cavity with several dry sinkholes and running water near Hojapil village discovered. The estimated length of the underground cavity is approximately 100 m, with a depth of approximately 25 m.
2. New sinkhole with dry lake in the bottom discovered.
3. New cave with an underground lake – *see figure 10* - discovered. The area of the lake is estimated to be 4,400 m^2 making it the largest underground lake not only in Turkmenistan but also in the whole territory of the former USSR. Although no biota have yet been found in the lake, studies should continue.

Fig. 10. Sketches of newly discovered cave with lake.

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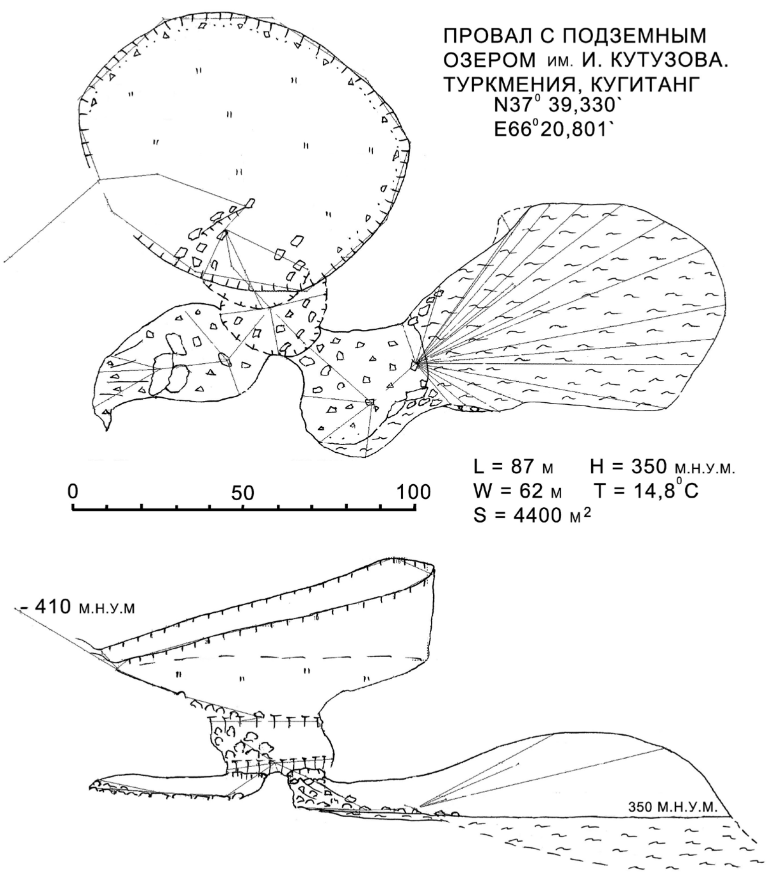


1.4 Discussion

Based on physical characteristics, five principle types of water body have been identified:

1) Highly mineralized water bodies in gypsum caves fed by water draining the mineral salt zone eg Kaptarhana. The fauna in these water bodies is represented by a complex of maritime relict species (Birstein and Lyovushkin 1967), as well as fish from the nearby river.
2) Small lakes and pools in the caves of the ridge, usually with a volume of only a few cubic metres. An exception is the lake in the Krasnoyarsk cave system at Gap-Gotan, which is approximately 10 m in length with an average depth of 40-50 cm. In contrast to the water bodies that have access to the surface, all of these water bodies are non-flowing, small in volume and are fed by water filtering through surface sediments. The fauna in these waters was not studied in 2015.
3) Water bodies occurring in gypsum, stable in volume with a weak inter-annual water exchange eg gypsum sinkholes in the foothills, including the sinkhole with the blind loach, sinkholes with lakes of variable water level and the lower horizons of the Karabulak sinkholes.
4) High mountain lakes in the limestone caves with standing fresh water – there is one known lake in this category in the upper An Dere canyon. The fauna in this lake was not studied in 2015.
5) On the basis of drilling data, there is a zone of artesian fresh water in the limestone under the valley at a depth of 200-300 m, but there is no information on these reservoirs.

Water bodies can also be classified according to their hydrochemical composition:

i) Calcium-hydrocarbonate HCO_3^- - Ca^{2+}. These waters form after contact with limestone. Salinity is usually up to 300 mg/l. Examples include two springs in the area of Hojapil, the spring near the remnant forest on the outskirts of Koyten village, the Aksay spring, and the Karabulak spring.
ii) Gypsum – Ca^{2+} - SO_4^{2-}. These waters form after contact with gypsum or anhydrite. Mineralization may be high, up to 2.5 g/l. One example is the Upper-Kaynar spring (2.5 g/l).
iii) Hydrogen sulfide water – H_2S. These waters are oxygen-free and form in the presence of organic matter. Salinity is low, up to 0.5 g/l. Examples include the lower Kaynar spring and Kunduzke spring, 6 km west of Kaynar and a spring 6 km to the east of Kaynar.
iv) Salty and bitter-salty springs. Cl- - Na+ and Cl- - K+ water. These waters form after contact with evaporates such as halite (NaCl) and silvina (KCl). Mineralization may be up to several hundred g/l. Almost all of the springs on the western bank of the Koytendarya are of this type. None have been recorded on the eastern bank.
v) Waters of mixed chemistry eg salt water with gypsum or salt-gypsum-hydrocarbonate. Mineralization is >2.5 g/l and should be referred to as Cl- - Na+ and a Cl- - K+. Examples include Kaptarhana (11 g/l), sinkhole with the underground lake (3 g/l) and the Suw Oyuk sinkhole (5 g/l).

From the work carried out to date and the known geology of the area, it appears that there are three distinct and separate hydrochemically homogeneous systems at Koytendag:
1) the western bank of the Koytendarya. Almost all water sources are salty or bitter-salty. According to the geological map – *see map 4* – the surface of this area consists of lower and upper Cretaceous deposits. These red-coloured Cretaceous sediments cover salt-bearing (upper Cretaceous) strata, belonging to the late Jurassic J_3.
2) the Koytendag karst massif to the east of the Koytendarya. All springs surveyed were of calcium hydrocarbonate and the rocks are limestones of the Celloveian-Oxfordian age (J_3cl-ox).
3) the downstream section of the Koytendarya valley where it becomes a wide alluvial plain, adjacent to the channel of the Amudarya. Here there are up to 40 sinkholes, some dry others with water. All are based on gypsum with brackish water. The sinkholes were formed by the dissolution of the gypsum-anhydrite strata of kimmeric - Tithonian (J_3km-t) age with a subsequent collapse of the red-layer of the roof. This region also includes a large water-filled cavity with a diameter of 100+ m and a depth of 80+ m.

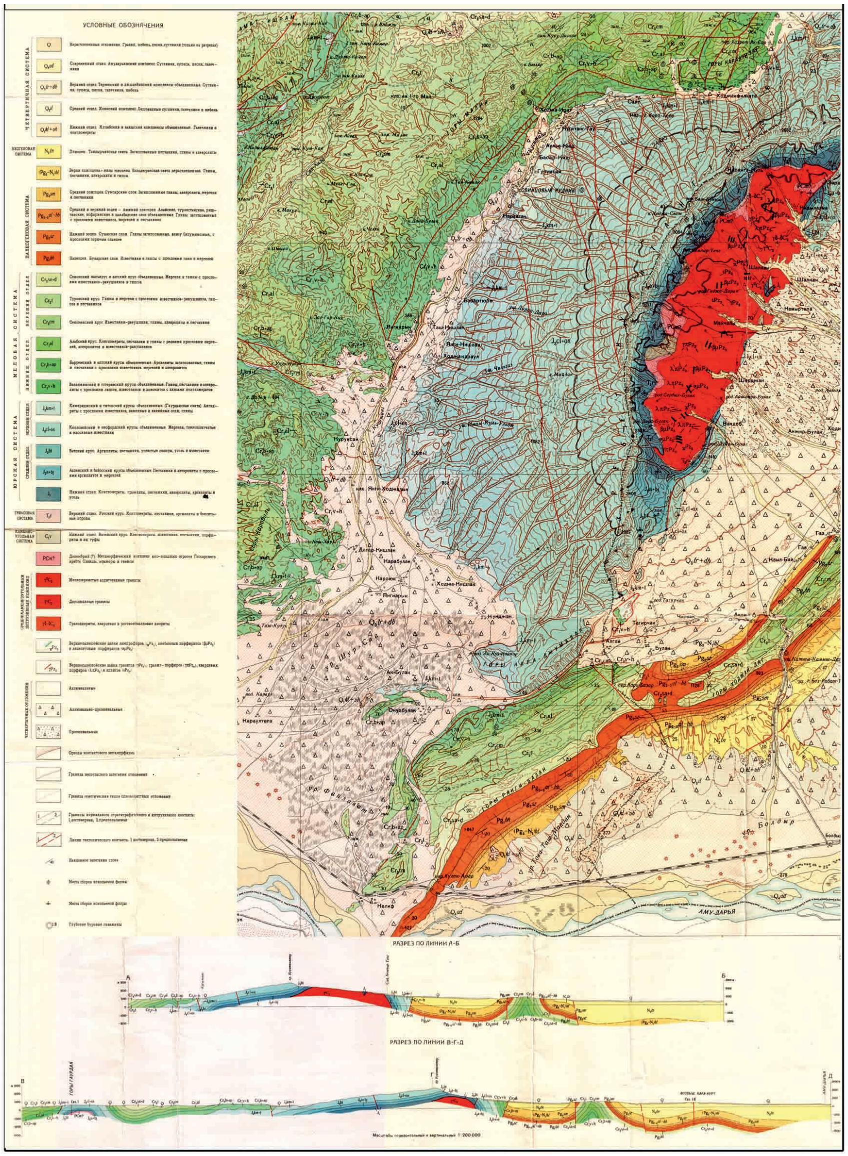
The Koytendarya is the boundary between gypsum and hydrocarbonate facies on the eastern side and salt facies on the western side. Its water is a product of their mixing. At its source (elevation 930 m) the water of the Koytendarya is hydrocarbonate-calcium and salty. In Koyten village on the eastern side of the valley an efflorescence with a characteristic taste of silvinite (KCl) was found. At altitudes of about 500 m the Koytendarya begins to dry out, branching and merging in a thick layer of alluvial deposits. The river then flows beneath the surface and streams are only observed during seasonal floods. At an altitude of about 260 m the water of the Koytendarya discharges into the Amudarya through submarine springs.

The findings of the 2015 survey and the literature raise several interesting questions regarding the hydrogeology of Koytendag.

1 Sinkholes in gypsum-bearing strata. These increase in number with decreasing altitude - singles (Kaptarhana and the 'Dead Lake' near Koyten) at c. 600 m; at the junction of the slope of the mountain and the river valley at c. 500 m there are scattered examples, then dozens are located in the bottom of the valley at 320–400 m. Although gypsum-bearing strata can be seen on the steep slopes of the Koytendag mountains, no sinkholes are known outside of the valley. The formation of sinkholes requires a combination of gypsum-bearing strata and a relatively constant supply of flowing water. At Koytendag this only occurs as groundwater associated with the river. The formation of sinkholes never occurs where there is only standing water. This explains the number of sinkholes found at the junction of the valley and the mountain slope and indicates that there is a movement of groundwater below the surface of the valley.

The morphology of sinkholes at Koytendag, with a predominance of vertical and even inwardly-sloping walls suggests that the process of dissolution of the gypsum strata is recent (on a geological time scale) and in one of the initial stages of development, i.e. they are of geomorphologically young origin. There is no reason to associate their formation with previous wet periods.

Map 4. Geological map of Koytendag.



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2 Subterranean water movement. Movement of water through the red-coloured and gypsum deposits of the alluvial layer on the plain has not been recorded but there is a theoretical possibility of water movement from the riverbed to the east through gypsum caverns or cavities. Salty water, characteristic of water in the Koytendarya, was noted in gypsum sinkholes that are level with the river (Kaptarhana [8.5g/l NaCl], Suw Oyuk [2.5g/l NaCl], in the sinkhole with the underground lake [0.5g/l NaCl], and the sinkhole with sazans). This indicates a flow of groundwater from the river to the sinkholes in a south-eastern or eastern direction. This, however, does not exclude the movement of hydrocarbonate-calcium waters of the karst massif from the north or north-east to the south or south-west i.e. from the mountains to the river, or from the north-west to south-east i.e. again from the mountains but along the course of the river. A mixture of chloride and hydrocarbonate waters occurs in the alluvial and gypsum-bearing rocks on the east bank between the river and edge of the alluvial valley.

3 Correspondence of water levels in sinkholes with the water level in the riverbed. This has been recorded for Kaptarhana, the sinkhole with the underground lake, Suw Oyuk and the sinkhole with sazans. There are currently no known sinkholes with suspended lakes, however, such lakes were observed in the 1980s - in the now dry Kooushner`s sinkhole (fluctuation exceeding 10 m), the now dry Smirnoff`s sinkhole (10+ m), the sinkhole with the underground lake (recent remains of aquatic plants at a height of 15+ m above the present level of the lake) and the dry sinkhole with cold air (10+ m). In the case of the last two mentioned, water levels were probably higher within the last few years. Such fluctuations are not linked to fluctuations of the groundwater level since the water level in the Suw Oyuk sinkhole, only 700 m from from Kooushner`s and Smirnoff`s sinkholes, would also fluctuate but its level does not change. Possible explanations are that there are canals, caverns or cavities in the substrate which periodically open and close or fluctuations are linked to major fluctuations in precipitation from year to year combined with difficulties in runoff.

4 Cave and water temperature. From the theory of karst massif formation, at least in areas with humid climates, they are supercooled in comparison with the average atmosphere. This is because the temperature in the atmosphere decreases by 6.5^0 C for each 1 km change in altitude. In addition, snow and rain water that has penetrated deep into the karst massif loses thermal contact with the atmosphere. The temperature inside the massif is determined by the heat generated by the movement of geothermal water – the potential energy of water is completely converted into kinetic energy and then fully into heat. This results in a warming of 2.34^0 C for each 1 km change in altitude. In other words, if, at a given altitude, the atmosphere and water entering the massif have the same initial temperature, at the outflow from the massif, i.e. a karst spring, the temperature will be $6.5^0 – 2.34^0 = 4.16^0$ C below the average temperature of the atmosphere for each kilometre change in altitude. This explains why very deep karstic springs contain abnormally cold water.

Measurements were made of several springs at the foot of the mountain - Two Springs close to Hojapil, the spring near the relict forest on the outskirts of Koyten village, Aksay spring, the highland spring near the Lead Mine and Karabulak spring – and these gave a paradoxical result, all temperatures were close to the atmospheric average. This is confirmed by the temperature of the caves at Gulshirin, Hashim-Oyuk and Gap-Gotan. In these caves air temperatures are close to the average annual atmospheric temperatures at the same altitude i.e. the entire massif does not show signs of negative anomalies in temperature. This means that none of the identified watercourses has passed through the massif, rather they all drained through the surface layers of soil and loose sediments which were in thermal contact with the atmosphere.

5 Karst features at Koytendag. The conclusion above regarding the movement of water through the Koytendag massif creates an interesting paradox - the karst massif in its present form is, apparently, not really karstical. Because of the large number of caves, this statement seems wrong. However, it should be noted that:
a) there is an almost complete absence of surface karstic formations on the surface of the mountain;
b) there are numerous deep canyons;
c) there is a general lack of water in the caves.

Typical karst topography is characterized by a large number of karstic craters and sinkholes and a complete lack of a surface river network. Koytendag exhibits the opposite i.e. a river network and an absence of craters. The lack of water in the caves can be explained by current aridity of the climate. Pluvial epochs, corresponding to the epochs of glaciation in Europe, could be accompanied by more humid conditions in the caves but the development of the canyons and the lack of surface karst forms are explained only by the absence of karstic capability of the rocks. It seems likely that Maltsev, who carried out detailed research of the karst systems of Koytendag, was correct in proposing that the karst systems are a relict, only activated in the recent geological past. However, the paradox remains because during the formation of the massif the rocks obviously exhibited karstical properties.

Karstical capability is determined not only by the solubility of the rocks but also by their fracture characteristic. The same rock may be karstical and non-karstical depending on the presence or absence of cracks. For example, cracks in limestone, especially small cracks, are easily sealed by material dissolved in flowing water. Where there is a vertical temperature gradient, water flowing down through the rocks increases in temperature and, as a result, the carbonate content of the water can easily become supersaturated leading to the sealing of the cracks. If orogenic (geological structural deformation) processes are reduced and do not generate new macroscopic fractures, the mountain will eventually lose its karstical capability. This seems to be the case at Koytendag and clearly there is much still to be studied and discovered at the site.

1.5 Recommendations for future work

As a general point, it is recommended that future research is carried out around the time of snowmelt (March) and/or furthest from the time of snowmelt (October, November) – this would complement the work carried out in May/June 2015.

1.5.1 To study the dynamics of the main characteristics of the waterbodies in all of the underground lakes.

1.5.2 Conduct a diving inspection of the underground lakes in order to assess their configuration, hydrological and hydro-chemical characteristics and the presence of relict fauna, especially the newly discovered lake.

1.5.3 Search for ‘suspended’ underground lakes on the upper plateau of the ridge, study the conditions of their formation, their hydrological characteristics and the presence of fauna.

1.5.4 Collect data on the structure of the salt deposits in the area of the reserve and on the horizons of underground water exposed by mining activities associated with the Garlyk potash plant.

1.5.5 Collect data on the potential impact of the Garlyk mine on the water resources in the foothills of the Koytendag ridge.

1.5.6 Assess the potential impacts of the development of gypsum quarries in the border area of Garlyuk wildlife sanctuary on the distribution of seasonal water flows.

1.5.7 Map the profile of salinity in the Koytendarya along its entire length.

1.5.8 Compare this profile with NaCl–salinity of sinkholes in the valley in order to determine the sources of water for the sinkholes - net river recharge with the addition of gypsum components; karst water with addition of gypsum components; mixing of karst hydrocarbonate waters with the waters of the river recharge?

1.5.9 Carry out quarterly monitoring of water levels and temperatures in the sinkholes (and caves), especially in the spring. Particular attention to be paid to those sinkholes with a variable water level - Kooshner, Smirnoff, Sinkhole with Underground Lake and Cold Sinkhole, and the stable Upper - and Lower-Kaynar springs. Compare these results with (a) river levels, (b) aquifer recharge rates from the mountain, (c) snowmelt in the mountains and (d) annual precipitation patterns. Confirm or refute the hypothesis that the Upper-Kaynar spring is the main discharge along the fault throughout the southern and possibly the central part of the Koytendag karst massif.

1.5.10 During periods of exceptionally heavy rains, occurring approximately every 5-10 years, monitor the behaviour of water levels in the sinkholes and flow of the Kaynar spring.

1.5.11 Explore the major water sources that were not surveyed in 2015 – Chindjirski and Bulak-Darinskii.

1.5.12 In the Underground Lake, measure the temperature of the air over the lake and the lake's water to investigate whether in winter the cave and lake accumulates the winter cold and thus provide an explanation of the abnormally cold temperatures recorded.

1.5.13 Examine in winter the abnormally cold (+10.5 C) air in Soouk-Komar, Big Sinkhole (with cold air) and the cold cave close to it to ascertain whether ‘winter’ air flow is opposite to ‘summer’ air flow. Additionally, in autumn measure the temperature of the air in these caves to find out whether increases in air temperature are the result of a ‘summer flux’ between summer and autumn. These data will answer the question about the nature of the anomalous cold – is it because of the temperature of the air in contact with cold karst waters or is it the cold, stored in winter, by the upward movement of air within the mountain?

1.6 Bibliography

Anonymous (1983) Jurassic formations south of the USSR. Proc. Science, Moscow, 208 pp. In Russian.

Anonymous (1972) Soviet Geology, Vol. XXII, Moscow, 649 pp. In Russian.

Degtyarev AP, Menliev S and Pereladov MV (2015) The discovery of the underground lake in the Koogitung (Turkmenistan). In Speleology and Spelestology – to the 170th Anniversary of the

Russian Geographical Society, Proceedings of the VI International Scientific Conference, Nabereznye Chelny: 63-66. In Russian.
Kamelin R (1979) The Kuhitansky mining district of Central Asia. Komarov Proc 31, Science. In Russian.
Kirsta BG (1976) Hydrological features of the western regions of Central Asia (Turkmenistan). Science, Ashgabat, 295 pp. In Russian.
Maltsev VA (1982) Carbonate Karst of the south-western slope of Kugitangtou. In Status, problems and methods of studying the deep karst USSR (Union of karst materials III and Speleology meeting). Moscow, VIEMS, 153 pp. In Russian.
Maltsev VA (1993) Minerals of karst caves Cap Kutan. World of Stones 2: 5-30. In Russian.
Maltsev VA (1994) Aerosol genesis of mineral aggregates of caves: a critical analysis of the available hypotheses. Issues of Physical Speleology Vol. 1. MIPT, Moscow: 89-99. In Russian.
Maltsev VA (1996) Sulfates filamentary crystals and their aggregates in caves. Proceedings of the University of the Bristol Speleological Society 20(3): 171-185.
Maltsev VA (1997) Stalactites, crystlactites, corlactites, tuflactites: four types of “stalactite-like” formations, generated from crystallization environments with different physical properties Transactions of 12th International Congress of Speology: 267-270.
Maltsev VA (1997) Minerals of Cupp-Coutunn cave. Cave minerals of the world, 2nd edition, NSS: 323-328.
Maltsev VA (1998) Stalactites with "internal" and "external" feeding. Proceedings of the University of the Bristol Speleological Society 21(2): 149-158.
Maltsev VA and Bartenev OS (1989) The results of mineralogical studies of caves at Cap Kutan in Turkmenistan. In Problems of a comprehensive study of karst mountainous countries (Proceedings of the International Symposium), Tbilisi: 209-211. In Russian.
Maltsev V and Belakowsky D (1992) The Cap Kutan cave system in the mountains of Eastern Turkmenistan Kugitang. Lapis Minerallien Magazin 17 (2): 13-18. In German.
Maltsev V and Korshunov V (1994) Geochemistry of fluorite and some other features in the Kugitangtou Ridge caves, Turkmenia. Breakthroughs in Karst Geomicrobiology and Redox Geochemistry, Karst Water Institute, 47 pp.
Maltsev VA and Malishevsky DI (1989) About the hydrothermal stage on the later part of the evolution of the Cupp-Coutunn cave system. Proceedings of the 10th International Congress of Speleology, Vol. III, Budapest: 815-816.
Maltsev VA and Self CA (1992) Cupp-Coutunn cave system, Turkmenistan, USSR. Proceedings of the Bristol University speleological society 19: 117-150.
Maltsev VA and Turchinov II (1989) Gypsum Cave Dzhurinskaya ephemera. In Geology and prediction of mineral deposits in Eastern Siberia, Irkutsk: 82-83. In Russian.

Flora

Fig. 11. ***Corydalis popovii*****, endemic to Koytendag. Photo credit: Jeremy Holden, RSPB.**

Flora

Mark Gurney, Owen Mountford, Galina Khamanov and *Shaniyaz Menliev*

2.1 Background

Knowledge of the flora of Koytendag is based largely on the literature, principally Nikitin and Geldihanov (1988) and Komarov *et al.* (1933-1964), and opportunistic recording by visiting botanists and reserve staff.

2.2 Methodology

Systematic recording and limited collection was carried out in April/May 2014 and these field records were supplemented by a detailed desk study of the available literature.

2.3 Results

Fieldwork in April/May recorded 23 endemic or near endemic species, though the identification of a few specimens has still to be confirmed. Based on information in Nikitin and Geldykhanov (1988), of these, 11 species are reported as being endemic to Koytendag – *see table 3*.

Table 3. Endemic species of Koytendag recorded in April/May 2014.

Species	**Location/comments**
Allium oschaninii	On rocks in the dry gorge at 37.727°N, 66.373°E
Anemone baissunensis	In higher grasslands and scree
Corydalis popovii	Occasional under scrub in the grasslands
Dianthus brevipetalus	Occasional on rocks in the lower parts of gorges
Ferula nevskyi	Occasional in higher grasslands
Fritillaria olgae	In scrub in the gorge at Tamcy at 37.765°N, 66.492°E, 1920 m asl
Impatiens nevskii	Frequent under trees along the bottom of the Daraydere gorge
Prangos bucharica	Frequent in grasslands and gorges
Pseudosedum longidentatum	On rocks in lower parts of gorges
Rhinopetalum bucharicum	Occasional in higher grasslands and scree, as at 37.785°N, 66.523°E, 2320 m asl
Scutellaria leptosiphon	Common on vertical rock faces in the lower parts of gorges

As the result of being situated at the intersection of three biomes, the Koytendag region has an outstanding and important floristic diversity and richness, with 1,136 species recorded. There are 242 species with known medicinal properties and 124 species which are the wild ancestors of crop and domestic fruit varieties.

The flora of Koytendag itself includes a minimum of 982 species of higher plants of 430 genera from 86 families. At least 197 species (20%) are endemic to the Pamir-Alay biogeographical region, with 48 species endemic to the property itself – *see table 4*. The taxonomic status of an additional ten species reported as being endemic is currently unclear. Ten species are listed in the Red Data Book of Turkmenistan (2011) – *see table 5*. Three species - walnut *Juglans regia* (NT), pistachio *Pistacia vera* (NT) and a species of almond *Amygdalus bucharica* (VU) – are included in the IUCN Red List.

2.4 Discussion

The Koytendag region is a distinct geo-botanical area in the western Gissar region of the mountainous Middle Asian province of the Iranian (Anatolian- Kurdistan-Mediterranean) group of mountain provinces (Afro-Asian arid zone, Dominion of the Ancient Mediterranean). Analysis of the flora of the region shows that Koytendag is transitional between the Kopetdag flora and the flora of the Pamir-Alay. There are many species in common with the flora of the western Pamir-Alay mountains, the Pamir-Alay-Tien Shan and the Upper Pandj Alps. There is also a notable number of Kopetdag-Khorasan and Turan mountain species.

A key feature of the vegetation communities of Koytendag is that they are usually formed by species associations where Pamir-Alay and Gissar rare and endemic species occur at the edges of their natural distributions and comprise more than 30% of the total number of species. The principal species are: *Juniperus seravschanica, Corydalis popovii, Salsola lipschitzii, Tulipa ingens, Allium oschaninii, Allochrusa gypsophiloides, Kuhitangia popovii, Cleome gordjaginii, Astragalus kelifi, Astragalus kuhitangi, Onobrychis nikitinii, Zizyphus jujuba, Pistacia vera* and *Ungernia victoris.*

Among the junipers and upland xerophytes there are many species whose origin is connected with the Koytendag region such as *Rubia komarovii, Xylanthemum rupestre, Glaucium squamigerum, Galatella coriaceae* and *Pseudolinosyris grimmii.* The subalpine belt (c. 2,900 m) is dominated by *Astragalus kuhitangi, Acanthalimon erythraeum* and *A. majewianum* and small bushes of *Rosa kuhitangi* and *R. ecae*. Above 3,000 m there are fragments of alpine meadows with species including *Juniperus seravschanica, Acer pubescens, Amygdalus bucharica, Atraphaxis pyrifolia, Kuhitangia popovii*, *Allochrusa gypsophiloides* and low tussocks of *Cleome gordjaginii.* Scattered copses are formed by *Platanus orientalis, Ziziphus jujuba* and *Pistacea vera.*

Table 4. Endemic plants reported as occurring at Koytendag.

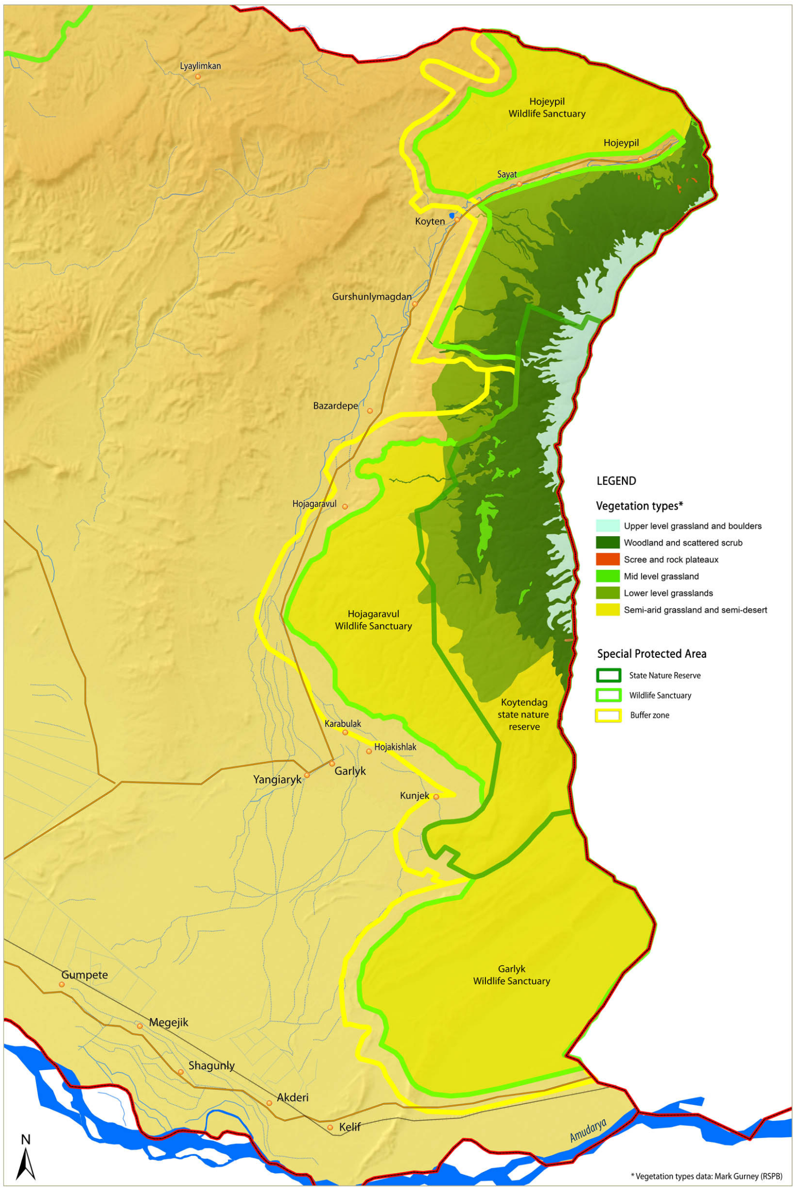
Species	Species	Species
Juno vvedenskyi	*Haplophyllum bucharicum*	*Pentanema propinquum*
Silene nevskii	*Haplophyllum vvedenskyi*	*Xylanthemum rupestre*
Silene plurifolia	*Aulacospermum dichotomum*	*Lepidolopha fedtschenkoana*
Silene bobrovii	*Bunium kuhitangi*	*Artemisia scotina*
Rosa bellicose	*Ferula tuberifera*	*Artemisia albicauli*
Astragalus densus	*Spirostegia bucharicas*	*Echinops praetermissus*
Astragalus bobrovii	*Scutellaria leptosiphon*	*Echinops multicaulis*
Astragalus subspinescens	*Scutellaria colpodea*	*Cousinia bobrovii*
Astragalus willisii	*Scutellaria nevskii*	*Cousinia leptoclada*
Astragalus kahiricus	*Scutellaria heterotricha*	*Cousinia glabriseta*
Astragalus kuhitangi	*Scutellaria squarrosa*	*Cousinia triceps*
Astragalus aemulans	*Phlomis spinidens*	*Cousinia dimoana*
Astragalus subschachimardanus	*Lagochilus nevskii*	*Jurinea popovii*
Astragalus plumbeus	*Eremostachys gypsacea*	*Jurinea tapetodes*
Oxytropis pseudoleptophysa	*Helichrysum mussae*	*Lactuca spinidens*
Oxytropis megalorrhyncha	*Pentanema parietarioides*	*Taraxacum gnezdilloi*
Reported endemics but with uncertain taxonomic status		
Gagea kamelinii	*Salsola lipschitzii*	*Onobrychis nikitinii*
Stipa kuhitangi	*Strigosella malacotricha*	*Hymenocrater incisodentatus*
Stipa gnezdilloi	*Astragalus rubri-galli*	
Ranunculus vvedenskyi	*Hedysarum plumosum*	

Table 5. Red Data plants recorded at Koytendag.

Species	Turkmenistan Red Data Book status	IUCN Red List status	Koytendag endemic	Pamir-Alay endemic
Asplenium trichomanes	II (EN)			
Cheilanthes pteridioides	II (EN)			
Corydalis popovii	IV (Rare)			X
Salsola lipschitzii	II (EN)		Status unclear	
Juglans regia	III (VU)	NT		
Cleome gordjagini	IV (Rare)			X
Astragalus kelifi	IV (Rare)			X
Onobrychis nikitini	IV (Rare)		Status unclear	
Tulipa ingens	II (EN)			X
Ungernia victoris	II (EN)			X

A broad classification of the vegetation types of Koytendag is shown on map 5.

Map 5. Broad vegetation classification of Koytendag. Map by Atamyrat Veyisov.



A review of the flora of Koytendag (Mountford 2015) shows that a significant proportion of the flora is representative of the Pamir-Alay mountains, including not only the endemic element but also many species with a somewhat greater range, extending to the adjacent ranges of southern Turkmenistan bordering Iran and Afghanistan and to the western Tien-Shan.

The strictly endemic element of the flora of Koytendag is found over a wide range of habitats within the site. Not surprisingly, endemic species are best represented in the higher altitudes of the mountains on stony or rocky slopes and in gorges, ravines and cliffs. Koytendag endemics are also frequent in the Central Asian juniper *Juniperus seravschanica* zone, though they are more associated with rock outcrops and open areas than the juniper scrub-forest *per se*. Certain endemic species have particular soil or bedrock requirements, being found only in either limestone, sandstone or gypsaceous strata. Endemism is least pronounced in the foothills and in anthropogenic habitats, though at least one apparently endemic species, *Lactuca spinidens*, is found in wheat fields.

The location of Koytendag along the border with Uzbekistan and relatively close to Afghanistan (and to a lesser extent Tajikistan) makes the definition of endemism more than usually difficult and artificial. However, using the biogeographical region of the Pamir-Alay as the context for assessing endemism stresses the real importance of Koytendag at an international level. Conversely species such as *Cheilanthes pteridioides*, which is designated as important in a Turkmenistan context, is well-distributed outside the country.

Very few of the species recorded from the site are included in the IUCN Red List and hence it is not possible to ascribe an international threat status to the majority. However, those plants restricted to Koytendag undoubtedly merit a higher IUCN threat category than 'Least Concern'. Nonetheless a handful of species from the property combine a wider international range with being near threatened or vulnerable and decreasing according to IUCN. The most prominent species in this category are fruit/nut trees - walnut, pistachio and one species of almond - all of which include the mountains of Turkmenistan in their native ranges. Walnut and pistachio are very widely cultivated and, in the case of walnut, naturalised in some countries, but within their very restricted native ranges they are decreasing and threatened by fruit collection, livestock grazing and cutting. The species of almond is endemic to Central Asia and has a small area of occupancy, with a severely fragmented distribution and continuing declines in habitat area and numbers of mature individuals.

Ideally the proportion of endemic species in the Koytendag area should be compared with other protected areas within the Central Asian mountains in order to assess the importance of Koytendag objectively. Throughout Central Asia there are several important centres of endemism and in no sense could one regard other centres as a substitute for Koytendag. The species accounts in *Flora SSSR* make it clear that Koytendag is one of the most important floristic areas when assessed either at the scale of the Pamir-Alay or more generally for the mountains of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, as well as adjacent areas of Iran and Afghanistan.

2.5 Recommendations for future work

2.5.1 Provide additional copies of Nikitin and Geldihanov (1988) and any additional general and easily understandable plant guides to assist reserve staff and visiting botanists learn the families of plants. Consideration should also be given to producing a simple photographic guide to the most important species of the site, with notes on distinguishing them from similar species for use by reserve staff.

2.5.2 Increase the field skills of reserve staff and local botanists through the provision of training in plant taxonomy, identification and recording.

2.5.3 To assist with the future research, conservation and management of the key species of the site, prepare 'ecological profiles' for all of the site-specific, regionally endemic and Turkmenistan Red Data Book species.

2.5.4 Whenever reserve staff come across important species, records of the location using GPS, population size (rough estimates eg 1-10, 11-50, 51-100, 101-500, >500), habitat and associated species should be taken. Additionally, as identification skills develop, reserve staff should record when they fail to record species in areas where the habitat appears to be suitable.

2.5.5 When collecting herbarium specimens, it is essential that details of location (GPS), date, habitat and population size are also noted. Specimens should be identified as soon as possible as some features can be lost as specimens dry.

2.5.6 Vegetation communities and habitats should be identified and mapped so that the distribution and extent of each can be documented. As far as is possible, each important species, both plants and animals, should then be assigned to each habitat or community.

2.5.7 Assess the state of the vegetation in the state nature reserve with respect to the impact of and recovery from past grazing.

2.5.8 Investigate past forest cover to assist in planning future reforestation activities if considered appropriate.

2.5.9 Use fixed point photographs to monitor vegetation changes and to illustrate 'good' and 'bad' habitat. This is particularly important in the grazed wildlife sanctuaries, the gorges that receive large numbers of visitors, the borders of the state nature reserve and throughout the high altitude zone.

2.5.10 Contract an experienced ecologist and land economist to investigate the sustainability of grazing in the wildlife sanctuaries especially in relation to their value for biodiversity.

2.6 Bibliography

Hasanov F (1987) Xerophytic trees and shrubs of Kugitangtau. Dissertation. Tashkent. In Russian

Kamelin R V and Hasanov F (1987) The vertical zonation of vegetation at Kugitang (Southwest Pamiroalay). Journal of Botany 72, 11. In Russian

Kamelin R (1973) Florogenetic analysis of the natural flora of mountainous Central Asia. Nauka, Leningrad. In Russian

Komarov VL (ed.) (1933-1964) Flora of the U.S.S.R. Vols. 1-30. Izdatel'stvo Akademii Nauk SSR. Leningrad.

Magnus L and Zetterlund H (1997) *Corydalis*: a gardener's guide and monograph of the tuberous species. Pershore: Alpine Garden Society.
Mountford O (2015) Assessment of the Vascular Flora of Koytendag (Kugitang). Report to RSPB.
Nevsky SA (1937) Materials on the flora of the Kugitang foothills. Flora and taxonomy of higher plants, vol. 4. Moscow-Leningrad. In Russian
Nikitin VV and Geldihanov AM (1988) Plants of Turkmenistan guidebook/finder. Nauka, Leningrad.
Udvardy MDF (1975) A Classification of the Biogeographical Provinces of the World, IUCN Occasional Paper no. 18 IUCN, Morges, Switzerland.
Vlasenko GP (1995) Biological and ecological foundations of the culture of saponin plants in southern Turkmenistan. Dissertation. Ashgabat. In Russian

Surface-dwelling invertebrates

Fig. 11. ***Heser stoevi*** **– a new species of spider from Koytendag (Photo credit: Christo Deltshev, https://doi.org/10.3897/BDJ.4.e10095)**

Invertebrates

Pavel Stoev, Christo Deltshev, *Yuri Marusik, Victor Fet, František Kovařík*, *Borislav Guéorguiev, Ivaylo Dedov, Toshko Ljubomirov, Dragan Chobanov,* and *Shanyiaz Menliev*

Note. The cave fauna, which consists primarily of invertebrates, is treated separately.

3.1 Background

Knowledge of the surface-dwelling invertebrates of Koytendag is incomplete and based primarily on the literature and opportunistic recording. As can be seen from the bibliography, no specific studies of the site have been carried out and the most recent publications are almost 20 years old. During the 2015 expedition Pavel Stoev collected in Koytendag a number of invertebrate taxa, mostly under stones and on plants which were subsequently identified by various experts.

3.2 Methodology

Limited systematic collection, mostly in the proximity of cave entrances, was carried out in May 2015 – *see table 6 and map 6*. Recording was a combination of visual surveys and hand collecting, mostly from grass tufts, shrubs or under stones; sieving of leaf litter with a leaf litter sieve; and using a light trap. In most cases, forceps were used to pick animals from the surface and put them into plastic tubes containing 95% alcohol. All specimens were labelled with temporary labels and later re-labelled under laboratory conditions with permanent labels. Active collecting of insects attracted by light was carried out at night at the state nature reserve headquarters using a mercury vapour light trap. Water beetles and other water bugs were collected opportunistically from springs or sinkholes with the aid of a hand net. Collecting sites are given in table 6.

Table 6. Invertebrate collecting sites at Koytendag, May 2015.

Reference number	Site name	Date	Habitat
1	Near Garlyk (1)	24 May	Dry grass
2	Kaptarhana (2)	24 May	Grassland and inside cave
3	State Nature Reserve headquarters, Bazardepe (3)	24 May	Grassland
4	Between Koyten and Kyrkgyz Dere, c7km from Koyten (4)	25 May	Under stones close to road
5	Between Koyten and Kyrkgyz Dere, c8-9 km from Koyten (5)	25 May	Under stones close to road
6	Kyrkgyz Dere (6)	25 May	Under stones
7	Kyrkgyz Grotto (7)	25 May	Humid habitats
8	Hojapil Dinosaur Plateau (8)	25 May	Under stones
9	Umbar Dere (9)	25 May	Under stones
10	Cave in Hojapil village (10)	25 May	Inside cave
11	Bashbulak spring (11)	25 May	In and around spring
12	Daraydere (12)	26 May	Under stones along track
13/14	Daraydere mine galleries (13 and 14)	26 May	In mine galleries
15	Daraydere (15)	26 May	Vegetation above stream
3	State Nature Reserve headquarters, Bazardepe (3)	26 May	Light trapping
16	Gap-Gotan (16)	27 May	In mine gallery
3	State Nature Reserve headquarters, Bazardepe (3)	27 May	Light trapping
17	Gulshirin (17)	28 May	Shrubs, grass, under stones and inside cave

3	State Nature Reserve headquarters, Bazardepe (3)	28 May	Light trapping
18	Suw Oyuk sinkhole (18)	29 May	Around sinkhole and in water
19	Hashim Oyuk	29 May	Under stones and in cave entrance
3	State Nature Reserve headquartewrs, Bazardepe	29 May	Light trapping
20	Gurshun Magdanly (Kette-Kamov) mine gallery	30 May	Inside mine gallery
2	Kaptarhana	30 May	Inside cave
21	State Nature Reserve headquarters, Sowuk Kamar cave	30 May	Around cave

3.3 Results

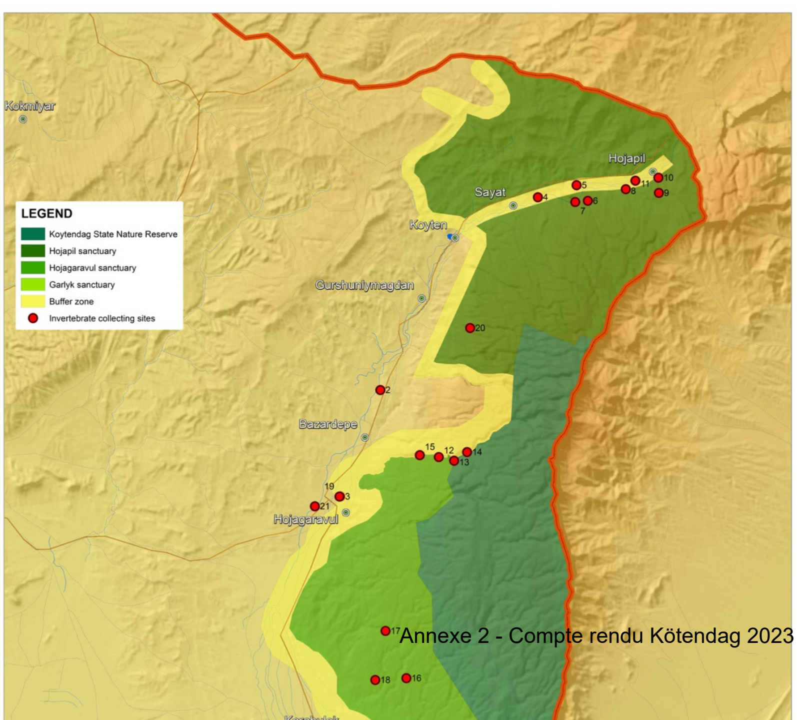
More than 300 species of invertebrates have been recorded from Koytendag but the true total will be considerably higher. Some species of conservation importance recorded in each of the main orders, prior to the May 2015 survey are given in table 7.

Table 7 Invertebrates recorded at Koytendag prior to May 2015

Order	No. of species	Comments
Mollusca	unknown	*Melanoides kainarensis* is included in the Red Data Book of Turkmenistan III (VU). This is the only species in this genus in Turkmenistan. It is believed that this species became separated from its nearest relatives in the Hindu Kush in the late Palaeogene, 66-23 million years ago
Ixodida (ticks)	unknown	Seven species new to science and endemic to Koytendag discovered in the last decade – *Imparipes kugitangensis*, *Imparipes placidus*, *Imparipes katalglyphi*, *Scutacarus sabinaesmilis*, *Scutacarus rotindulus*, *Premicrodispus paradoxus* and *Premicrodispus heterocaudatus* – Khaustov and Chydyrov (2004, 2010)
Orthoptera	38	Two species endemics to Koytendag – *Canophyma zimini* and *Canophyma bactrianum* – one species *Saga pedo* is listed as VU by IUCN and is included in the Red Data book of Turkmenistan category II (EN)
Coleoptera (beetles)	154	Two species included in the Red Data Book of Turkmenistan – *Carabus (Axinocarabus) fedtschenkoi* IV (Rare) and *Melanotus dolini* IV (Rare)
Lepidoptera (butterflies and moths)	59	Two species of note – *Parnassius mnemosyne* and *Papilio machaon*
Formicidae (ants)	30	One species endemic to Koytendag – *Monomorium kugitangi*

Snails collected in 2015 have been identified by Dr. Ivaylo Dedov from the Institute of Biodiversity and Ecosystem Research at the Bulgarian Academy of Sciences. The specimens were assigned to six morphospecies belonging to 6 genera: *Pseudonapaeus sogdianus* E.C. Von Martens, 1874, *Oligolimax annularis* (S. Studer, 1820), *Gibbulinopsis signata* (Mousson, 1873), *Laevozebrinus* cf. *lenis* Schileyko, 1984, *Macrochlamus* sp. and *Radix* sp.

Map 6. Invertebrate sampling sites at Koytendag. Map by Atamyrat Veyisov.



In May 2015, a scorpion potentially new to science – *see fig. 12* - was found which, based on examination of the collected specimens, Dr. Victor Fet and František Kovařík, world authorities in scorpion research, considers to be a member of the widespread *Mesobuthus caucasicus* complex (Scorpiones: Buthidae), which is today being split into several species. The species was formally described in 2018 as *Mesobuthus gorelovi* from Kazakhstan, Turkmenistan and Uzbekistan (Fet et al., 2018).

Fig. 12. *Mesobuthus gorelovi* Fet et al., 2018 – a species of scorpion recently described from Central Asia (Photo credit: Pavel Stoev)

A new species of spider, *Heser stoevi* Deltshev, 2016, was discovered in 2015 with specimens collected around the Dinosaur Plateau area at Hojapil and close to the Gulshirin cave at Garlyk. This genus is currently known to compromise 10 species distributed from India to the United States of America. It is considered that the new species at Koytendag is categorised as a localised endemic.

Further 10 species of spiders have been identified by Dr. Christo Deltshev and Dr. Yuri Marusik: *Uroctea limbata* (C.L. Koch, 1843) (Oecobiidae), *Hippasa partita* (O.P.-Cambridge, 1876) (Lycosidae), *Philaeus chrysops* (Poda, 1761) (Salticidae), *Megalepthyphantes nebulosoides* (Wunderlich, 1977) (Linyphiidae), *Trachyselotes pedestris* (C. L. Koch, 1837) (Gnaphosidae), *Enoplognatha thoracica* (Hahn, 1833) (Theridiidae), *Metleucauge dentipalpis* (Kroneberg, 1875) (Tetragnathidae), *Eusparassus walckenaeri* (Audouin, 1826) (Sparassidae), *Artema transcaspica* Spassky, 1934 (Pholcidae) and *Steatoda triangulosa* (Walckenaer, 1802) (Theridiidae).

Ants collected in 2015 have been identified by Dr Toshko Ljubomirov, a hymenopterist at the Institute of Biodiversity and Ecosystem Research – Bulgarian Academy of Sciences. All belong to the Formicideae:

Camponotus turkestanus (Reserve headquarters)
Cataglyphis aenescens (Koytendag)
Pheidole pallidula (Reserve headquarters)
Tetramorium chefketi (Reserve headquarters).

The beetles collected in 2015 have been identified and published by Guéorguiev et al. (2018). The study is based on identification of 242 specimens belonging to 57 species from 15 families of the order Coleoptera. The following eight species are new for Turkmenistan: *Bembidion aeneum* Germar, 1823, *Chlaenius extensus* Mannerheim, 1825, *Gyrinus distinctus* Aubé, 1838, *Trichophya pilicornis* (Gyllenhal, 1810), *Thinodromus behnei* Gildenkov, 2000, *Gabrius hissaricus* Schillhammer, 2003, *Quedius novus* Eppelsheim, 1892, and *Galeruca jucunda* (Faldermann, 1836).

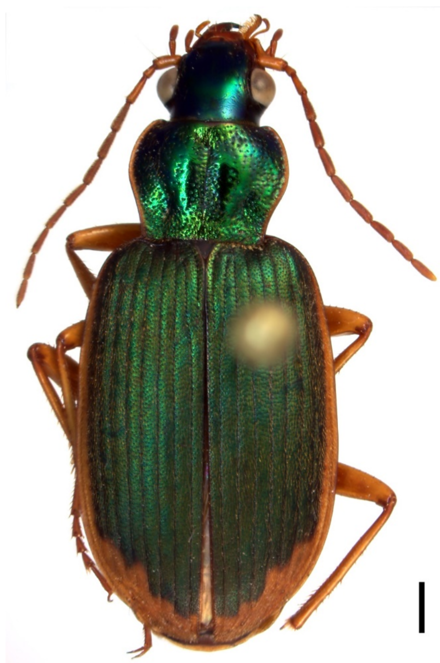


Figure 13. Habitus of *Chlaenius extensus*. Scale line = 1 mm. (Photo credit: Guéorguiev et al. 2018. Historia naturalis bulgarica. http://nmnhs.com/historia-naturalis-bulgarica/pdfs/hnb-2018-29.pdf)

Figure 14. Habitus of *Galeruca jucunda*. Scale line = 1 mm. (Photo credit: Guéorguiev et al. 2018. Historia naturalis bulgarica).

Two species of cockroaches have been collected on Koytendag in 2015 – *Polyphaga saussurei* and *Shelfordella lateralis*. Mantises (order Mantodea) are represented by three morphospecies: *Bolivaria brachyptera* (?), *Empusa pennicornis* (?) and *Ameles* sp. (?) (det. D. Chobanov).

3.4 Discussion

Based on the available information, the site supports one species *Sago pedo* which is globally threatened (VU) and classed as EN in the Red Data Book of Turkmenistan. Five additional species are included in the Red Data Book – *Saxetania cultricollis* (VU), *Anthia mannerheimi* (Rare), *Carabus* (*Axinocarabus*) *fedtschenkoi* (Rare), *Melanotos dolini* (Rare) and *Melanoides kainarensis* (VU).

Including the new species discovered in 2015, nineteen surface-living species are known to be endemic either to the site or to Turkmenistan – *Conophyma zimini*, *C. bactrianum*, *Microdera semenoviana*, *Dichillus dentipes*, *Prosodes kuhitangiana*, *Penthicus pinguis kughitangi*, *Turanana airibaba*, *T. kugitangi*, *Chazara staudingeri*, *Parornix kugitangi*, *P. asiatica*, *Imparipes kugitangensis*, *I. placidus*, *I. katalglyphi*, *Scutacarus sabinaesmilis*, *S. rotindulus*, *Premicrodispus paradoxus*, *P. heterocaudatus* and *Heser stoevi.* An additional six species – *Colposcelis lopatini*, *Prosodes subpilosa*, *P. monticola*, *Blaps medvedevi*, *Dissonomus latusculus* and *Hyponephele toharica* – may be endemic but their status is unclear due to presumed changes in taxonomy. A further six species – *Gnathosia kuhitangi*, *Dailognatha arnoldi*, *Blaps* *bogatshevi*, *Adesmia planidorsis* and *Melitaea didyma* – are reported to be endemic but actually occur outside Turkmenistan.

As little systematic work has been carried on the invertebrate fauna of Koytendag many more species that are endemic and/or of national conservation importance almost certainly await discovery.

3.5 Recommendations for future work

3.5.1 Continue investigation of surface-dwelling invertebrates, especially in the areas at and above 2,000 m, with particular emphasis on myriapods, insects, arachinds, snails.

3.5.2 Contact major museums to see whether they have records of invertebrates from Koytendag.

3.5.3 Organise a team of invertebrate experts to collect specimens for later identification. The team should include local and international experts who can place the species and site in context and provide training of local counterparts.

3.5.4 Extract all the records and information for Koytendag from the *Rare and insufficiently studies animals of Turkmenistan* and other legacy literature.

3.6 Bibliography

Atamuradov HI (1994) Peculiarities of composition and formation of coleopterofauna of South-Western Middle Asia (on example of Coleoptera, Elateridae, Tenebrionidae, Curcilionidae). PhD thesis, Kiev, 47 pp.

Deltshev C (2016) A new spider species, *Heser stoevi* sp. nov., from Turkmenistan (Araneae: Gnaphosidae). Biodiversity Data Journal 4: e10095. https://doi.org/10.3897/BDJ.4.e10095

Fet V and Atamradov K (eds) (1994) Biogeography and Ecology of Turkmenistan Monographiae Biologicae vol. 7

Fet V, Kovařík F, Gantenbein B, Kaiser RC, Stewart AK, Graham MR (2018) Revision of the *Mesobuthus caucasicus* complex from Central Asia, with descriptions of six new species (Scorpiones: Buthidae). Euscorpius 255: 1-77.

Guéorguiev B, Merkl O, Schülke M, Fery H, Szénási V, Král D, Kejval Z, Németh T, Szalóki D (2018) Coleoptera (Insecta) from Ashgabat City and Köýtendag Nature Reserve, with nine first records for Turkmenistan. Historia naturalis bulgarica 29: 9-20.

Medvedev GS (1964) Zoogeographic characteristics of Tenebrionidae from Kugitang and a description of new forms. Zoological Zhurnal: 54-64

Tokgaev TB (1998) Biological diversity of insects of Turkmenistan. Ashgabat, In Russian.

Tsikolovets V (1998) The Butterflies of Turkmenistan. Kiev. 237 pp.

Cave fauna

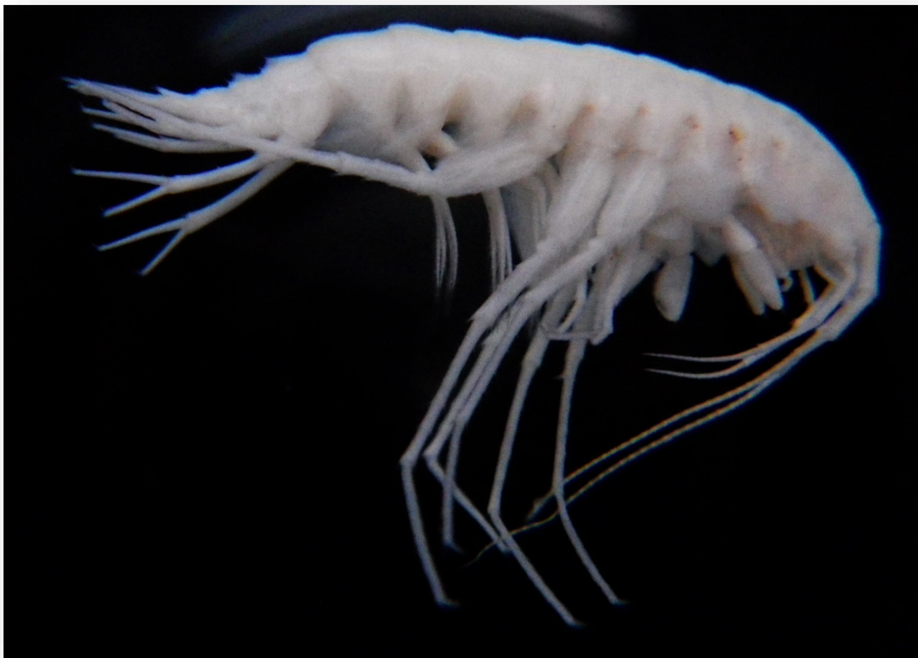


Fig. 15. ***Gammarus troglomorphus*** **Siderov, Hou, Sket, 2018 (Amphipoda) from Garlyk, collected at Suuv Oyuk (Photo credit: Boris Sket)**

Cave fauna

Boris Sket, Pavel Stoev, Christo Deltshev, Yuri Marusik, Louis Deharveng

4.1 Background

Knowledge of the cave fauna of Koytendag is limited (for the cave fauna of Central Asia see Decu et al. 2019). Published records comprise only 26 species of invertebrates: Protozoa (15); Gastropoda (2); Crustacea (Copepoda) (3); Crustacea (Malacostraca) (3); Coleoptera (2) and Psocoptera (1) plus the endemic blind loach – *see section 5*.

The systematic study of the fauna of the underground hydrological system of the Koytendag ridge began in the second half of the 20th century and initially consisted of collecting cave aquatic organisms which were found in the surface waters of large springs such as Kaynar and Chindzhir. Filtering the water flowing out of such springs revealed the presence of a localized blind isopod crustacean *Stenasellus asiaticus* whose physical appearance suggested they had a predominantly underground lifestyle. At the same time, work began on describing a relict fauna of marine origin in the Kaptarhana cave (Birstein and Ljovushkin 1967).

4.2 Methodology

In May 2015, 13 sites were investigated – *see table 8 and map 6* - including six caves (Gap-Gotan, Hashim Oyuk, Gulshirin, Kaptarhana, Kyrkgyz Grotto and a cave in Hojapil village), four abandoned mine galleries and one sinkhole. Kaptarhana and Gap-Gotan were visited twice as pitfall traps were set in both. Survey techniques were visual surveys of approximately 1 km of corridors close to the entrances of Gap-Gotan cave; filtering of water and sediment in limestone pools using a hand-net with 0.5 mm mesh width (finer nets were tried but rapidly became blocked with silt); and ten pitfall traps[2] made from plastic cups baited with meat and/or cheese for several days in Gap-Gotan (4) and Kaptarhana (6). As there was a scarcity of water bodies in the caves, samples were also collected from springs which provide 'windows' into the ground water system. All specimens were processed in the laboratory using a binocular microscope. After sorting, specimens were provisionally identified and, where necessary, sent to specialists for confirmed identification. In addition to invertebrate sampling, Amphibia and Odonata were photographed and a separate detailed survey was made of the endemic blind loach – *see section 5*.

[2] Pitfall traps are the standard sampling method used in the Dinaric karst caves, the Alpine region of the Balkan Peninsula, from Slovenia to N Albania and extending across W Coatia, and most of Bosnia and Herzegovna, and Montenegro, which has a particularly rich cave fauna.

Table 8. Cave fauna sampling locations.

Site name	Date	Habitat
Koytendag canal	24 May	Vegetated canal connected to the Amudarya
Kaptarhana	24 May	Sediment of lake in cave
Bashbulak	25 May	Gravel spring at the head of the Koyten river and large spring pool with rich submerged vegetation
Kyrkgyz	25 May	Spring
Below Dinosaur Plateau	25 May	Spring and narrow entrance to excavation
Daraydere	26 May	Strong spring at the artificial head of the stream and spring from a drilling hole in the wall of an unnamed tunnel
Gap-Gotan	27 May	Limestone pool in cave and limestone pool near entrance
Karabulak river	28 May	Small stream with rich submerged vegetation, spring and spring from gravel deposit
Gaynarbaba	28 May	Sulphurous spring, large karst spring and spring
Jarma-Tasbulak	28 May	Karst spring and spring
Hasim Oyuk cave	29 May	Dry cave
Suw Oyuk	29 May	Sinkhole lake, baited trap in sinkhole lake and environs of the sinkhole
Newly discovered lake in sinkhole	31 May	Sediment of lake in cave
Gap-Gotan	1 June	Baited pitfall trap in spacious dry part of cave

4.3 Results

In addition to confirming the occurrence of the majority of previously recorded species and increasing the known distribution of many of these, the most significant result of the May 2015 survey was the discovery of two species of *Gammarus* new to science from Garlyk and Koyten, respectively (Figs 14, 15) (Siderov et al. 2018). Three previously unrecorded species of beetle were also found at Gap-Gotan Cave – *Bembidion (Ocyturanes) dyscheres* Netolitzky, 1943, *Eremosphodrus (Rugisphodrus) dvorshaki* Casale & Vereschagina, 1986 and *Cymindis (Paracymindis) asiabadense kryzhanovskii* Emetz, 1972 (Guéorguiev et al. 2018).

Among the most striking discoveries in the caves of Koytendag was a remarkable new genus and species of Campodeidae (Diplura), *Turkmenocampa mirabilis* Sendra & Stoev gen.n., sp.n., found in Kaptarhana cave (Sendra et al. 2017). This represents the first record of Diplura from Central Asia and also the first terrestrial troglobiont found in Turkmenistan. Although *T. mirabilis* was tentatively placed by the authors in the subfamily Plusiocampinae, its true affinities remain uncertain. The new finding provides further support to the importance of Kaptarhana as a refuge for a number of endemic invertebrates.

The caves of Koytendag revealed to harbour also a few species of spiders (identified by Christo Deltshev and Yuri Marusik): *Pholcus parthicus* Senglet, 2008 (Kyrkgyz grotto, a cave in the village Hojeypil, cave Gulshirin); *Megalepthyphantes nebulosoides* (Wunderlich, 1977) (v. Garlyk, caves Gap Gotan and Hashim Oyuk); and *Tegenaria* sp. (cave Hashim Oyuk).

Although not necessarily strict cave-dwelling species, an additional several species potentially new to science were also recorded: springtails (Collembola): *Deuteraphorura* n. sp. (Kyrgiz grotto), Entomobryidae sp. (Cave Gap Gotan), *Coecobrya* n. sp. (cave Kaptarahana) (det. Louis Deharveng), and a Latridiidae beetle of genus *Corticaria* (Coleoptera) at Kaptarhana (identified by Wolfgang Rücker).

Fig. 16. *Gammarus parvioculatus* Siderov, Hou, Sket, 2018 from Koyten, collected at Hojapil (Photo credit: Boris Sket)

Based on differences in the species recorded it appears that there are at least three distinct and separate hydrological systems at Koytendag – Suw Oyuk, Kaptarhana and Koyten.

A large roost of *Rhinolophus bocharicus* bats was found in Kaptarhana. This cave is rich in guano and has a diverse invertebrate fauna. It also contains permanent water apparently fed by underground sources. Together these features make the cave of high conservation importance.

At Suw Oyuk, the only known location for the endemic blind loach, the following were recorded – *Bufotes oblongus* (Amphibia), *Ischnura elegans* and *Orthetrum coerulescens* (Odonata); *Gerris* sp. and *Notonecta* sp. (Hemiptera); plus unidentified Chironomidae, Cyclopoida, Ostracoda, Dytiscidae and Mollusca.

Although in no way to be considered a 'cave dwelling' species, porcupine *Hystrix indicus* 'toilets' were found in several caves and these appear to provide an important food supply for the invertebrate fauna.

During the 2012 International Scientific Expedition, a beetle was collected from a limestone pool in Gap-Gotan cave on 25 May which appears to be a new species of *Xestodium*, however none were recorded during the 2015 survey.

Gammarus troglomorphus Siderov, Hou, Sket, 2018 from Garlyk recorded from Suw Oyuk is a very aberrant species, one of the most troglomorphic within the genus. Eyes and pigmentation are totally absent and the appendages are very elongated. It is a troglobiont (Siderov et al. 2018).

Gammarus parvioculatus Siderov, Hou, Sket, 2018 from a spring-cave at Hojapil near Koyten shows no troglomorphy except the slight eye diminution (Siderov et al. 2018). It was found in three springs, one of them in a half-cave, and individuals exhibit a variable degree of pigmentation; the eye is reduced to half the size of 'normal' gammarid populations. The species is considered to be an eutroglophile.

4.4 Discussion

As a rule, subterranean (cave) faunas are often significant constituents of national nature monuments as they are generally localised and therefore strictly or narrowly endemic. Each troglobiotic species is usually only present in one area and therefore vulnerable to extinction if the local population disappears. Troglobiotic and eutroglophile species are also scientifically very informative, illustrating the courses of adaptation and evolution in general. By contrast, subtroglophile and trogloxene species are usually much more widely distributed and not troglomorphic, however subtroglophiles may be very important as vectors of food between the surface and underground.

In addition to the newly discovered *Gammarus* species, other notable troglobites are the isopod *Micrcharon halophilus* and the hydrobiid gastropod *Pseudocaspia ljovuschkini*. Additionally, there are a number of endemic relict species including *Stenasellus asiaticus* and *Bogidiella ruffoi* which were recorded from the Hodza-Kaynar spring.

Subterranean habitats, including caves, are characterised by the darkness, high air humidity, stable climatic conditions and a lack of food resources. The general morphological adaptation of troglobionts to these conditions is the reduction of non-functional structures, eg., reduction of pigmentation and eyes, and the elongation of appendages. These traits are called troglomorphy.

The Koytendag area is distinctly arid compared to most karst areas in the world. The average annual precipitation in Turkmenistan is 110-200 mm, compared to 900-1,600, extreme 4,600 mm, in the troglobiotically rich Dinaric karst area. This almost certainly explains the striking complete absence of cave crickets (Orthoptera: Rhaphidophoridae) which elsewhere are one of the most regularly present components of cave faunas. They are however mainly subtroglophiles, depending on feeding on the surface but regularly searching shelter in the entrance areas of caves. An additional characteristic of the Koytendag caves is the absence or extreme rarity of hygrophile troglobiotic beetles (Coleoptera); they are replaced by the explicitly xerophile groups Tenebrionidae and Ptinidae.

According to the literature (Brodsky 1928, 1929; Birstein and Ljovuschkin 1965; Chibisova 1967) there are relict Foraminifera in the lake at Kaptarhana. As foraminifera are principally marine animals, it is supposed that these are relicts of the past sea in the area but it is unclear whether any animals were found alive, they could possibly be sub-fossil specimens.

4.5 Recommendations for future work

4.5.1 Further studies of the caves in February / March, which are the most favourable for collecting months in the area. This is especially important for collecting living specimens of the tenebrionid beetles in Hashim Oyuk and the likely new callipodidan millipedes in Gulshirin.

4.5.2 Extending the biospeleological surveys to other caves and mine galleries in the area, especially in the higher parts of the mountain (above 1,000 m), where air temperatures in the caves are expected to be lower and the humidity higher.

4.5.3 Explore the fauna of the newly discovered cave that appears to have the largest underground lake in Turkmenistan and former SSSR.

4.5.4 Explore the cave near 'Svincovyi rudnik' mentioned by Ljovushkin (1969).

4.5.5 Carry out a pilot study of the totally unexplored Mesovoid Shallow Stratum (MSS) of the mountain which may reveal several new species.

4.5.6 Carry out regular monitoring of the invertebrate communities in the caves.

4.5.7 Search the flooded caves on the ridges of Karabil and Karadzhimulak where there may be refugia of relict fauna of the Tethys Ocean.

4.5.8 Collate data on the bioiversity of waterbodies in the adjoining Surkhandarya reserve in Uzbekistan. Ideally this would be a synchronous expedition on both sides of the Koytendag ridge.

4.6 Bibliography

Birstein YA (1985) The genesis of freshwater and deep cave faunas. Moscow. Science. 247 pp In Russian

Birstein YA and Ljovushkin SI (1965) Faune des eaux souterraines saumâtres de l'Asie centrale. International Journal of Speleology 1: 307-320.

Brodsky AL (1928) Foraminifera (Polythalamia) in Grundwater der Wuste Kara-Kum. Acta Universita Asiae Mediae, Ser. 8, Zoologica, 5, 1-17. In Russian

Brodsky AL (1929) The fauna of the basins of the desert Kara-Kum. Acta Universita Asiae Mediae, Ser. 12, Geographica 5: 1-43. In Russian

Chibisova OI (1967) Testacea from some caves and karst reservoirs. Zoologicheskii Zhurnal 46: 181-186 (in Russian with English summary)

Decu V, Juverhie C, Lepure S, Gheorguiu V, Nazareanu G (2019) An overview on the subterranean fauna from Central Asia. Ecologica Montenegrina 20: 168-193.

Guéorguiev B, Merkl O, Schülke M, Fery H, Szénási V, Král D, Kejval Z, Németh T, Szalóki D (2018) Coleoptera (Insecta) from Ashgabat City and Köýtendag Nature Reserve, with nine first records for Turkmenistan. Historia naturalis bulgarica 29: 9-20.

Kniss V A (2001) Cave fauna of Russia and adjacent countries (history of study, composition and distribution). Bashkir University Publishing House, Ufa.

Lyovushkin SI (1969) About the subterranean fauna of Soviet Central Asia. 4th Int. Speleology Congress. Actes IV, Ljubljana. CIS 4-5: 145-149.

Sendra A, Sket B, Stoev P (2017) A striking new genus and species of troglobitic Campodeidae (Diplura) from Central Asia. Subterranean Biology 23: 47-68. https://doi.org/10.3897/subtbiol.23.14631

Sidorov D, How Z, Sket B (2018) Three new remarkable amphipod species (Crustacea: Gammaridae) from springs and subterranean waters of Central Asia. Zootaxa 4444 (4): 437-461. http://www.mapress.com/j/zt/

Fish

Fig. 17. Starostin's blind loach *Troglocobitis starostini*, collected at Suw Oyuk (Photo credit: Brian Zimmerman, ZSL)

Fish

Brian Zimmerman, Rachel Jones and Sarah Ball

5.1 Background

The fish fauna of Koytendag is limited to ten species. The most important species is the endemic blind cavefish Starostin's loach *Troglocobitis starostini* (VU) which appears to be restricted to the Suw Oyuk sinkhole. In addition to being endemic to Koytendag, the loach is the only blind cavefish species found in Northern Eurasia. Of the other species, these are mainly represented by Ponto-Caspian-Aral species (Turkestan barbel *Barbus capito* ssp. *conocephalus*, Turkestan gudgeon *Gobio gobio* ssp. *lepidolaemus* and striped bystranka *Alburnoides taeniatus*) and Iranian species such as *Capoeta capoeta* ssp. *capoeta*. Two species – common marinka *Schizothorax intermedius* and grey stone loach *Triplophysa dorsalis* – are restricted to the water basins of Koytendag within Turkmenistan. Two alien species have been introduced to the area – the numerous and widespread mosquitofish *Gambusia affinis* and *Cyprinus carpio* which in 2015 was only recorded from the swimming hole at Gaynarbaba and is presumably confined to this location. These species were introduced for a number of reasons including for food and biological control. In the case of *Gambusia affinis*, according to WHO this was introduced to Turkmenistan in the 1930s for the control of malaria mosquitoes.

5.2 Methodology

Fish fauna, environmental parameters and water quality were sampled at eight springs, rivers and cave systems within the site – *see table 9 and map 7*. The sample sites comprised a range of representative locations of the key aquatic habitats in the reserve. A range of basic water quality parameters were tested using probes and colorimetric tests, both simple and rugged for field use. The tests explored the physical characteristics of the water at each site and the levels of common organic nutrients. Sites where open water can be sampled are abundant, however the majority are irrigation channels that feed water from springs to villages and fields and most are used heavily for the watering, and in some cases washing, of livestock with inevitable inputs of organic pollutants. Though constant flow of new spring-fed water means nutrient levels are diluted and data show relatively low levels as a result - *see table 10* - there was some evidence of local eutrophication such as abundant algae and cyanobacteria growth in pools. The sample sites were selected to allow comparisons to be made with the blind loach sinkhole site and to gain an understanding of their interconnectedness both hydrologically and biologically.

During the expedition the ZSL team, aided in interpretation by Michail Pereladov from VNIRO, conducted a training session with six staff members from the Koytendag State Nature Reserve team. The session covered the basics of water quality analysis using the Salifert test kits used during the fieldwork (calcium, alkalinity, pH, dissolved oxygen content, phosphate and nitrate). Some background was given for each parameter explaining what it was, the significance for aquatic animals and the implications of change in reflecting pollution events for example. A programme of regular monitoring was agreed with the reserve's Scientific Director, with samples to be taken monthly from three sites; the Suw Oyuk sinkhole, the Koytendarya and the newly explored cave lake and analysed for the parameters shown in table 10 plus temperature. The cave lake is a new site and it would be valuable to investigate if there is any connection between that and the Suw Oyuk sinkhole hydrosystem. The Koytendarya is the only sample site containing significant numbers of native fish fauna and which might be sensitive to environmental changes. In addition to the regular sampling programme, opportunistic samples will also be taken after notable events such as flooding that may affect the aquatic environment.

Table 9. Ichthyological survey sample sites.

Site number	Site name	GPS coordinates	Altitude (m)	Species identified
1	Suw Oyuk sinkhole	N 37°35.824’ E 066° 24.318’	373	*Troglocobitis starostini*
2	Karabulak	N 37°36.332’ E 066°21.200’	327	*Gambusia affinis*
3	Jarme	N 37°36.633’ E 066°21.348’	332	*Gambusia affinis*
4	Gaynarbaba	N 37°32.265’ E 066°24.375’	324	*Cyprinus carpio, Gambusia affinis, Alburnoides sp.* (*taeniatus*)?
5	Koytendarya	N 37°43.444’ E 066°19.523’	443	*Paracobitus longicauda, Capoeta* sp. (*capoeta capoeta*)
6	Bashbulak	N 37°56.421’ E 066°33.298’	913	None
7	Kaptarhana	N 37°49.686’ E 066°24.627’	610	*Capoeta* sp. (*capoeta capoeta*)
8	Gazlyk oba	N 37°35.604’ E 066°20.839’	326	*Alburnoides* sp. (*taeniatus*)?, *Gambusia affinis*
9	Ketdekol reservoir			*Capoetobrama kuschakewitschi*

Table 10. Environmental data from sample sites.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Temp °C	21.8	21.1	22.6	23	27.3	19	n/a	21	n/a
pH	7.08	7.58	7.41	6.32	8.08	7.06	n/a	7.57	n/a
DO mg/l	5.74	4.42	8.66	0.68	7.12	8.15	n/a	5.44	n/a
Conductivity ms/cm)	13.46	9.67	9.43	11.83	8.83	2.10*	n/a	10.21	n/a
Calcium mg/l	690	200	165	225	140	100	n/a	253	n/a
Alkalinity meq/l	3.3	3.82	3.65	3.57	2.89	3.58	n/a	0	n/a
Phosphate mg/l	0	0	0	0	0.02	0	n/a	4.1	n/a
Ammonia mg/l	0.25	<0.25	<0.25	<0.25	<0.25	0	n/a	0	n/a
Nitrite mg/l	0	0	0	<0.1	0	0	n/a	0	n/a
Nitrate mg/l	7	10	5	5	1	5	n/a	10	n/a
Flow	None	Medium	None	Low	Medium	Medium	None	Low	n/a

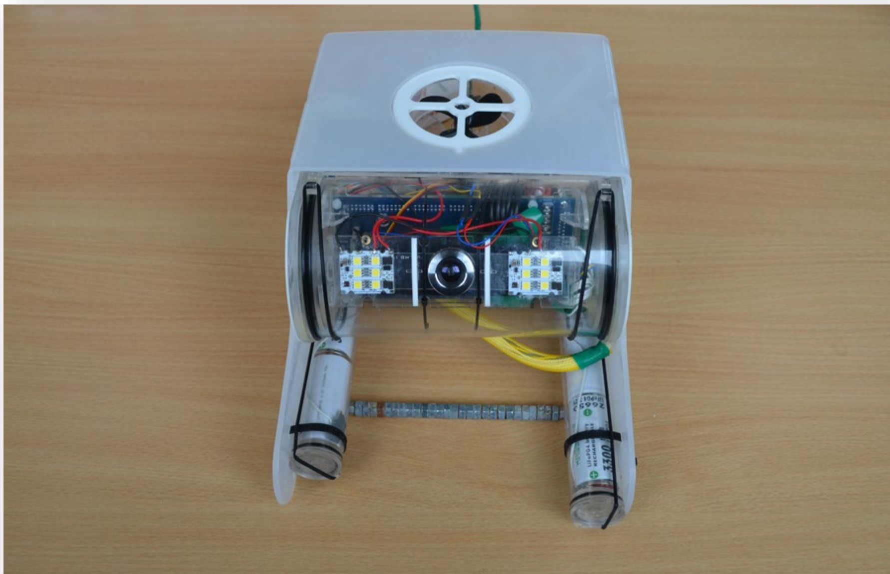
For fish, the principal sampling methods were by hand net and two hexagonal, multi-entry baited minnow traps of 1 m diameter. In total seven of the eight sites were thoroughly sampled. Site 7 was not sampled extensively however a specimen was obtained opportunistically. Additional opportunistic sampling was carried out at Ketdekol reservoir in Koyten village.

For the blind loach, collection of specimens was attempted via two methods; swimmers using hand held nets and baited minnow traps left overnight – *see Fig. 18*. The traps were set in the shaded part of the sinkhole at approximately 3m depth near the two entrances to the cave system. One was baited with cheese and the second with sausage and secured with a cord to a rock at the surface for easy retrieval. The baited traps proved unsuccessful after two trapping sessions, one of 15 hours and the second of 48 hours. Collection using hand nets was successful once the fish moved into relatively shallow water to enable a free-diving swimmer to reach them.

Fig. 18. Setting a minnow trap (Photo credit: Brian Zimmerman, ZSL)

In addition, two novel environmental monitoring techniques were tested. The first was the use of a remotely operated vehicle (ROV) for gathering video footage of the habitat and fish behaviour in-situ with minimal disturbance – *see Fig. 19*. The ROV used was the openROV v 2.7 from http://www.openrov.com/ assembled and tested at ZSL. The ROV was controlled from a laptop connected by an umbilical cable to the unit with a live video feed streaming directly to the laptop from the on-board camera. The use of the ROV was unsuccessful due to damage to the unit caused by water intrusion to the main chamber containing the electronics. The damage may have been sustained during shipping to the site and it was not possible to conduct repairs in the field. However, the limited time the unit spent in the water and the observations it gained from the site indicate that this approach could prove to be a useful tool for undisturbed monitoring and data collection of sensitive species in relatively inaccessible locations.

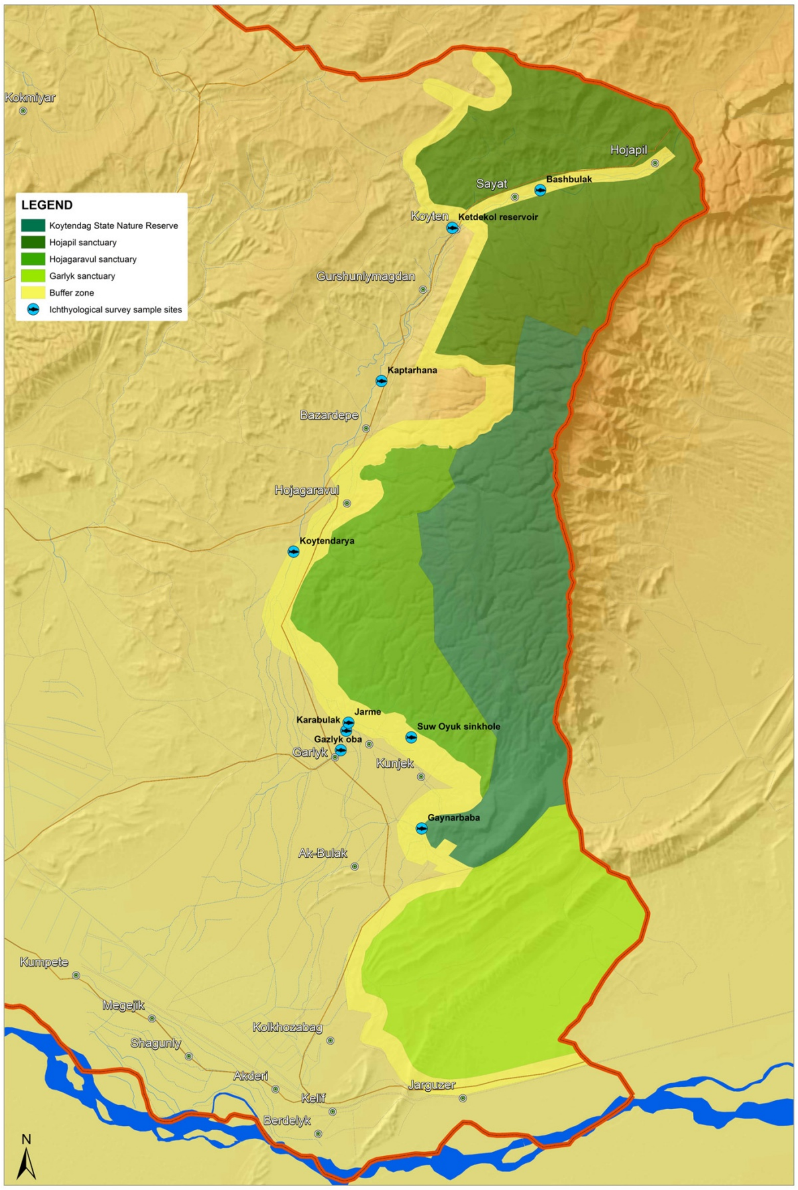
Fig. 19. openROV v 2.7 (remotely operated vehicle) trialled for observing Starostin's blind loach *in situ* (Photo credit: Brian Zimmerman, ZSL)



The second technique was to collect genetic material from the loach and any related species from the watershed to profile their DNA to test the potential for environmental DNA (eDNA) collection in the future as a means of measuring the full area of occupancy by the fish in the extensive cave system. The method of utilising environmental DNA is currently being used with amphibian population detection although its use for fish in cave systems is untried. The basic premise is developed from the DNA bar coding concept - http://www.barcodeoflife.org/content/about/what-dna-barcoding

The premise is that the cytochrome oxidase 1 gene (COI) located on the mitochondria of eukaryotic organisms encodes a relatively unique sequence for a species. The concept relies on taking a source of DNA and amplifying the COI gene from this source in order to identify what species are present in the source. This concept is applied to everything from probable single species sources (meat and skins in illegal wildlife trade, for example) up to sources with mixed species DNA, like water samples. By extension, this concept then becomes a means of identifying what eukaryotic species are present in environmental samples, like soil, snow and, in the cavefish scenario, water. By knowing how COI genes are unique to a certain species, PCR primers can then be designed that determine what region is amplified during PCR to target only the COI gene of the species of interest. To do this, other potential sources of DNA that would be most similar to the focal species present in the environment need to be sampled in order to exclude these as much as to target the focal species.

Map 7. Ichthyological survey sample sites. Map by Atamyrat Veyisov.



For the mitochondrial DNA analysis nine individual fish samples were included in the study, comprising four *Troglocobitis starostini*, two *Paraobitis longicauda*, one *Capoeta capoeta* and one *Alburnoides* sp. Samples (eight fin, one body) had been stored in ethanol. Samples were assigned a code TF1 – TF9 and studied blind to the identity of the individual to reduce subjective bias. DNA was extracted using a Qiagen blood and tissue kit and amplified PCR using universal primers for mitochondrial DNA (mtDNA) 12S and 16S RNA genes. PCR products were sequenced at GATC Biotech, using a Sanger method. Sequences were aligned using ClustalW in Bioedit. BLAST searches of Genbank and Mitofish nucleotide databases were used to identify closely homologous sequences.

5.3 Results

Seven of the ten species recorded for the area were identified during the sampling period – *see table 7*. For the blind loach, a total of eight individuals was observed. Seen *in-situ* the fish were all in contact with solid surfaces rather than free-swimming in the water column, presumably for purposes of orientation. Most were observed near the cave entrance in more than 3 m of water but one was observed within a metre of the water surface. Fish were seen in pairs on two occasions. Two whole fish were collected for further analysis, and fin clips were taken from a further three specimens. These specimens will provide more detailed anatomical information, as well as the first opportunity to carry out gut content analysis to understand the dietary preferences and to develop the genetic profile of this species for eDNA work.

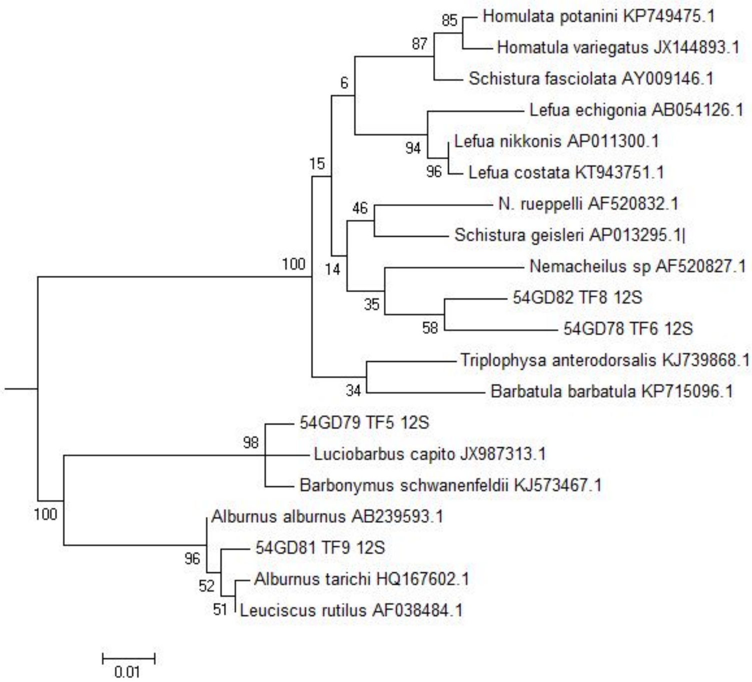
The results of the mitochondrial typing analysis showed that groups of individuals showing identical haplotypes for 12S were also identical for 16S. Four 12S/16S haplotypes were identified. The 12S/16S haplotype groupings were consistent with the species of the test individuals:

a) TF1, TF2, TF4 and TF8 – all *Troglocobitis starostini*
b) TF6, TF7 – both *Paracobitis longicauda*
c) TF5 – *Capoeta capoeta*
d) TF9 – *Alburnoides* spp.

The phylogenetic tree of 12S mtDNA – *see figure 20* – from the sampled individuals and closely homologous sequences in the nucleotide databases shows two strongly supported clades:

a) A 'loose' clade including the *T. starostini* and *P. longicauda* individuals in which there is generally low bootstrap support for subclades illustrating the limitation of resolution with the current representation of related taxa in the databases.
b) A second clade including two well supported subclades, the *Alburnoides* spp. individual (TF9) grouping with *Alburnus* spp. and *Capoeta capoeta* (TF5) with the sister subclade.

Fig. 20. Blind loach mtDNA phylogenetic tree of the 12S haplotypes identified in the test individuals and closely homologous sequences from the Genbank nucleotide database



Results of follow-up monthly water quality monitoring by reserve staff at eight sites within the reserve are given in tables 11 to 14, with information from less regularly monitored sites in tables 15 to 18.

Table 11. Suw Oyuk, Hojagaravul Wildlife Sanctuary (N 37º35.604’ E 066º 20.839’; 326 m asl).

Date	Temp. outside cave (ºC)	Temp. inside cave (ºC)	Water temp. (ºC)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
26.05.2015	-	-	26.8	11.30	11.30–13.36	0.08	0.38 (3.36%)	0.62 (690%)	6.74	0	7
29.06.2015	43	24.1	26.8	12.50	12.52–13.36	7.7	0.44 (3.08%)	1.46 (770%)	8	0	25
29.07.2015	39	38	22.4	11.55	12.10–12.57	7.5	0.57 (2.39%)	1.63 (690%)	10	0	75
28.08.2015	28.4	-	20.2	10.55	11.03–11.34	7.5	0.40 (3.30%)	2.78 (1110%)	8	0.03	30
29.09.2015	39.1	27.2	20.1	14.15	14.15–14.46	7.6	0.20 (4.45%)	1.37 (810%)	10	0.03	75
29.10.2015	30.0	21.2	20.1	13.10	13.30–13.53	7.6	0.28 (3.99%)	1.24 (880%)	6	0.03	75
30.11.2015	12.3	13.1	19.1	10.16	10.16–10.46	7.5	0.36 (3.53%)	1.22 (890%)	10	0.03	30
06.01.2016	19.3	16.3	19.1	09.38	09.41–10.15	7.5	0.22 (4.33%)	1.36 (820%)	10	0.03	50
06.02.2016	20	22.1	19.3	09.15	09.20–09.55	7.4	0.48 (2.85%)	-	6	0	25
06.04.2016	22	16.0	19.4	14.45	14.48–15.21	7.4	0.40 (3.30%)	0.42 (290%)	10	0	50
12.05.2016	29.3	24.1	20.1	10.20	10.24–10.59	7.4	0.40 (3.30%)	0.56 (220%)	8	0	50
06.06.2016	38.2	26.0	21.2	15.43	15.45–16.11	7.6	0.38 (3.42%)	0.60 (200%)	9	0	50
06.07.2016	39.4	26.0	21.4	12.36	12.40–13.08	7.8	0.42 (3.19%)	0.72 (140%)	10	0	50
12.08.2016	34.3	23.4	20.1	11.53	11.56–12.30	7.6	0.42 (3.19%)	0.54 (250%)	8	0	50
08.09.2016	31.3	26.0	20.2	14.10	14.13–14.40	7.4	0.40 (3.30%)	0.72 (140%)	8	0	50

Table 12. Gaynarbaba, Garlyk Wildlife Sanctuary (N 37°32.265' E 066° 24.375'; 324 m asl).

Date	Temp. outside cave (°C)	Temp. inside cave (°C)	Water temp. (°C)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
29.08.2015	-	27.0	21.4	08.41	08.45-09.15	7.5	0.34 (3.65%)	0.30 (350%)	2	0	25
29.09.2015	-	39.2	21.4	12.02	12.02-12.38	7.5	0.32 (3.76%)	0.40 (300%)	6	0	25
29.10.2015	-	30.0	21.2	11.25	11.25-11.56	7.5	0.32 (3.76%)	0.14 (430%)	8	0	25
30.11.2015	-	9.2	21.0	07.01	07.01-07.35	7.5	0.35 (3.76%)	2.90 (1090%)	10	0.03	25
29.12.2015	-	22.0	21.0	11.55	11.55-12.25	7.5	0.34 (3.65%)	0.36 (320%)	10	0	25
06.01.2016	-	19.3	21.3	12.02	12.05-12.30	7.5	0.32 (3.76%)	0.54 (230%)	8	0	50
06.02.2016	-	18.1	21.2	11.28	11.30-11.56	7.4	0.32 (3.76%)	0.32 (340%)	8	0	25
11.03.2016	-	26.0	20.2	16.02	16.05-17.00	7.4	0.44 (3.08%)	0.56 (220%)	8	0	50
05.04.2016	-	26.0	20.01	12.59	13.02-13.36	7.4	0.32 (3.76%)	0.54 (230%)	8	0	25
06.05.2016	-	26.5	21.2	10.30	10.33-11.00	7.7	0.32 (3.76%)	0.54 (230%)	8	0	25
06.06.2016	-	30.3	22.0	10.48	10.50-11.25	7.7	0.32 (3.76%)	0.46 (270%)	8	0	10
06.07.2016	-	29.7	22.1	10.28	10.30-11.11	7.8	0.28 (3.99%)	0.48 (200%)	8	0	25
12.08.2016	-	23.0	21.3	09.27	09.30-10.08	7.8	0.50 (2.73%)	0.50 (250%)	12	0	25
08.09.2016	-	27.1	22.0	11.40	11.43-12.25	7.5	0.32 (3.76%)	0.54 (230%)	8	0	10

Table 13. Koytendarya, Bazardepe village on border with Hojagarawul Wildlife Sanctuary (N 37°43.444' E 066° 19.523'; 443 m asl)

Date	Temp. outside cave (°C)	Temp. inside cave (°C)	Water temp. (°C)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
28.05.2015	-	-	27.3	03.45	03.45-04.38	8.08	0.48 (2.89%)	0.72 (140%)	7.12	0.02	1
29.06.2015	-	41.0	28.4	17.45	18.01-18.37	8.0	0.54 (2.50%)	0.58 (210%)	8	0	10
29.07.2015	-	38.0	28.1	18.19	18.29-18.58	8.1	0.36 (3.53%)	0.18 (410%)	10	0.03	10
28.08.2015	-	33.0	25.1	16.55	17.00-17.35	8.1	0.18 (4.56%)	0.14 (430%)	10	0.03	10
29.09.2015	-	25.2	20.2	17.14	17.24-17.45	8.2	0.34 (3.65%)	0.39 (300%)	10	0.03	50
29.10.2015	-	22.3	15.1	16.05	16.13-16.39	8.1	0.28 (3.99%)	0.12 (440%)	10	0	15
30.11.2015	-	18.9	10.4	11.03	11.03-11.56	8.2	0.24 (4.22%)	0.41 (300%)	10	0	15
29.12.2015	-	16.1	9.3	16.06	16.35-17.00	8.2	0.26 (4.1%)	0.16 (470%)	12	0.03	25
06.02.2016	-	14	11.4	15.55	16.08-16.25	7.9	0.26 (4.10%)	0.14 (430%)	12	0	25
11.03.2016	-	20.0	14.2	11.14	11.18-11.50	7.7	0.82 (0.90%)	0.72 (140%)	12	0	10
06.04.2016	-	17.2	15.0	10.50	11.23-11.35	7.8	0.34 (3.65%)	0.60 (200%)	12	0.03	10
06.05.2016	-	19.4	15.6	15.10	15.14-15.45	7.8	0.36 (3.53%)	0.60 (200%)	12	0	10
06.06.2016	-	26.0	24.3	10.44	10.47-11.27	7.8	0.36 (3.53%)	0.58 (210%)	12	0	10
06.07.2016	-	31.0	33.1	15.36	15.40-16.09	8.1	0.64 (1.93%)	0.56 (220%)	12	0	10
12.08.2016	-	26.4	24.5	16.51	16.54-17.28	7.8	0.12 (4.90%)	0.58 (210%)	12	0	25
08.09.2016	-	26.0	16.2	16.00	16.03-17.40	8.2	0.64 (1.93%)	0.60 (200%)	12	0	10

Table 14. Kutuzov cave, Hojagaravul Wildlife Sanctuary (N 37°35.824' E 066° 24.318'; 373 m asl).

Date	Temp. outside cave (°C)	Temp. inside cave (°C)	Water temp. (°C)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
29.06.2015	43.0	14.2	13.3	16.18	16.22-17.00	7.4	0.46 (2.96%)	1.64 (680%)	8	0.03	35
29.07.2015	22.8	19.1	13.2	16.52	17.10-17.46	7.6	0.48 (2.85%)	1.42 (700%)	8	0.03	50
28.08.2015	36.0	20.4	13.3	14.55	15.10-15.52	7.6	0.52 (2.62%)	1.24 (880%)	10	0	60
29.09.2015	-	19.5	13.0	15.50	15.55-16.38	7.7	0.38 (3.42%)	2.00 (1000%)	12	0.03	75
29.10.2015	-	-	-	-	-	-	-	-	-	-	-
30.11.2015	11.2	12.1	12.4	08.50	08.50-09.30	7.8	0.52 (2.62%)	1.35 (830%)	12	0	25
29.12.2015	14.3	12.0	12.1	14.40	14.57-15.27	7.6	0.46 (2.96%)	1.44 (780%)	15	0	75
06.02.2016	15.0	12.1	11.1	14.29	14.32-14.55	7.6	0.56 (2.39%)	1.56 (720%)	8	0.03	50
11.03.2016	20.0	16.0	11.4	10.27	10.30-11.11	7.4	0.62 (2.05%)	-	12	0	50
06.04.2016	23.0	15.1	12.2	17.14	17.18-17.52	7.7	0.46 (2.96%)	0.00 (500%)	12	0	50
06.05.2016	26.0	16.2	12.6	12.25	12.28-12.50	7.7	0.46 (2.96%)	0.40 (300%)	12	0	50
06.06.2016	34.2	13.4	14.0	17.41	17.44-18.10	7.5	0.46 (2.96%)	0.52 (240%)	10	0	50
06.07.2016	40.2	14.0	13.3	11.57	12.00-12.30	7.5	0.50 (2.73%)	0.66 (170%)	9	0	50
12.08.2016	34.2	13.0	11.2	14.44	14.47-15.23	7.8	0.56 (2.39%)	0.18 (410%)	15	0	50
08.09.2016	30.0	14.2	13.0	15.10	15.13-16.00	7.5	0.46 (2.96%)	0.32 (340%)	9	0	50

Table 15. Garabulak, Garlyk village border with Hojagaravul Wildlife Sanctuary (N 37°35.604' E 066° 20.839'; 326 m asl)

Date	Temp. outside cave (°C)	Temp. inside cave (°C)	Water temp. (°C)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
28.05.2015	-	-	21.1	10.57	11.30-12.10	7.57	3.32 (3.82%)	0.60 (200%)	4.72	0	10
31.05.2015	-	-	21.0	09.00	09.00-09.50	7.57	0.26 (4.10%)	0.60 (200%)	2.25	0	10

Table 16. Jarme, Garlyk village border with Hojagarawul Wildlife Sanctuary (N 37°36.633' E 066° 21.348'; 326 m asl)

Date	Temp. outside cave (°C)	Temp. inside cave (°C)	Water temp. (°C)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
28.05.2015	-	-	22.6-21.1	11.10	11.15-12.18	7.41	0.34 (3.65%)	0.68 (162%)	8.66 (104%) 4.87 (57%)	0	5

Table 17. Jarme, Gaynarbaba 'Ak suw' spring, Garlyk Wildlife Sanctuary (N 37°32.265' E 066° 24.375'; 324 m asl)

Date	Temp. outside cave (°C)	Temp. inside cave (°C)	Water temp. (°C)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
28.05.2015	-	23	22.3	02.30	-	6.32	0.36 (3.57%)	0.60 (200%)	2.25	0	5
28.08.2015	-	26.0	21.4	09.20	09.25-09.50	7.5	0.26 (4.10%)	0.78 (110%)	2	0	5

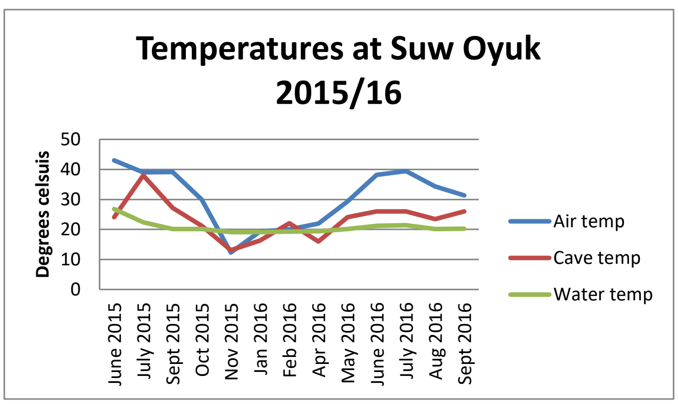
Table 18. Bashbulak, Gyzylay village, Hojapil Wildlife Sanctuary (N 37°56.421' E 066° 33.298'; 913 m asl)

Date	Temp. outside cave (°C)	Temp. inside cave (°C)	Water temp. (°C)	Sampling time	Time of analysis	Acidity (PH) mg/l	Alkalinity (KH) mg/l	Calcium (ca) mg/l	Oxygen (O_2) mg/l	Phosphate (PO_4) mg/l	Nitrate (NO_3) mg/l
29.05.2015	-	-	19.0	04.16	-	7.06	0.36 (3.58%)	100	8.15 (100%)	0	5

Analysis of data from the 16 month period - May 2015 to September 2016 – for the Suw Oyuk sinkhole allow some broad observations of selected parameters to be made but a continued data series into a second complete year is necessary in order to draw inter-annual comparisons – *see 5.4 Discussion*. The analysis carried out relates to:

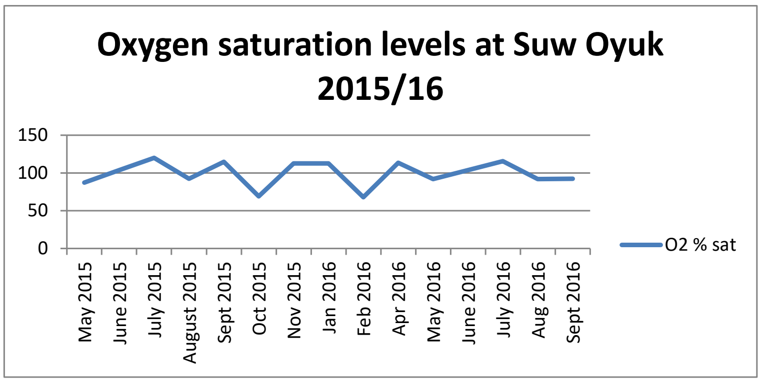
1. Temperature

This appears to be a reliable and consistent set of data comparing temperatures at ground level above the sinkhole (Air), with those inside the sinkhole (Cave) and in the Water of the sinkhole lake.



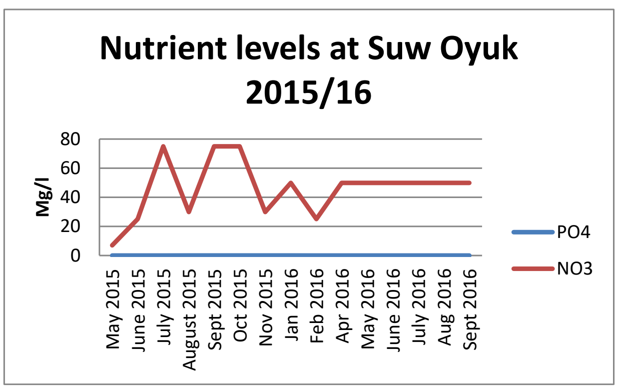
2. Oxygen levels

This parameter is difficult to measure accurately using the simple tests provided. Any agitation of the samples changes the oxygen saturation levels quickly as does any delay in conducting the test. The data are variable between 67% and 115%. The mg/l values in the raw data were converted to % saturation levels using altitude and temperature data.

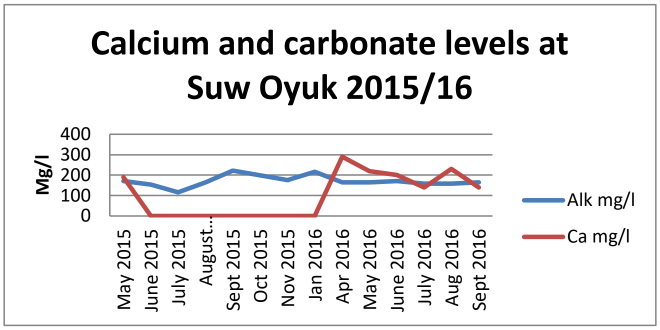


3. Nutrient levels

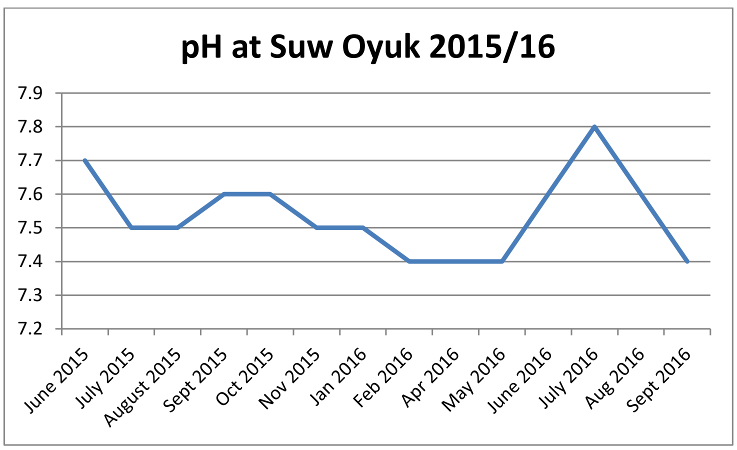
These data record levels of phosphate (PO_4) and nitrate (NO_3) collectively tracking dissolved organic nutrient levels in the water.



4. Calcium and carbonate levels



5. pH



5.4 Discussion

In terms of the DNA analysis the haplotype grouping of the test samples is consistent with the species of the individuals. The extent of polymorphism within the 12S and 16S sequences was sufficient to allow resolution between the species included in this study. However, identification at the species level was not possible due to limited database representation of related taxa, a well-recognised limitation of mtDNA species 'barcoding'.

The primers used in this study would be unsuitable for the investigation of the distribution of the blind loaches using DNA from water samples as they amplify across a wide range of taxa. However, it should be possible to generate more specific blind loach primers from the polymorphic regions within the 12S and 16S regions amplified in the current study.

The evolutionary history was inferred using the maximum likelihood method based on the Kimura 2-parameter model. The tree with the highest log likelihood is shown. The percentage of trees in which the associated taxa clustered together (based on 500 bootstrap replications) is shown next to the branches. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. There were a total of 359 positions in the final dataset. The analysis involved 20 nucleotide sequences. Evolutionary analyses were conducted in MEGA6. Accession numbers are shown for homologous sequences downloaded from Genbank.

Based on current knowledge of the hydrogeology of Koytendag, it is generally agreed that the blind loaches were originally species living in the surface waters of the area which colonized Suw Oyuk probably from water courses which formerly linked Karabulak and Kaynar springs with the Amudarya, though the possibility that they reached the sinkhole during times of extensive flooding by the Koytendarya cannot be discounted. This hypothesis is based on the following geological conditions:

1. Analysis of the geological structure of the surface water bodies and the structure of deposits in the sinkholes shows that depressions in the valley are covered from above with a thick layer of alluvial deposits (pebbles, sand and gravel) which were brought either by flooding of the river in the historical past, or through the flow of debris from the canyon.
2. Analysis of the dry beds of the Koytendarya shows that even now during flash floods a large part of the valley can be covered by water.
3. In the recent past (a few hundred years ago) the Koytendarya was significantly larger and deeper and frequently overflowed into the Amudarya – there was even shipping up as far as Bazardepe village.

Therefore, during seasonal flooding, water from the Koytendarya could potentially have entered the sinkholes and brought with it fauna from the river. An estimate of the length of time that the river and cave fish fauna have been separated could be obtained by analysing the genetic distance between loach caught in the Koytendarya and blind loach in the sinkholes.

Maltsev also hypothesised that the loaches became isolated from other loach populations through the establishment of hydrogen sulphide 'barriers' – hydrogen sulphide is both toxic and creates anaerobic conditions – using the presence of three hydrogen sulphide springs in the area to support this theory.

However, it is thought that the hydrogen sulphide springs are of recent geological origin and formed after the loaches had colonized Suw Oyuk.

Troglocobitis starostini was first recorded in 1979 by Vladimir Maltsev, first caught in 1981 by Nikolai Swerden and described in 1983 by Nikolai Parin. In 1986 the first scuba exploration of the sinkhole was conducted by Sergei Smirnoff who collected specimens and tried to keep them in an aquarium unsuccessfully. In 1987, which was a dry spring and the water level was lower, a further scuba survey descended into the cave system to a depth of 62 m – noting over 100 fish 10-15 m below the surface. In 1988, a wet spring, a survey noted the surface of the sinkhole was covered in debris and there had been a partial collapse of one of the side walls but the fish were seen feeding on the mud in the water. The latter was the last significant study of the site. In 1989 a smaller trip noted 20-30 fish near the surface of the water. In 1994 another small expedition collected fish in an attempt to breed them *ex-situ* (Salnikov) and the results of his work were published in 2004 and 2008 in Russian.

Distribution of the species is strongly associated with the distribution of bacterial films on the surface of cave bottom sediments. In the dry season plant debris (or other forms of organic matter) is blown into the sinkholes and becomes deposited on the bottom of the shallow lakes near the surface. At this time the majority of the fish population spreads into the upper (illuminated) part of the lake. After periods of heavy rain larger quantities of plant debris and animal matter can be found throughout all parts of the underwater caves and the fish disperse throughout the cave system. Additionally, it is thought that inter-annual fluctuations in water temperature in the sinkhole lake can be significant and can have a significant impact on the distribution of blind loaches and biological processes in their population.

In 1994, after an extensive flood when the sinkhole lake received a considerable amount of organic residues, local officials decided to close the channel that flowed directly into the lake and divert the water into the neighboring sinkhole which had no direct access to the main water body. As a result for the past 20+ years mudslides have never entered the Suw Oyuk sinkhole resulting in the formation of an entirely different seasonal succession. Instead of the periodic enrichment of the sinkhole lake by 'fresh' organic matter, the underground lake now receives water filtered through several hundred metres of gypsum rock that has dramatically changed the food source of the population of blind loaches. This raises the question as to whether it is necessary or preferable to leave the channel providing organic matter blocked or restore the old watercourse which periodically brings mud with organic residues to the sinkhole lake? As the flow of organic matter into the cave lake ecosystem existed since the formation of the sinkholes and the development of the blind loach populations, this can be considered as a normal process. However, there is a risk that should there be the deposition of another large amount of surface mud the connection between the lake and the main underground cavity could become completely blocked for further study. Such a blockage is unlikely to be an impenetrable barrier for the blind loach but it would prevent human access to the lower levels of the lake. In an extreme case, a major deposition of mud could cause complete blockage of the external lake and turn the sinkhole into a cavity filled with loose sediments – as has happened to a neighboring sinkhole that has absorbed debris flows from the Bulakdere canyon.

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Fish species were recorded in three 'cave systems' – sazan near Jarme north of Garlyk, *Capoeta* sp. in Kaptarhana and blind loaches in Suw Oyuk – and there is speculation over how fish colonized each of these sites. In the case of the sazan, these are known to have been introduced. As Kaptarhana is located within 200 m of the Koytendarya where *Capoeta* sp. are known to occur, it is considered likely that there are existing or geologically recent connections between the two waterbodies. The presumed origin of the blind loach in Suw Oyuk is discussed in detail above.

Of the two introduced species recorded during the survey *Gambusia affinis* were virtually ubiquitous. The only sites where this species was noticeably absent were the sinkhole where the blind loach is found, the newly discovered cave lake and the main channel of the Koytendarya. In the case of the main channel of the Koytendarya the flow rate was higher than expected for typical *Gambusia affinis* habitat. The cave lake was completely devoid of any life or light and therefore considered unsuitable habitat for *Gambusia affinis*. However the potential for introduction of *Gambusia affinis* to the sink hole should be considered; though unlikely the implications would be serious and should be considered a major risk.

Preliminary analysis of the water sampling at Suw Oyuk indicates the following:

1 Temperature

The data reveal the large range of seasonal temperatures from the surrounding environment (min: 12.3°C, max: 43°C, mean: 30.4°C, SD: 9.2, n=14) which is tracked by that inside the sinkhole despite generally less extreme values (min: 16°C, max: 38°C, mean: 23.4°C, SD: 6.24, n=13). In contrast the water in the sinkhole lake itself shows a remarkably constant temperature year round with a range of only 7.7°C (min: 19.1°C, max: 26.8°C, mean: 21.09°C, SD 2.49, n=15). Given that the samples are assumed to have been taken at or very near the surface of the water where temperatures could be expected to be most variable, this might suggest even more constant temperatures at depths in the main subterranean water system.

2 Oxygen levels

As the water in the sinkhole lake is relatively still with no apparent currents or turbulence the results showing O_2 saturation levels >100% are most likely an artefact due to sampling error.

3 Nutrient levels

PO_4 levels are inconsequential whereas NO_3 levels, though variable ranging from 7 to 75mg/l, could generally be interpreted as high. The EU Nitrates Directive describes rivers and groundwater with nitrate concentration above 25 mg NO_3/l as reflecting a threshold of concern, and those above 50 mg NO_3/l as contaminated. This concern is reflected by the Environmental Protection Agency which has adopted a maximum contaminant level of 10 mg/l for nitrate-nitrogen in regulated public water systems, and the Secretary of State Standards of Zoo Practice states that levels above 20 mg/l in seawater should be avoided – the limit for freshwater is likely to be similar. The data from the sinkhole samples record values ≥50mg/l in 10 of the 15 months sampled (66%). The NO_3 in the water might reflect decomposition of debris blown into the upper layers of the lake from the surface and dead frogs and birds have been observed in the water which would also contribute nutrients as they break down. It may also represent contamination from agricultural practices on surrounding land, or from other water sources that may feed into the cave system elsewhere. There is no obvious seasonal pattern which might reflect agricultural use of fertilisers on crops, which is encouraging, but a longer data series is required to draw any firm conclusions.

The significant quantities of NO_3 in the upper waters of the lake would seem to confirm the sinkhole as a major source of nitrogen into the wider subterranean hydrological system and potentially a key driver of the productivity of this system that supports *Nemacheilus* and its associated sources of food. However, at higher levels of NO_3 problems of eutrophication leading to algae blooms are often a problem and this should be recorded if observed. It would be instructive to see what mixing of nutrients (if any) is happening by taking water samples from deeper in the cave system if possible. The NO_3 contamination may in fact be quite localised if mixing is limited or it may constitute a major source if input as noted above. Further analysis of this parameter using laboratory techniques might be useful.

4 Calcium and carbonate levels

The data for calcium is slightly confusing; assuming that the units it has been recorded in reflect the amount of reagent used for the test then after a conversion to mg/l several consecutive samples would record a reading of 0. The months that do record a positive result vary between 140 and 290 mg/l which would seem to be within a reasonable range for a cave system made from calcium sulphate. The months for which there is a reading of 0 may be due to testing error. The consistent alkalinity results (showing carbonate levels in mg/l) would also support the supposition that the calcium readings are errors and also support the observations of quite stable water quality in the cave system.

5 pH

pH varies between 7.4 and 7.8 and appears to show a high point in June/July for both years but a longer data series is required to draw conclusions about a seasonal pattern with any confidence.

In conclusion, nutrient levels in the sinkhole lake are of concern and warrant further investigation but overall the data are useful and create a good baseline to build on. A longer time series is required to allow inter-annual comparisons and a continued sampling and testing effort is recommended. Some re-training of reserve staff in the use of O_2 and Ca test kits may be required but it may also be the case that the tests are unsuitable for the field conditions at Koytendag. The value of building up a picture of how the water chemistry in the sinkhole varies seasonally and therefore a confident assessment of what is 'normal' should allow good recognition of the effects of any changes in the environment of the area in the future. It may be sensible to provide reserve staff with more accurate probe type water quality analysis equipment.

5.5 Recommendations for future work

5.5.1 Carry out a detailed survey of the cave system that the sinkholes form part of to understand the hydrological and biological importance and level of hydrological connectivity. This is particularly relevant for the newly discovered cave lake. This will require extensive equipment and specialist skills.

5.5.2 Quantify the size of the blind loach population in the underground system.

5.5.3 Compile a basic database of the physical and ecological characteristics of the sinkhole to allow a better understanding of the way the sinkhole functions and enable risks and threats to it to be better identified. The reserve staff are well placed to collect data on the seasonal and environmental changes happening in and around the sinkhole based on observations and simple water quality tests.

5.5.4 Carry out a programme of regular (monthly) monitoring of three sites - the sinkhole, the Koytendarya and the newly discovered cave lake – with analysis for the parameters listed in 4.4 plus temperature. This programme was agreed with the reserve's scientific director. The Koytendarya is the only sample site containing significant numbers of native fish fauna which might be sensitive to environmental changes. As well as regular sampling, opportunistic samples should also be taken after notable events such as flooding that may affect the aquatic environment. A simple data sheet was designed for this purpose. The sheet is designed to be printed out and taken into the field for observations by the rangers, then handed over to whoever is doing the water testing. The final data should be transferred to a spreadsheet for ease ofcomparison and to establish trends over time.

5.5.5 Consideration should be given to carrying out more detailed water quality analysis using techniques with a higher degree of accuracy. A range of potentially problematic substances such as pesticides, or evidence of hydrocarbon pollution can be established though this would require the coordination of international shipment of refrigerated samples to complete.

5.5.6 With specific reference to the blind loach – sequencing of the COI gene of the blind loach and other phylogenetically similar fish species in the area should be carried out and searches made for available genetic sequence databases for the COI gene sequence of phylogenetically similar fish species. Once all the sequences are compared, the primers specific to the blind loach can be designed. Searches of the genetic databases using the sequence that encapsulates the primer sequences and the intervening sequence should then be carried out to confirm that this amplicon is unique (by chance or through evolutionary convergences, species that are not closely related to the target species may share strong sequence similarity despite the lack of shared evolutionary history). If successful this will provide a set of primers that will only amplify the COI gene of the blind loach, allowing the extraction of DNA from water samples to show where the DNA of the blind loach occurs in the cave system. Because both water and fish move, this will not be a 100% representation of where the fish live but it should guide where more extensive ROV work should be carried out to confirm the eDNA results (Garner, pers. comm).

5.5.7 Investigate the current or geologically recent existence of hydrological connectivity between Suw Oyuk and Karabulak and Kaynar springs.

5.5.8 Net surveys of the Koytendarya and drainage channels to search for the relict Amudarya shovelnose sturgeon *Pseudoscaphirhynchus kaufmanni*.

5.6 Bibliography

Aliyev DS, Sukhanova A and Shakirova FM (1988) Fish of inland waters of Turkmenistan. Science, Ashgabat, 156 pp. In Russian

Iwasaki W, Fukunaga T, Isagozawa R, Yamada K, Maeda Y, Satoh TP, Sado T, Mabuchi K, Takeshima H, Miya M and Nishida M (2013) Mitofish and MitoAnnotator: A mitochondrial genome database of fish with an accurate and automatic annotation pipeline. Molecular biology and evolution 30 (11): 2531-2540.
Kimura M (1980) A simple method for estimating evolutionary rate of base substitutions through comparative studies of nucleotide sequences. Journal of Molecular Evolution 16: 111-120.
Smirnov S (1983) A Blind Cave Loach from Southwestern Asia, *Noemacheilus starostini*. Tropical Fish Hobbyist 3: 54-58.
Parin NYa and Dolzhansky VY (1982) Kugitang blind loach – the first blind fish fauna of the USSR. Priroda [Nature] 8: 29-32. In Russian
Parin NV (1983) *Noemacheilus (Troglocobitis) starostini* sp.n. (Osteichthys, Gobitidae) A New Eyeless Fish from Underground Waters of Kugitangtau (Turkmenia). Zoologicheskii Zhurnal 62 (1): 83-89.
Pereladov MV (in preparation) A History of Investigations and Modern problems of Subterranean Aquatic Fauna Research and Protection at Kugitang-Tay Mountain Region, Turkmenistan. (Unpublished).
Prokofiev AM (2009) Problems of the Classification and Phylogeny of Nemacheiline Loaches of the Group Lacking the Preethoid I. (Cypriniformes: Balitoridae: Nemacheilinae). Journal of Ichthyology, 2010, 49, 10: 874-898.
Prokofiev AM (2010) Morphological Classification of Loaches (Nemacheilinae). Journal of Ichthyology 50, 10: 827-913.
Salnikov VB (2006) Ichthyofauna of the reservoirs of Kugitang. In: Problems of desert development. Ministry of Nature Protection of Turkmenistan and National Institute of Deserts, Flora and Fauna.
Shilin NI and Pereladov MV (2014) Koytendag (Kugitan) Blind Cave Loach – Rare and Vulnerable Representative of the Cave Fish Fauna. Caves, section Biospeleology 37: 150-157. In Russian
Starostin IV (1945) Materials on the fish fauna of the Karlyuk TSSR area. Proceedings of the Turkmen branch of the USSR Academy of Sciences, 5-6: 131-136. In Russian
Starostin IV (1992) The fauna of inland waters of Turkmenistan. Ashgabat, 256 pp. In Russian
Swaim KM and Boeing WJ (2008) Relating Fish Abundance and Condition to Environmental Factors in Desert Sinkholes. Department of Fish, Wildlife and Conservation Ecology. New Mexico State University. Progress Report to U.S. Fish and Wildlife Service, Bitter Lakes NWR, 18 pp.
Tamura K, Stecher G, Peterson D, Filipski A and Kumar S (2013) MEGA6: Molecular Evolutionary Genetics Analysis version 6.9. Molecular Biology ans Evolution 30: 2725-2729.
Yang Li, Zongqing Tan, Wang Daren, Xue Ling, Guan Mix-xin, Huang Taosheng and Ronghua Li (2014) Species identification through mitochondrial rRNA genetic analysis. Scientific reports 4, 4089 | DOI: 10.1038/srep04089.

Amphibians

Fig. 21. ***Bufotes (Pseudepidalea) variabilis*****, Hojapil (Photo credit: Jeremy Holden, RSPB)**

Amphibians

Geoff Welch

6.1 Background

There have been no recent systematic surveys of amphibians at Koytendag – *see Bibliography* - and only two species were known to occur at the site – *Rana ridibundus* and *Bufotes viridis / variabilis*.

6.2 Methodology

Opportunistic recording of amphibians was carried out in all wetlands visited.

6.3 Results

According to Litvinchuk et al. (2011), the species of green toad ocurring at Koytendag should be *Bufo turanensis*, however during recent survey work *Bufotes (Pseudepidalea) variabilis* was noted at Hojapil in 2014 and *Bufotes oblongus* in the Suw Oyuk sinkhole in 2015 making these records of significance.

6.4 Discussion

Without further study, given the paucity of species and observations, no meaningful comments can be made regarding the amphibian fauna of Koytendag.

6.5 Recommendations for future work

6.5.1 As part of any future surveys of wetlands at Koytendag, principally in relation to the fish fauna, all observations of amphibians should also be recorded.

6.6 Bibliography

Litvinchuk SN, Mazepa GO, Pasynkova RA, Saidov A, Satorov T, Chikin YuA, Crottini DA, Borkin LYa, Rosanov YuM and Stock M (2011) Influence of environmental conditions on the distribution of Central Asia green toads with three ploidy levels. Journal of Zoological Systematics and Evolutionary Research 49(3): 233-239.

Shammakov SM, Marinina LS, Marochkina VV and Karryeva ShB (2004) The species composition of amphibians, reptiles and mammals of the reserves of Turkmenistan. Problems of Desert Development 4: 45-51. In Russian

Shukurov OSh (1975) On the ecology of the glass-lizard (*Ophisaurus apodus*) in eastern Turkmenistan. Proceedings of the 15th nauchno-teoreticheskoy konferencii prepodavatel’skogo sostava, Chardzhou: 17-19. In Russian

Shukurov OSh (1976) Herpetofauna of Kugitang and its foothills. Herpetology: 74-76. In Russian

Reptiles

Fig. 22. Rapid Racerunner *Eremias velox*, Garlyk (Photo credit: Jeremy Holden, RSPB)

Reptiles
Geoff Welch

7.1 Background

As with amphibians, there have been no recent systematic surveys of reptiles. Previous studies have recorded 34 species. Six species are regionally endemic – *Agama chernovi* and *Agama turkestanica* plus four species included in the Red Data Book of Turkmenistan (2011) – Levantine viper *Macrovipera lebitina* (VU), Tartar sand boa *Eryx tataricus* (Rare), Tajik racerunner *Eremias regeli* (VU) and black-spotted racerunner *Eremias nigrocellata* (VU).

7.2 Methodology

No specific recording of reptiles was made during recent visits to the site, though Turkestan rock agama *Paralaudakia lehmanni* was photographed close to the reserve's headquarters in 2015 – *see fig. 23* – and rapid racerunner *Eremias velox* near Garlyk and Asian snake-eyed skink *Ablepharus pannonicus* at Tamcy in 2014.

Fig. 23. Turkestan rock agama *Paralaudakia lehmanni* (Photo credit: Pavel Stoev)

7.3 Results

Because of the lack of observations, there are no results to report.

7.4 Discussion

Without further study, given the paucity of observations no meaningful comments can be made regarding the reptile fauna of Koytendag.

7.5 Recommendations

7.5.1 As part of any future biodiversity surveys of Koytendag all observations of reptiles should also be recorded, particularly those that are regionally endemic or included in the Red Data Book of Turkmenistan.

7.6 Bibliography

Atayev Ch (1985) Reptiles of the mountains of Turkmenistan. Science, Ashgabat. 344 pp. In Russian

Bogdanov OP (1962) Reptiles of Turkmenistan. Turkmenian Academy of Sciences, Ashgabat 232 pp. In Russian

Habibullov MR (1990) Reptiles of Kugitang Tau (East Turkmenistan): fauna, ecology, conservation. Dissertation Candidate. Biol. Science. Leningrad. 18 pp. In Russian

Habibullov MR (1987) New discovery of Afghan (Defrashi) *snake Lytorhynehus ridgewayi* Boulenger, 1887 in Turkmenistan. Math. Turkmenian Academy of Sciences, Ser. biol. Science, 2: 69-70.

Rustamov AK, Habibullov MR (2009) Once again about the state of knowledge of the herpetofauna of Koitendag (Kugitang). Selevinia, Alamaty: 93-98. In Russian

Rustamov AK, Sopyev OS, Karaev M, Atayev ChA and Pinyasova RM (1988) Fauna and ecology of the birds and reptiles of the Kugitang Range - rare and little-studied animals in Turkmenistan. Ashgabat. In Russian

Shammakov SM, Marinina LS, Marochkina VV and Karryeva ShB (2004) The species composition of amphibians, reptiles and mammals of the reserves of Turkmenistan. Problems of Desert Development 4: 45-51. In Russian

Shammakov SM, Ataev ChA and Rustamov EA (1993) Herpetogeographical Map of Turkmenistan. Asiatic Herpetological Research 5: 127-136.

Shammakov SM, Atayev ChA (1972) About snakes in Turkmenistan. Science, Ashgabat, 29 pp. In Russian

Shammakov SM (1981) Reptiles of the plains of Turkmenistan. Science, Ashgabat, 312 pp. In Russian

Shukurov O Sh (1975) On the ecology of the glass-lizard (*Ophisaurus apodus*) in eastern Turkmenistan. Proceedings of the 15th nauchn.-teor.konf. prep.sostava, Chardzhou: 17-19. In Russian

Shukurov O Sh (1976) Herpetofauna of Kugitang and its foothills. Herpetology: 74-76. In Russian

Birds

Fig. 24. Egyptian vulture *Neophron percnopterus*, one of the globally endangered species at Koytendag (Photo credit: Jeremy Holden, RSPB)

Birds

Paul Donald, Petar Iankov, Eldar Rustamov, Shaniyaz Menliev and Geoff Welch

8.1 Background

This is one of the best studied groups at Koytendag, and although past research has not been as intensive as at some other sites in Turkmenistan, the birds of Koytendag have been the subject of many studies from the 19th Century until the present day (Shestoperov 1936, Dementiev 1952, Rustamov 1958, Ataev et al. 1978, Sopyev 1979, 2012, Mischenko and Scherbak 1980, Red Data Book of Turkmen SSR 1985, Rustamov et al 1988, Saparmuradov and Eminov 1993, Bukreev 1997, Red Data Book of Turkmenistan 1999, 2011, Efimenko 2004, 2008, Rustamov 2013a, 2013b, 2018). Data is restricted and fragmentary and mainly about species composition, distribution and the phenology and biology of selected species, there are, however, a few quantitative studies (Rustamov et al., 1969, 1988).

The international importance of the site was recognised by its designation as one of 50 Important Bird Areas (IBAs) in Turkmenistan (Rustamov et al, 2009) qualifying under criteria A1 (Globally threatened species - saker falcon *Falco cherrug,* cinereous vulture *Aegypius monarchus,* Egyptian vulture *Neophron percnopterusl* Lammergeier *Aegypius barbatus*, steppe eagle *Aquila nipalensis* and eastern imperial eagle *Aquila heliaca*) and A3 (Biome-restricted species' assemblages – Eurasian high mountains (Alpine and Tibetan), Irano-Turanian mountains and Sino-Himalayan temperate forests) reflecting its unique position at the crossroads of several biogeographic zones. At the time of publication of the IBA inventory in 2009, the number of species recorded at Koytendag was 158 species. Ongoing research and taxonomic revisions have increased this figure to 229 species.

8.2 Methodology

Systematic surveys and opportunistic recording of birds at Koytendag were carried out between May 2012 and March 2016, with most effort in spring 2014.

Between 21 April and 17 May 2014 an intensive survey was carried out using three methodologies:

a. random visits to different habitat types and elevations within the survey area to collect data about bird population composition and status;
b) targeted survey visits to areas known or considered likely to support species of high conservation importance (A1 Globally threatened / IUCN Red List species, A3 Biome-restricted species and species in the Red Data Book of Turkmenistan); and
c) transect and point counts to obtain information on the abundance or density of the birds in different habitats.

Observations were carried out between 07.00 and 18.00 hrs, including while travelling. Transect and point counts of all bird species were made in both mornings and evenings, and point counts of raptors between 09.00 and 17.00. GPS data were collected for all species of conservation interest, as well as at the start and end points of transects and for all counting points. All parts of the site were visited, though the majority of observations were made in the central section. The fewest observations were made in the south where access is restricted.

Seven point counts and nineteen transects (Bibby et al. 1998) of the breeding birds in different habitats were carried out. In addition, thirteen point counts were done especially for raptors (with larger distance belts than the 'conventional' point counts). Thus, in total 39 counts were made during the survey. The collected data regarding species composition and density of bird species in the main habitats of the mountain can be of help for assessment of the ornithological significance of the different parts of the site for the purposes of the management plan. In addition, a baseline for a future monitoring scheme of the birds in the Koytendag State Nature Reserve was set up.

Four of the six habitat types for bird complexes as defined by Rustamov et al (1988) and Rustamov and Rustamov (2007) were surveyed – *see below and table 19*. Due to historical differences in land use, each consists of a variety of habitats for birds. Urban and other anthropogenic areas (49 breeding species) were excluded and the High mountain belt (27 breeding species) was only observed for large and demonstrative birds distantly whenever observers were in the area.

Habitat 1. Mountain gorges and ravines with tree-shrub thickets (39 breeding species) located between 500 and 2,500m asl. Various types were covered by the study ranging from deep canyons with vertical cliffs and limited vegetation to relatively gentle slopes with rich vegetation. In general, the lowest parts have been modified by previous management, middle areas exhibit some anthropogenic influence and the highest areas, as a rule, are very natural due to their difficult accessibility.

Habitat 2. Mountain slopes covered by shrub-forb vegetation (57 breeding species) are covered with grassy and medium-sized bushy vegetation, generally up to 2m in height, but grassy areas predominate. These areas consist mainly of 'shiblyak' and semi-savanna vegetation (Efimenko 2006, http://iucnca.net/inforeserve572). Surveys were carried out between c. 1,200-1,850m asl. Grazing here is less intense and habitats in general are less degraded with predominately natural features.

Habitat 3. Juniper zone (53 breeding species) are dominated by bushes and juniper trees, although grass cover is also well developed. Surveys were carried out between 1,500-2,200m asl. This habitat overlaps with habitat 2 but the two differ in general appearance and dominance of bushes/trees and grasses respectively. The habitats in this zone are to a large extent natural, with a well preserved tree component, mainly *Juniperus seravschanica*, including many mature trees.

Habitat 4. Foothill areas and adjacent plains (30 breeding species) are very open with a simple plant composition of several species of low and shrubby grasses and consist principally of pastures and semi-desert areas lying between 300 and 600m asl. These are the most degraded areas and heavy grazing is ongoing.

Table 19. Point counts and transects.

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
Mountain gorges and ravines with tree-shrub thickets						
P_V_01	Point	0-50 m; 50-100 m; 100-150 m	37.768381 N 66.47305 E, 1,710 m	26.04.2014 (06:00-06:15) 11.05.2014 (06:00-06:15)	P. Iankov	Both sides of a ca. 120 m deep and narrow valley with shallow stony slopes in lower parts, steep in upper parts, with scattered but abundant bushes *Amygdalus spinosissima*, *Juniperus seravschanica*, *Acer pubescens*, tussocks of tall grasses and single trees *Juniperus seravschanica*, *Acer pubescens* etc. According to Efimenko (2006, http://iucnca.net/inforeserve572) *Scutellaria leptosiphon*, *S. nevskii*, *Andrachne fedtschenkoi*, *Parietaria judaica*, *Campanula fedtschenkoana* and others are common amongst the rocks of the Koytendag canyons
P_V_02	Point	0-50 m; 50-100 m; 100-150 m	37.76809 N 66.470322 E, 1,703 m	27.04.2014 (06:45-07:00)	P. Iankov	Edge of a deep rocky canyon with steep terrace-like stony slopes with grass patches, scattered *Amygdalus spinosissima* and single *Juniperus seravschanica*. In general, the vegetation of this altitudinal belt is of semi-savanna type (tussocks with *Artemisia scotina*, *A. albicaulis*, *A. tenuisecta)* and various semi-savanna communities with *Amygdalus spinosissima, Atraphaxis spinosa* and others (Efimenko 2006, http://iucnca.net/inforeserve572)
P_V_03	Point	0-50 m; 50-100 m; 100-150 m	37.78603 N 66.52692 E, 2,435 m	27.04.2014 (12:15-12:30)	P. Iankov	Edge of a deep rocky canyon at the tree-line with steep terrace-like stony slopes with large bare areas and scattered single low *Juniperus seravschanica,* and *Amygdalus spinosissima* and others. According to Efimenko (2006, http://iucnca.net/inforeserve572), at 2,300-2,800m a 'stlanik'(low) form of *Juniperus seravschanica* dominates, and it can be mixed with *Astragalus kuhitangi*, *A. bobrovii*, *Acantholimon erythreum*, *A. pungens*, *Silene plurifolia*, *Onobrychis echidna* and others, as well as prickly bushes such as *Cerasus amygdaliflora and Rhamnus minuta*
P_V_04	Point	0-50 m; 50-100 m; 100-150 m	37.67350 N 66.39577 E, 880 m	30.04.2014 (14:30-14:45)	P. Iankov	Relatively open rocky canyon with terrace-like slopes, cliffs, cave, scattered *Amygdalus spinosissima*, *A. bucharica*, *Atraphaxis spinosa*, with *Pistacia vera*, *Acer pubescens* and other tree species scattered on the slopes but also forming groups in the bottom of the dry valley. According to Efimenko (2006, http://iucnca.net/inforeserve572) in some canyons tree communities composed of *Crataegus turkestanica*, *Prunus cerasifera*, *Fraxinus sogdiana*, *Cerasus magaleb* occur.

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
P_V_05	Point	0-50 m; 50-100 m; 100-150 m	37.71344 N 66.45531 E, 1,660 m	01.05.2014 (11:00-11:15)	P. Iankov	Gentle slope on the edge of a narrow rocky valley with scattered *Atraphaxis spinosa* and ***Amygdalus** spinosissima*, with numerous single ***Juniperus** seravschanica, Acer pubescens* and *Prunus cerasifera* and others
P_V_06	Point	0-50 m; 50-100 m; 100-150 m	37.91544 N 66.49398 E, 841 m	05.05.2014 (07:10-07:25)	P. Iankov	Deep canyon with vertical cliffs and gentle slopes. Relatively abundant vegetation of *Amygdalus spinosissima*, *Atraphaxis spinosa* and others plus low *Acer pubescens, Fraxinus sogdiana,* and others. According to Efimenko (2006, http://iucnca.net/inforeserve572) in deep canyons tree species can be represented by *Crataegus turkestanica*, *Prunus cerasifera*, *Fraxinus sogdiana, Cerasus magaleb* together with *Scutellaria leptosiphon, S. nevskii, Andrachne fedtschenkoi, Parietaria judaica, Campanula fedtschenkoana* and others.
T_V_01	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.91970 N 66.49015 E, 794 m End: 37.91608 N 66.49354 E, 863 m	05.05.2014 (06:15-06:50)	P. Iankov	Deep and gently rising canyon with vertical cliffs in places, steep and gentle slopes with vegetation in others. Vegetation generally abundant, consisting of *Amygdalus spinosissima*, *Atraphaxis spinosa* and others, plus low *Acer pubescens, Fraxinus sogdiana, Cerasus magaleb* and others. According to Efimenko (2006, http://iucnca.net/inforeserve572) in the deep canyons tree species can be represented by *Crataegus turkestanica*, *Prunus cerasifera*, *Fraxinus sogdiana, Cerasus magaleb* together with *Scutellaria leptosiphon, S. nevskii, Andrachne fedtschenkoi, Parietaria judaica, Campanula fedtschenkoana* and others
T_V_02	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.92175 N 66.49444 E, 816 m End: 37.91966 N 66.49963 E, 849 m	06.05.2014 (06:55-07:30)	P. Iankov	Deep and dry rocky canyon with vertical cliffs along most of its length, with some tree and bush cover along the canyon bed - *Atraphaxis spinosa, Amygdalus spinosissima*, *Acer pubescens, Fraxinus sogdiana* and others. According to Efimenko (2006, http://iucnca.net/inforeserve572) in the deep canyons tree species can be represented by *Crataegus turkestanica*, *Prunus cerasifera*, *Fraxinus sogdiana, Cerasus magaleb* together with *Scutellaria leptosiphon, S. nevskii, Andrachne fedtschenkoi, Parietaria judaica, Campanula fedtschenkoana* and others

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
T_V_03	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.93877 N 66.65559 E, 1,302 m End: 37.93460 N 66.65868 E, 1,312 m	06.05.2014 (10:10-10:35)	P. Iankov	Deep narrow rocky canyon with vertical cliffs along its length, with single *Atraphaxis spinosa, Amygdalus spinosissima* and *Acer pubescens,* cold stream and waterfall. Busy touristic site with many visitors
T_V_04	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.73914 N 66.42019 E, 956 m End: 37.73977 N 66.41435 E, 918 m	07.05.2014 (18:05-18:30)	P. Iankov	Open, dry wide valley with gentle slopes and few vertical cliffs, with patches of *Amygdalus spinosissima, Atraphaxis spinosa, Acer pubescens, Pistacia vera* and others
T_V_05	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.782954 N 66.445391 E, 1,171 m End: 37.78452 N 66.43996 E, 1,001 m	08.05.2014 (17:25-17:55)	P. Iankov	Deep rocky gorge with vertical cliffs in places, steep and gentle vegetated slopes in others. Stream running along the valley, with abundant vegetation *Acer pubescens, Fraxinus sogdiana, Cerasus magaleb, Amygdalus spinosissima*, *Atraphaxis spinosa* and others, plus some grassy areas. According to Efimenko (2006, http://iucnca.net/inforeserve572) in the deep canyons tree species can be represented by *Crataegus turkestanica*, *Prunus cerasifera*, *Fraxinus sogdiana, Cerasus magaleb*, and amongst the rocks common are groups with species as *Scutellaria leptosiphon, S. nevskii, Andrachne fedtschenkoi, Parietaria judaica, Campanula fedtschenkoana* and others
T_V_06	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.785520 N 66.439017 E, 957 m End: 37.78381 N 66.43508 E, 923 m	08.05.2014 (18:10-18:35)	P. Iankov	As T_V_05, but stream only along about 100 m at the eastern end of the transect, the remaining 400 m being a dry valley

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
T_V_07	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.782659 N 66.432849 E, 841 m End: 37.78278 N 66.428370 E, 819 m	08.05.2014 (18:45-19:05)	P. Iankov	As T_V_05 and T_V_06, but valley completely dry and more open, with fewer cliffs and less steep slopes.
T_V_08	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.72245 N 66.49242 E, 1,854 m End: 37.723595 N 66.487814 E, 1,877 m	12.05.2014 (10:05-10:35)	P. Iankov	Dry stony valley with gentle grassy slopes, densely covered by tree and bushy vegetation, including *Juniperus seravschanica, Acer pubescens, Amygdalus spinosissima*, *Atraphaxis spinosa* and other. According to Efimenko (2006, http://iucnca.net/inforeserve572) the 'shyblyak' complex of xerophyle trees and bushes is well represented by *Zygophyllum atriplicoides* in association with *Pistacia vera*, *Acer pubescens, Amygdalus spinosissima, Sageteria brandtheriana*
T_V_09	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.72807 N 66.37642 E, 617 m End: 37.727003 N 66.371661 E, 564 m	14.05.2014 (18:25-18:55)	P. Iankov	Dry open valley with gentle grassy slopes close to the bottom of the valley, but upper parts with high cliffs (especially the southern slope). On the slopes and at the bottom of the valley scattered bushes and low trees occur, mainly *Amygdalus spinosissima*, *Atraphaxis spinosa, Acer pubescens, Salvia* sp. and others. According to Efimenko (2006, http://iucnca.net/inforeserve572) the 'shyblyak' complex of xerophyle trees and bushes is well represented by *Zygophyllum atriplicoides* in association with *Pistacia vera*, *Acer pubescens, Amygdalus spinosissima, Sageteria brandtheriana*

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
Mountain slopes covered by shrub-forb vegetation						
T_GB_01	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.779358 N 66.483403 E, 1,797 m End: 37.776322 N 66.479217 E, 1,767 m	26.04.2014 (08:05-08:25)	P. Iankov	Open predominantly grassland area on a gentle slope with western exposure, covered with various communities of semi-savanna vegetation with single scattered *Amygdalus spinosissima* and low *Juniperus seravschanica* bushes. According to Efimenko (2006, http://iucnca.net/inforeserve572) the predominant species in plant communities on typical and dark grey soils include *Artemisia scotina*, *A. albicaulis*, *A. tenuisecta* and various semi-savanna low grasses, amongst which *Amygdalus spinosissima, Atraphaxis spinosa* occur, plus *Cousinia sprygini, C. rotundifolia, C. dimoana, Alhagi canescens, A. kirghisorum* and others, with some*Jurinea bipinnatifida*
T_GB_02	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.775684 N 66.480558 E, 1,791 m End: 37.779295 N 66.484004 E, 1,811 m	26.04.2014 (08:30-08:45)	P. Iankov	Open grassland communities of semi-savanna type with patches of *Amygdalus spinosissima* and low/tall *Juniperus seravschanica* on both slopes of a small and shallow stony valley with patches of low bushes. The grassland communities according to Efimenko (2006, http://iucnca.net/inforeserve572) are composed of *Artemisia scotina*, *A. albicaulis*, *A. tenuisecta, Amygdalus spinosissima, Atraphaxis spinosa, Cousinia sprygini, C. rotundifolia, C. dimoana, Alhagi canescens, A. kirghisorum* and other species
T_GB_03	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.93933 N 66.63258 E, 1,240 m End: 37.93914 N 66.62682 E, 1,243 m	04.05.2014 (06:25-06:50)	P. Iankov	Open grassland (pasture) on a gentle slope with northern exposure with tussocks of tall grasses, low *Amygdalus spinosissima* and groups of low *Acer pubescens* and other species, with two small and shallow (open) stony valleys. At the of the periphery of the low and medium belts of the mountain, at altitudes between 700 (800) and 2,000-2,300m, the 'shiblyak' and semi-savanna belt is represented by *Artemisia scotina*, *A. albicaulis*, *A. tenuisecta* and various low-grass semi-savanna communities with *Amygdalus spinosissima*, *Atraphaxis spinosa* (Efimenko 2006, http://iucnca.net/inforeserve572)

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
Juniper zone						
T_BG_01	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.781013 N 66.517302 E, 2,172 m End: 37.776322 N 66.479217 E, 2195 m	27.04.2014 (08:45-09:15)	P. Iankov M. Gurney	Generally open stony area on a gentle slope with western exposure, close to the upper limit of *Juniperus seravschanica* associations. Bushes and single trees determine the general appearance, although there is significant grassland cover. Bushes represented by *Amygdalus spinosissima, A. bucharica* and others, mixed with low *Juniperus seravschanica* and *Acer pubescens*. Mature *Juniperus seravschanica* form the tallest plant stratum. According to Efimenko (2006, http://iucnca.net/inforeserve572) 'archovniks' (*Juniperus seravschanica* associations) are semi-savanna, semi-savanna-*Artemisia*-'shiblyak' and steppe associations. Amongst *Amygdalus spinosissima* there are single *Acer pubescens*, *Amygdalus bucharica*, *Pistacia vera*, *Cotoneaster suavis*, *Cerasus erythrocarpa*, *C. amygdaliflora*. Amongst 'archovniks' and 'tragakantniks' (1,700-2,800 m) steppe grasses occur, such as *Stipa kuhitangi*, *S. arabica*, *S. gnezdilloi* and others, as well as *Elytrigia setulifera*, *E. pulcherrima*, *E. intermedia*, *Festuca valesiaca* and *F. regeliana*
T_BG_02	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.71784 N 66.47283 E, 1,917 m End: 37.72037 N 66.46811 E, 1,885 m	01.05.2014 (18:00-18:20)	P. Iankov	Gentle hill slope with south-western exposure, with scattered mature *Juniperus seravschanica*, single scattered *Amygdalus spinosissima, A. bucharica* and others. Significant grassland cover, mainly *Artemisia* sp.. According to Efimenko (2006, http://iucnca.net/inforeserve572) together with *Juniperus seravschanica* there are *Acer pubescens*, *Amygdalus bucharica*, *Pistacia vera*, *Cotoneaster suavis*, *Cerasus erythrocarpa* and *C. amygdaliflora*, which give this altitudinal belt a characteristic "bushy" appearance
T_BG_03	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.71407 N 66.47088 E, 1,958m End: 37.70996 N 66.46854 E, 1,900 m	02.05.2014 (06:35-07:00)	P. Iankov M. Gurney	Open gentle hill slope with north-western exposure, with closely spaced mature *Juniperus seravschanica*, single *Acer pubescens* and scattered *Amygdalus spinosissima, A. bucharica* and others. Grassland with a significant proportion of *Artemisia* sp. According to Efimenko (2006, http://iucnca.net/inforeserve572) together with *Juniperus seravschanica* there are *Acer pubescens*, *Amygdalus bucharica*, *Pistacia vera*, *Cotoneaster suavis*, *Cerasus erythrocarpa*, *C. amygdaliflora*, which give this altitudinal belt a characteristic "bushy" appearance

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
T_BG_04	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: (37.92834 N 66.65504 E, 1,581m End: 37.92403 N 66.65683 E, 1,703 m	05.05.2014 (14:20-14:50)	P. Iankov	Steep stony slope with dense tree and bushy vegetation of scattered *Juniperus seravschanica* and more dense patches of *Acer pubescens, Crataegus turkestanica*, *Prunus cerasifera, Fraxinus sogdiana* with *Amygdalus spinosissima*, *Atraphaxis spinosa* and others. Grass cover relatively restricted, composed of *Artemisia sp.* and others. According to Efimenko (2006, http://iucnca.net/inforeserve572) on variable soils the main species are *Zygophyllum atriplicoides* together with with *Pistacia vera, Acer pubescens, Amygdalus spinosissima, Sageteria brandtheriana* and others
T_BG_05	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.76637 N 66.46761 E, 1,667m End: 37.77087 N 66.46747 E, 1,665 m	10.05.2014 (08:40-09:00)	P. Iankov	Gentle stony slope with western exposure and abundant scattered bushes and low trees *Amygdalus spinosissima*, *Atraphaxis spinosa, Juniperus seravschanica, Acer pubescens, Prunus cerasifera, Fraxinus sogdiana* and others. Grass cover well represented, composed of *Artemisia scotina, A. albicaulis* and others. On the typical dark grey soils dominant species are *Artemisia* sp. and variable low grasses with obligatory presence of *Amygdalus spinosissima*, *Atraphaxis spinosa* and others. Xerophyle trees and bushes at the 'shiblyaks' include good numbers of *Zygophyllum atriplicoides* in association with *Pistacia vera*, *Acer pubescens*, *Amygdalus spinosissima*, Sageteria brandtheriana and others (Efimenko, 2006, http://iucnca.net/inforeserve572)
P_BG_01	Point	0-50 m; 50-100 m; 100-150 m	37.92931 N 66.65578 E, 1,546 m	05.05.2014 (11:35-11:50)	P. Iankov	Open hollow with steep slopes with predominantly *Amygdalus spinosissima*, *Atraphaxis spinosa, Acer pubescens, Crataegus turkestanica*, *Prunus cerasifera, Fraxinus sogdiana* and others. On the rocky areas scattered *Juniperus seravschanica* occur. Amongst grasses *Artemisia scotina, A. albicaulis, A. tenuisecta, Inula macrophylla* and others predominate. According to Efimenko (2006, http://iucnca.net/inforeserve572) on variable soils main species are *Zygophyllum atriplicoides* together with *Pistacia vera, Acer pubescens, Amygdalus spinosissima, Sageteria brandtheriana* and others

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date and time of count(s)	Observer	Brief description
Foothill areas and adjacent plains						
T_DP_01	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.75624 N 66.37161 E, 522 m End: 37.75259 N 66.36826 E, 561 m	29.04.2014 (06:50-07:10)	P. Iankov	Highly degraded pasture on an open semi-desert area with low and very poor grass composition on a flat and a gentle loess hill slope with north-eastern exposure. According to Efimenko (2006, http://iucnca.net/inforeserve572) at these altitudes there is a belt of mountain semi-desert (desertified low-grass semi-savanna and vegetation) gypsum-containing soils
T_DP_02	Transect	0-50 m; 50-100 m; 100-150 m 500m	Start: 37.44172 N 66.36163 E, 335 m End: 37.44269 N 66.36716 E, 348 m	29.04.2014 (17:40-18:10)	P. Iankov M. Gurney	Semi-desert area on a gentle southern slope with low and very poor vegetation, composed mainly by scattered low grasses and *Ferula* sp., mixed with scattered single low bushes
Raptor point counts						
P_R_01	Point	0-500 m; 500-1,000 m; > 1000 m	37.778804 N 66.478197 E, 1,744 m	26.04.2014 (09:00-09:15)	P. Iankov	
P_R_02	Point	0-500 m; 500-1,000 m; > 1000 m	37.76349 N 66.46676 E, 1,633 m	26.04.2014 (17:55-18:10)	P. Iankov S. Menliev	
P_R_03	Point	0-500 m; 500-1,000 m; > 1000 m	37.78644 N 66.52727 E, 2,457 m	27.04.2014 (12:45-13:00)	P. Iankov	

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date of count(s)	Observer	Brief description
P_R_04	Point	0-500 m; 500-1,000 m; > 1000 m	37.44100 N 66.35857 E, 336 m	29.04.2014 (15:25-15:40)	P. Iankov	
P_R_05	Point	0-500 m; 500-1,000 m; > 1000 m	37.64896 N 66.32936 E, 378 m	30.04.2014 (09:55-10:10)	P. Iankov	
P_R_06	Point	0-500 m; 500-1,000 m; > 1000 m	37.67337 N 66.39592 E, 885 m	30.04.2014 (13:45-14:00)	P. Iankov	
P_R_07	Point	0-500 m; 500-1,000 m; > 1000 m	37.71432 N 66.47154 E, 1,964 m	01.05.2014 (16:00-16:15)	P. Iankov	
P_R_08	Point	0-500 m; 500-1,000 m; > 1000 m	37.67875 N 66.47661 E, 1,746 m	02.05.2014 (11:05-11:20)	P. Iankov	
P_R_09	Point	0-500 m; 500-1,000 m; > 1000 m	37.71613 N 66.44721 E, 1,543 m	02.05.2014 (17:50-18:05)	P. Iankov	
P_R_10	Point	0-500 m; 500-1,000 m; > 1000 m	37.90791 N 66.48064 E, 796 m	04.05.2014 (16:40-16:55)	P. Iankov	
P_R_11	Point	0-500 m; 500-1,000 m; > 1000 m	37.92789 N 66.65598 E, 1,583 m	05.05.2014 (16:35-16:50)	P. Iankov	

Ref	Count type	Distance belts used/ Transect length	GPS reference and altitude	Date of count(s)	Observer	Brief description
P_R_12	Point	0-500 m; 500-1,000 m; > 1000 m	37.84821 N 66.43139 E, 661 m	08.05.2014 (09:55-10:10)	P. Iankov	
P_R_13	Point	0-500 m; 500-1,000 m; > 1000 m	37.77473 N 66.38938 E, 591 m	09.05.2014 (10:00-10:15)	P. Iankov	

Opportunistic recording, associated with other activities being carried out at the site were:
23 to 26 May 2012 - during the International Scientific Expedition, linked to the development of the UNESCO World Heritage nomination. Areas visited were Kyrkgyz, Hojapil, Umbardere, Daraydere, Gap-Gotan and around the guesthouse in Koyten village;
April/May 2013 - during a Darwin Initiative Scoping visit – Kyrkgyz, Hojapil, Umbardere, Daraydere, Gap-Gotan and around the reserve headquarters at Bazardepe;
21 to 26 August 2014 – during a management planning workshop. Areas visited were the juniper forest in the core zone and the vicinity of the reserve headquarters at Bazardepe;
6 to 9 October 2015 – during the IUCN Evaluation visit linked to the UNESCO World Heritage nomination. Areas visited were Kyrkgyz, Hojapil, Umbardere, Daraydere, Gap-Gotan and around the reserve headquarters at Bazardepe; and
25 to 30 March 2016 - during a raptor identification and monitoring training course. Areas visited were Kyrkgyz, Umbardere, Hojapil, Daraydere, Kojachilgazbaba and several gorges near the reserve headquarters at Bazardepe.

8.3 Results

Of the 229 species reported as occurring at Koytendag, recent research has recorded 154 (67%) of these, including two species new to Turkmenistan – Himalayan griffon Gyps *himalayensis* and common koel *Eudynamys scolopaceus* (Rustamov et al. 2016). Following several observations of vultures showing characteristics of Himalayan griffon, an adult bird was photographed on 27 April 2014 in the vicinity of Airy-baba Peak (3,139 m asl). Single birds were then observed several times in different parts of the reserve. The species was also observed in October 2015. Himalayan griffon is also a new biome-restricted species for the site, characteristic of the Eurasian high mountains (Alpine and Tibetan) biome. The common koel was a female observed in the Koytendarya valley near Khodjagaraul in the foothills of the western escarpment of the Koytendag mountain range on 8 May 2013. This bird was found dead in the same area on 14 May (Rustamov et al. 2016).

Five of the eight globally threatened species known from the site were recorded - saker falcon *Falco cherrug*, Egyptian vulture *Neophron percnopterus* and steppe eagle *Aquila nipalensis* (all EN) and lammergeier *Gypaetus barbatus* and cinereous vulture *Aegypius monachus* (both NT). The three species not recorded recently are greater spotted eagle *Aquila clanga* and eastern imperial eagle *Aquila heliaca* (both VU) and pallid harrier *Circus macrourus* (NT), all of which are scarce passage migrants or winter visitors.

Similarly, ten of the eleven biome-restricted species were recorded – see-see partridge, *Ammoperdix griseogularis*, yellow-breasted tit *Parus flavipectus*, dark-grey tit *Parus rufonuchalis*, sulphur-bellied warbler *Phylloscopus griseolus*, eastern rock-nuthatch *Sitta tephronota*, white-throated robin *Irania gutturalis*, Finsch's wheatear *Oenanthe finschii*, variable wheatear *Oenanthe picata*, white-winged grosbeak *Mycerobas carnipes* and chestnut-breasted bunting *Emberiza stewarti*. The only omission is bar-tailed treecreeper *Certhia himalayana*.

Data was also collected on 13 of the 17 species included in the Red Data Book of Turkmenistan (2011) - black stork *Ciconia nigra*, lesser kestrel *Falco naumanni*, saker falcon, peregrine falcon *Falco peregrinus*, barbary falcon *Falco pelegrinoides*, lammergeier, Egyptian vulture, cinereous vulture, short-toed snake-eagle *Circaetus gallicus*, steppe eagle, golden eagle *Aquila chrysaetos*, Bonelli's eagle *Aquila fasciatus* and Asian paradise-flycatcher *Terpsiphone paradisi*.

The distribution of all globally threatened, biome-restricted and Turkmenistan Red Data Book species recorded is summarised on map 8.

As point count and transect data was collected using pre-defined distance bands, it will be possible to calculate estimates of bird density using the computer programme *Distance*. However, this analysis has not yet been carried out.

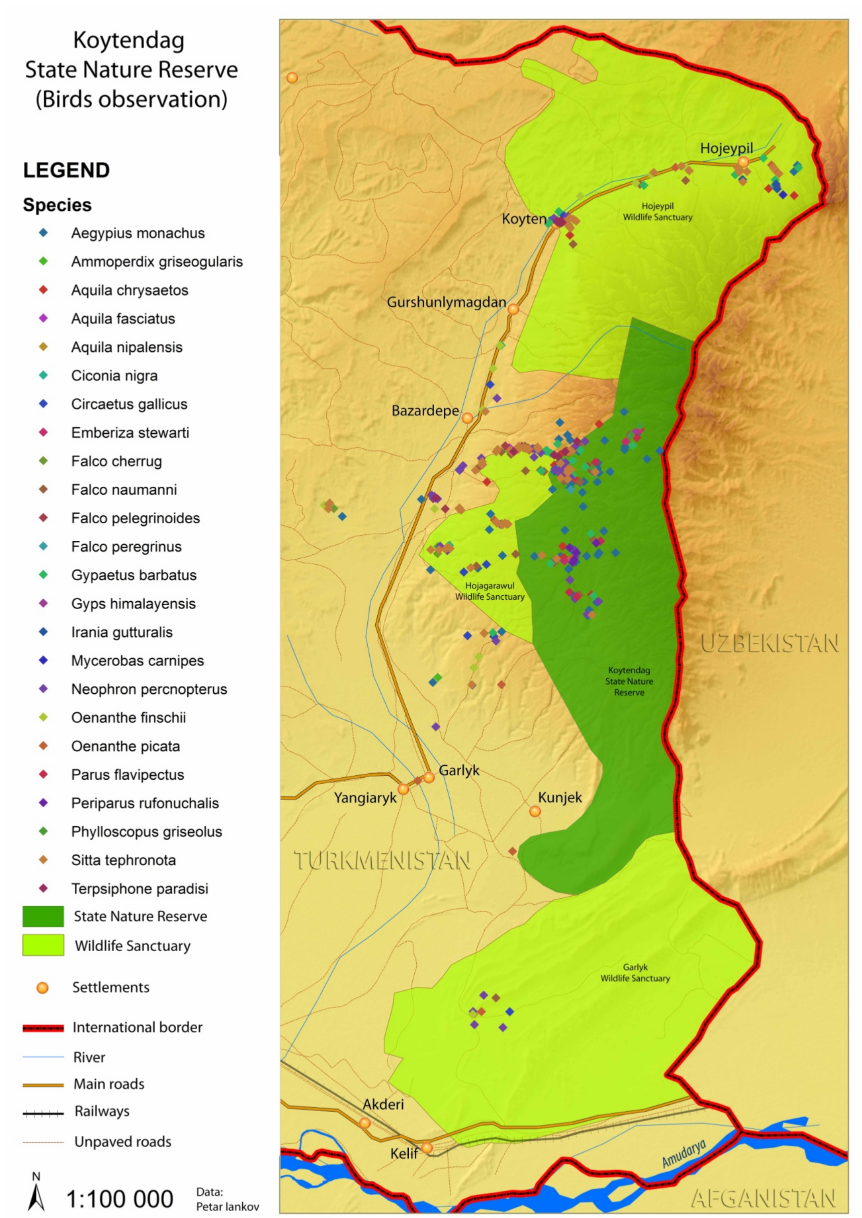
Due to the limited duration of the main 2014 survey, as well as a lack of systematically collected standard data for the area, it was very difficult to assess trends in population or distribution of key species. Some species eg eastern rock nuthatch appeared to be much more numerous than mentioned in the literature (Efimenko 2006) but it is impossible to say whether this is due to an increase in the population or underestimation in the past.

8.4 Discussion

The site clearly supports a rich and diverse avifauna. Of particular note is the large number and variety of birds of prey, including five species of vulture all of which are known or could potentially breed. Such a diversity of ‘top predators’ and scavengers is an indication of the overall high quality of the habitats and, at present, limited disturbance and persecution. However, there is the future risk of increased disturbance through activities such as rock climbing, paragliding and off-road driving and such activities need to be closely monitored and controlled.

The discovery of two bird species new to Turkmenistan is an indication of the value of future surveys as additional species are likely to be found, particularly given the site’s proximity to Uzbekistan and Afghanistan. In Central Asia the Himalayan griffon is principally resident in the high mountain areas of eastern Afghanistan, Uzbekistan, Tajikistan, Kyrgyzstan and Kazakhstan, with limited westward dispersal in winter. However, observations of at least one individual at Koytendag in October 2015 suggests that the species may be resident at the site and could represent a significant westward expansion in the species’ range. The common koel was an even more significant discovery as the species has not been recorded in Kazakhstan (Sklyarenko et al. 2008, Wassink 2015) or Uzbekistan (Kashkarov et al. 2008) and Ayé et al (2012) only include it in appendix 1 (old vagrants, undocumented records and doubtfully recorded species) for Afghanistan. Mike Blair *in litt* considers that the species is uncommon, local, but regular in Afghanistan south of the Khyber range perhaps due to the large increase in small dams and local irrigation schemes there. The species might be found in extreme southern Uzbekistan and southwestern Tajikistan in the future.

Map 8. Observation locations of birds of conservation importance at Koytendag, April/May 2014. Map by Atamyrat Veyisov.



8.5 Recommendations

8.5.1 Development of a systematic, objective monitoring programme, plus associated training of staff, to assist planning of future site management.

8.5.2 Appointment of an ornithologist to the state nature reserve staff.

8.5.3 Assessment of existing and potential future visitor impacts to key species, especially breeding raptors, in the main tourist areas of the site and development of a visitor management programme.

8.5.4 Development of a grazing strategy for the wildlife sanctuaries to reduce/reverse the effects of over-grazing and related habitat degradation.

8.6 Bibliography

Ataev K, Vasiliev VI, Gorelova RI, Karavaev AA, Kekilova AF, Sopyev O and Eminov A (1978) Data on the rare and threatened by extinction birds of Turkmenistan. Bulletin Academy of Science of Turkmenian Soviet Republic, Series of Biology Science 4: 70-80. In Russian

Ayé R, Schweizer M, Roth T (2012) Birds of Central Asia. Bloomsbury, London, 336 pp.

Bibby C, Jones M and Marsden S (1998) Bird Surveys, Expedition Field Techniques. Royal Geographical Society, Expedition Advisory Centre, London, 134 pp. In Russian and English

Bukreev SA (1997) Ornitho-geography and preservation of Turkmenistan. Center for Wildlife Conservation, Moscow, 160 pp. In Russian

Dementiev GP (1952) Birds of Turkmenistan. Turkmen SSR Science Academies, Ashgabat. In Russian

Efimenko NN (2004) Birds of the western part of Koytendag mountains. Problems of desert development 2: 56-58. In Russian

Efimenko NN (2008) Cadastre of Populations of the rare and poorly studied animals of Koytendag. Problems of desert development, 4: 48-51. In Russian

Kashkarov RD, Welch GR and Brombacher M (eds) (2008) Important Bird Areas in Uzbekistan. Uzbekistan Society for the Protection of Birds, Tashkent.

Lunina GA (1990) New data on the fauna and abundance of shorebirds in eastern Turkmenistan. In: Environmental issues. MY. 1. Inventory of natural resources Chardjou area. Chardjou: 103-108. In Russian

Mischenko YV, Scherbak NN (1980) New Records of new and poorly studied birds of Turkmenia. In: Journal of Zoology 1, Kiev: 13-17. In Russian

Red Data Book of Turkmen SSR (1985) Rare and Threatened Plants and Animals. Ashgabat, 413 pp.

Red Data Book of Turkmenistan (2011) Volume 2: Invertebrates and Vertebrates Animals Ed. 3rd, Revised and updated. Ashgabat, Ylym, 384 pp.

Red Data Book of Turkmenistan (1999) Invertebrate and Vertebrate Animals V. 1, Second Edition, Ashgabat, 371 pp.

Rustamov AK, Sopyev OS, Karaev M, Atayev ChA and Pinyasova RM (1988) Fauna and ecology of the birds and reptiles of the Kugitang Range. In: Flint VE (Ed.). Rare and poorly studied animals of Turkmenistan. Ashgabat, Ylym: 82-117. In Russian

Rustamov AK, Sopyev OS, Karaev M (1969) Numbers of breeding birds of the Kugitang Ridge. In: Ornithology of the USSR. 1969. Proceedings of the 5th Soviet Union Ornithological Conference, Book 2, Ashgabat, Ylym: 82-117. In Russian
Rustamov AK (1958) Birds of Turkmenistan Vol. 2. Academy of Science of Turkmen Soviet Republic, Ashgabat, 252 pp. In Russian
Rustamov EA (2013a) Conspectus of the Contemporary Bird Fauna of Turkmenistan. In: Sopuyev OS, Herremov ShR (eds) Studies on the Biological Diversity of Turkmenistan (Vertebrata). Menzbir Ornithological Society, Central Asia Branch, Moscow-Ashgabat: 125-169. *In Russian*
Rustamov EA (2013b) Birds of Turkmenistan: Illustrated Field Guide. Ylym, Ashgabat.
Shestoperov EL (1936) Materials on the Fauna of Karlyuk Region of TSSR. Bulletin of the Turkmenistan Zoological Station, No 1, Ashgabat: 157-172.
Rustamov EA, Menliev S and Agryzkov E (2016) Common Koel *Eudynamys scolopaceus* new for Turkmenistan. Sandgrouse 38 (2): 197-198.
Rustamov EA, Welch GR and Brombacher M (eds) (2009) Important Bird Areas in Turkmenistan: priority sites for conservation. Ministry for Nature Protection of Turkmenistan. Ashgabat, 197 pp. (English, Russian and Turkmen editions).
Rustamov EA (2015) An annotated checklist of the birds of Turkmenistan. Sandgrouse 37 (1): 28-56.
Rustamov EA (2018) Modern checklist of the birds of Turkmenistan, version 2018. Herpetological and ornithological research: current aspects. Dedicated to the 100th Anniversary of A.K. Rustamov (1917–2005). Moscow: KMK Scientifi c Press. In Russian
Saparmuradov J, Eminov A (1993) Data about the numbers of some rare and threatened with extinction bird species in Southern Turkmenistan. In: Study of the Animal World of Turkmenistan. Ashgabat, Ylym: 109-119.
Sopyev OS (1979) Data on the birds of Order Galliformes of Kugitang. In: Protection of Turkmenistan Nature 5, Ashgabat, Ylym. In Russian
Sopyev OS (2012) Birds of Koytendag require special protection. In: Turkmen Nature, Undiscovered Miracles of Koytendag, Abstracts of reports of the International Scientific Conference, May 23-39, 2012, Ashgabat, Ylym: 365-366. In Russian and English
Sklyarenko SL, Welch GR and Brombacher M (eds) (2008) Important Bird Areas in Kazakhstan Association for the Conservation of Biodiversity of Kazakhstan, Almaty.
Stepanian LS (1990) Synopsis of the ornithological fauna of the USSR. M. Science. In Russian
Wassink A (2015) The New Birds of Kazakhstan. Wassink, De Cocksdorp, Texel, Netherlands.

Mammals

Fig. 25. Camera trap image of male Markhor *Capra falconeri* (Photo: Koytendag State Nature Reserve)

Mammals

Kiril Georgiev, Shaniyaz Menliev and John Linnell

8.9 Background

Commented [PS5]: Change to 9.1

Several studies have been made of the mammal fauna of Koytendag – *see Bibliography* – and selected species, notably markhor *Capra falconeri* and urial *Ovis orientalis*, have been monitored annually since 1995. A total of 43 species of mammals has been recorded though four species – Libyan jird *Meriones libycus,* brown bear *Ursus arctos,* leopard *Panthera pardus* and goitered gazelle *Gazella subguttorosa* - have not been observed in the last 10+ years and are assumed to be locally extinct, and two species – small five-toed jerboa *Allactaga* (*Microallactaga*) *elater* and northern mole vole *Ellobius talpinus tancrei* – though known from the area are restricted to the lowlands bordering the protected area. Five species are listed in the 2011 Red Data Book of Turkmenistan – Geoffroy's bat *Myotis emarginatus* (Rare), European free-tailed bat *Tadarida teniotis* (Rare), Eurasian lynx *Lynx lynx* (Critically Endangered), markhor (Critically Endangered) and urial (Endangered) – with markhor and urial also listed as globally threatened by IUCN – Near Threatened and Vulnerable respectively.

8.9 Methodology

Commented [P6]: Change numbering to 9.2

Annual monitoring by reserve staff is by direct counts at locations and/or times of year when animals are naturally concentrated – at the start of the autumn breeding season in the case of markhor and around watering points in winter in the case of urial. RSPB-supported research has focussed on the deployment of 30 camera traps (Bushnell Trophy Cam HD Max - Black LED) for 71 camera trap station sessions during 2013, 2014 and 2015 – *see map 9* - principally in order to record the species present at the site and obtain a general impression of numbers. More systematic use of camera traps is planned for the future and will build on the experience of reserve staff in using this methodology.

9.3 Results

Annual monitoring of markhor shows an increase in numbers from 69 in 1995 to 882 in 2013 – *see figure 26*. This is partly an actual increase in numbers but principally due to improved counting techniques over the years. Monitoring of urial shows a similar, those less marked, increase in numbers from 164 in 1995 to 250 in 2013 but numbers reached a maximum of 320 in 2010 – *see figure 27*. The changes from year to year are considered to be natural fluctuations.

With the camera traps, a total of 844 events of mammals passing cameras were recorded – *see table 20*. Separate events were recorded if at least 10 minutes passed between the camera being activated. As some cameras were placed at waterpoints some of events involved photographing 10-20 individuals during almost continual sessions.

Ten identifiable mammal species were recorded. However, it should be noted that the image quality from the video sequences that the camera traps were set to record on was not very high, making some species identification difficult, therefore certain assumptions have been made based on known species' distributions.

Table 20. Camera trap recording frequency summary.

Species	**No. of recording events**	**% frequency**	**Comments**
Tolai hare *Lepus tolai*	301	35.7	
Markhor *Capra falconeri*	254	30.1	Photographs revealed a well-balanced population structure, with very large males, females and young.
Eurasian lynx *Lynx lynx*	68	8.1	Pictures indicated the presence of both reproductive females (followed by young) and single animals. Video quality was too poor to allow individual recognition.
Indian crested porcupine *Hystrix indica*	62	7.3	
Grey wolf *Canus lupus*	37	4.4	Pictures indicated the presence of reproduction (pictures of pups) and packs of up to 4 individuals.
Urial *Ovis orientalis*	36	4.3	Photographs revealed a well-balanced population structure, with very large males, females and young.
Red fox *Vulpes vulpes*	35	4.1	
European badger *Meles (meles) cansecens*	24	2.8	Koytendag represents one of the few areas where the European badger *Meles meles* overlaps with the recently separated Asian badger *Meles leucurus*. Taxonomy is still uncertain, and morphological criteria are not unambiguous, however, it appears that most of the 24 images represent European badgers.
Marten sp. *Martes foina*??	15	1.8	Image quality did not allow a definite identification but it is likely that they represent the beech marten.
Asian wild cat *Felis lybica*	12	1.4	Wild cat taxonomy is under constant revision but the 12 images obtained are considered most likely to belong to this recently recognised species.
Total	**844**	**100**	

Map 9. Camera trap locations at Koytendag. Map by Atamyrat Veyisov.

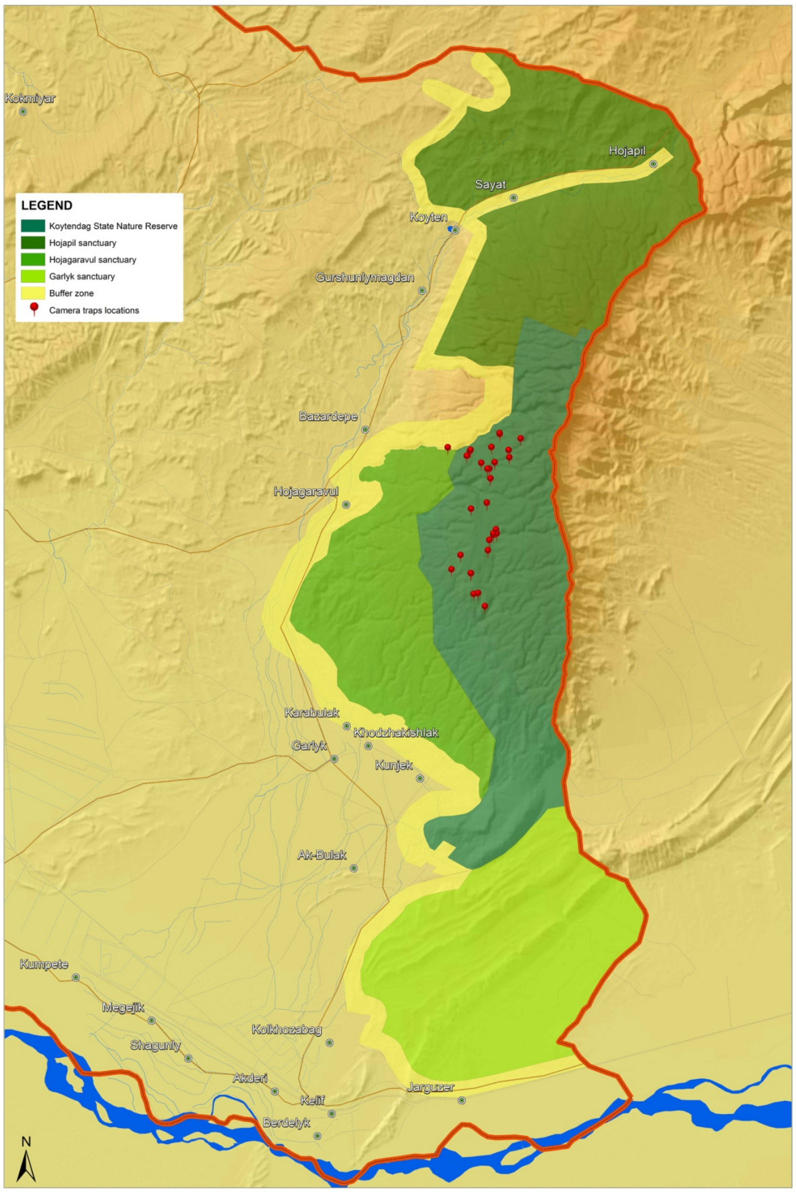


Fig. 26. Population trends of *Capra falconeri* at Koytendag State Nature Reserve 1995 to 2013

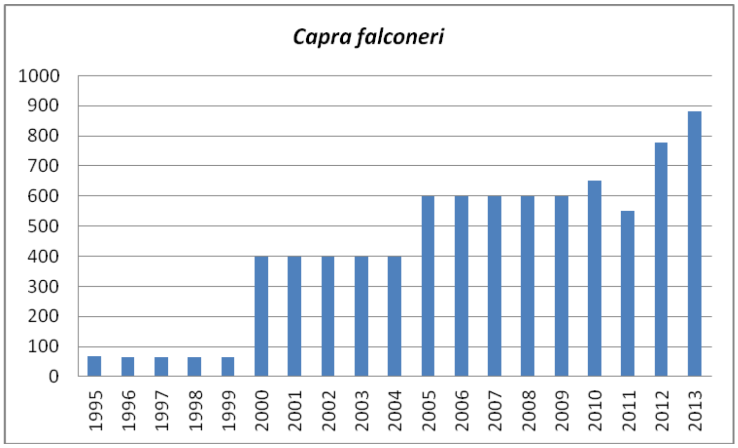
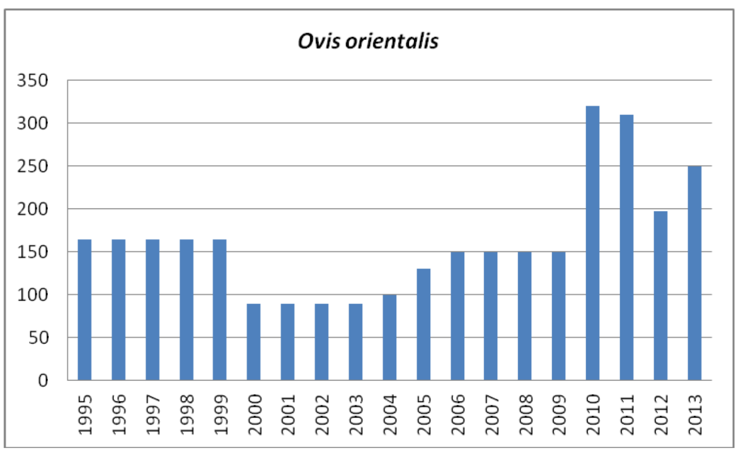


Fig. 27. Population trends of *Ovis orientalis* at Koytendag State Nature Reserve 1995 to 2013



9.4 Discussion

Although the mammal species found at Koytendag are not highly endangered globally – most are LC, with one VU and one NT – there is still significant conservation value in the area. Firstly, the presence of a healthy markhor population is a major contribution to the conservation of a species that has a very limited global distribution – Koytendag supports the most western and isolated population of this species.

Secondly, the presence of Eurasian lynx and urial in the site represents the western edge of the Tian Shan populations. Although widespread, both species have very uncertain status and distribution in the region, such that the documentation of their presence in Koytendag is significant. The high number of Eurasian lynx pictures is especially positive. Although their ecology in the region has never been studied, it is likely that the high density of hares provides their major food source.

Thirdly, and most significantly, is the presence of a relatively intact mammalian community with large predators (wolves, lynx), medium sized predators (foxes, martens, badgers) and prey (markhor, urial, hares). The only species not detected was leopard *Panthera pardus* though the species is known to have occurred previously. Given the camera trapping density and the frequency with which other predators such as wolves and lynx were detected, it is highly unlikely that leopards escaped detection if they had been present.

Notes on the camera trapping

The staff at Koytendag have done a good job with the cameras available. There were some mistakes – placing cameras too far from the trail, or not taking care to remove vegetation in front of the camera – but such mistakes have been rectified with practice. The main limitation is in the quality of video images made by the cameras and the trigger time. Using still images would be an improvement over video, and the equipment is suitable for monitoring the distribution of the larger species across the landscape and monitoring water hole use, for example. However, for individual recognition of lynx to facilitate a population estimate, and for producing less ambiguous identification of the smaller carnivores (foxes, badgers, martens) it would be desirable to upgrade to cameras with faster trigger times (so they can be placed closer to trails) and with better image quality. White flash produces better images but causes more disturbance, and the better quality infra-red units should be sufficient for most purposes. However, it would have been useful to deploy at least a few units with white flash (NOT at water points) to accumulate some better images of several species.

It would have been useful to deploy cameras in a more structured manner, that span the whole study area in both space and time, including the lower regions that were not very well assessed in this survey.

Data management could also be improved. Although it is helpful to extract the images showing animals from those that do not, it is crucial that all images are stored to allow an assessment of camera function and facilitate analysis. Record keeping could also be improved as it was not always clear if the end of a session was due to a camera being taken down, running out of batteries, or another malfunction.

9.5 Recommendations for future work

9.5.1 Systematic deployment of camera traps throughout the site to gain a better understanding of the distribution of species.

9.5.2 Deployment of some cameras using white flash.

9.5.3 Systematic positioning of camera traps to enable the identification of individual Eurasian lynx to assist determining population size.

9.5.4 Improved data management.

9.5.4 Establishment a National Park (II category IUCN) covering the state nature reserve and four wildlife sanctuaries – 129,047 ha. This would be in line with recommendations in the UNDP Project 3961 *Strengthening the management effectiveness of the protected area system of Turkmenistan* and several strategic planning documents of Turkmenistan eg *State of the Environment report for Turkmenistan* (SOE, 1998), the *National Environmental Action Plan* (NEAP, 2002) and the *National Biodiversity Strategy and Action Plan* (NBSAP, 2002). Recommendations in these documents include (i) developing a 'functional network' of protected areas; (ii) expanding and rationalising the Strict Nature Reserves; (iii) reviewing the conservation status of the current Protected Areas; (iv) establishing new national parks and (v) establishing new Protected Areas in under-represented habitats. In response to these strategic priorities, the Ministry of Nature Protection, now the State Committee of Turkmenistan on Environmental Protection and Land Resources, drafted a package of project proposals to direct the rationalization and expansion of the Protected Areas Draft Main Trends of Development of Protected Area System up to 2030 (2009) which includes the establishment of six National Parks (Central Karakum, Magtymguli, Balkan, Koytendag, Serhetabad, Archabil) within the next 20 years.

9.5.5 Training and motivation of staff, including overseas training visits. This should be organised both for staff of the state nature reserve and key officials from the State Committee for Environmental Protection and Land Resources. Training should include Management of protected areas; Study and monitoring of biodiversity; Fundraising; Stakeholder involvement; use of GIS and other high-technology methodologies; Public relations and information; Education, etc. Overseas training should involve not only western countries, but also former socialist countries eg Bulgaria and Romania which are similar in experience and cultural background.

9.5.6 Provision of equipment, based on a preliminary needs assessment and directly linked to implementation of the management plan, together with training of staff in its use. Particular emphasis should be given to the development and implementation of objective Scientific and Monitoring Programmes.

9.5.7 The feasibility of establishing close working relationships with conservation administrations in Uzbekistan, especially the Surkhan State Nature Reserve which adjoins Koytendag should be investigated. A trans-boundary site would provide opportunities for future collaboration, such as establishment of Peace Park, common scientific and monitoring programmes, experience exchange etc.

9.6 Bibliography

Lukarevsky VS (2000) Fauna and current status of populations of some species of large mammals in the Kugitang Range. Problems of desert development 4: 12-16. In Russian

Lukarevsky VS (2001) Leopard, striped hyena and the wolf in Turkmenistan. M. SIGNAR, 128 pp.

Marochkina VV (1993) Materials on bats (Chiroptera) of Eastern Turkmenistan. Math. Academy of Sciences of Turkmenistan, ser. Biol. nauk, No 3: 51-57.

Marochkina VV (1995) Materials on carnivorous mammals of Eastern Turkmenistan. Lutreola 5: 20-23.
Marochkina VV (1996a) The role of the reserves in eastern Turkmenistan - biodiversity of mammals. In: The problems of nature conservation. Conference proceedings. Ekaterinburg: 170-172. In Russian
Marochkina VV (1996b) Notes on the distribution of the mole vole (Rodentia, *Ellobius*) in East Turkmenistan. Zoologicheskyi zhurnal 75, 11: 1722-1728. In Russian
Marochkina VV (1996c) The mole vole (Rodentia, *Ellobius*) in East Turkmenistan. Notes AN Turkmenistan 5: 42-49. In Russian
Marochkina VV (2004) The results of monitoring the population dynamics of small mammals of East Turkmenistan. Arid ecosystems 10, 21: 62-69. In Russian
Marochkina VV, Agryzkov EN (1998) On the problems of biodiversity of East Turkmenistan. In Current issues of environmental protection and sustainable development in Turkmenistan. Ashgabat, 115 pp. In Russian
Marochkina VV, Marinina LS (2003) Inventory of the rodents of Turkmenistan. In Teriofauna of Russia and adjacent territories (VII Congress Theriological society). Proceedings of an international meeting on February 6-7, 2003, Moscow. Moscow, 214 pp. In Russian
Shammakov SM, Marinina LS, Marochkina VV and Karryeva ShB (2004) The species composition of amphibians, reptiles and mammals of the reserves of Turkmenistan. Problems of Desert Development 4: 45-51. In Russian
Strelkov PP, Sosnovtseva V, Babaev H 1979. Bats of Turkmenia. Trudy Zoologicheskogo instituta AN SSSR [Trans. Zool. Inst. Acad. Sci. USSR] 79: 3-71. In Russian.
Taryannikov VI and Persianova LA (1991) On the ecology of the Indian porcupine. Ecology, acclimatization and mammals in Uzbekistan. Fan. Tashkent: 12-16. In Russian
Weinberg PI, Valdez R and Fedosenko AK (1997) Status of the Heptner's markhor *(Capra falconeri* Heptner) in Turkmenistan. Journal of Mammology 78 (3): 826-829.

Summary

Major international expeditions to Koytendag were organised by the RSPB in 2014 and 2015, following a scoping mission in 2013. Opportunistic recording, principally of birds, was made during separate technical visits between May 2012 and March 2016.

The most significant findings from the research carried out are:

1 Hydrogeology

a) discovery of a new cavity with several dry sinkholes and running water near Hojapil village. The estimated diameter of the underground cavity is approximately 100 m, with a depth of approximately 25 m.

b) discovery of a new sinkhole with a dry lake in the bottom.

c) discovery of a new cave with an underground lake with an estimated area of 4,400 m^2 making it the largest underground lake not only in Turkmenistan but also in the whole territory of the North Eurasia.

d) confirmation that there are three discrete hydrological systems within the site.

2 Flora

A thorough review of the botanical literature, supplemented by limited fieldwork confirmed that:

a) a minimum of 982 species of higher plant occur at the site, with 48 species endemic to the site itself.

b) ten species listed in the Red Data Book of Turkmenistan (2011) and three species - walnut *Juglans regia* (NT), pistachio *Pistacia vera* (NT) and a species of almond *Amygdalus bucharica* (VU) included in the IUCN Red List – are known from the site.

3 Surface dwelling Invertebrates

A survey in 2015 resulted in the discovery of several species new to science or to Turkmenistan:

a) a new species of scorpion, *Mesobuthus garelovi* Fet et al., 2018 – a species of scorpion recently described from Central Asia

b) a new species of spider, *Heser stoevi* Deltshev, 2016 with specimens collected around the Dinosaur Plateau area at Hojapil and close to the Gulshirin cave at Garlyk. Further 10 species of spiders have been identified by Dr. Christo Deltshev and Dr. Yuri Marusik.

c) Eight species of beetles new for Turkmenistan: *Bembidion aeneum* Germar, 1823, *Chlaenius extensus* Mannerheim, 1825, *Gyrinus distinctus* Aubé, 1838, *Trichophya pilicornis* (Gyllenhal, 1810), *Thinodromus behnei* Gildenkov, 2000, *Gabrius hissaricus* Schillhammer, 2003, *Quedius novus* Eppelsheim, 1892, and *Galeruca jucunda* (Faldermann, 1836).

A review of the literature showed that:

d) nineteen species of surface-living invertebrates are endemic either to the site or to Turkmenistan.

e) one globally threatened species *Sago pedo* (VU) occurs (classed as EN in the Red Data Book of Turkmenistan)

f) five additional species are included in the Red Data Book of Turkmenistan (2011) - *Saxetania cultricollis* (VU), *Anthia mannerheimi* (Rare), *Carabus (Axinocarabus) fedtschenkoi* (Rare), *Melanotos dolini* (Rare) and *Melanoides kainarensis* (VU).

4 Cave fauna

A survey in 2015 resulted in the discovery of seven cave-dwelling species new to science:

a) two species of amphipods – *Gammarus troglomorphus* and *Gammarus parvioculatus*; a dipluran *Turkmenocampa mirabilis* Sendra & Stoev gen.n., sp.n., found in Kaptarhana cave, three species of springtails (Collembola) from three caves, a Latridiidae beetle (Coleoptera) at Kaptarhana.

b) three previously unrecorded species of beetles were also found at Gap-Gotan - *Bembidion (Ocyturanes) dyscheres*, *Eremosphodrus (Rugisphodrus) dvorsh*aki and *Cymindis (Paracymindis) asiabadense kryzhanovsky*.

c) three previously unrecorded species of spiders were also found - *Pholcus parthicus* Senglet, 2008, *Megalepthyphantes nebulosoides* (Wunderlich, 1977) and *Tegenaria* sp.

d) ongoing analysis of samples may result in the identification of new troglobiotic cyclopoid copepods from Gap-Gotan.

e) in May 2012, a beetle was collected from a rimestone pool in Gap-Gotan cave which appears to be a new species of *Xestodium*, though none were recorded in 2015.

5 Fish

a) seven of the ten species recorded for the area were identified in 2015.

b) eight individuals of the endemic Starostin's blind loach *Troglocobitis starostini* (VU) were observed.

c) two novel survey techniques for the blind loach were trialled – use of a remotely operated vehicle to observe fish *in situ* and the collection of DNA samples in order to develop a means of detecting the presence of blind loach in water samples for surveying locations inaccessible to divers or remotely operated vehicles. More work is required to refine the DNA sampling methodology.

6 Amphibians

Two species were recorded that were new to the site:

a) *Bufotes (Pseudepidalea) variabilis* at Hojapil in 2014.

b) *Bufotes oblongus* in the Suw Oyuk sinkhole in 2015.

7 Reptiles

No dedicated survey work carried out.

8 Birds

a) of the 229 species of birds reported as occurring at Koytendag, 154 species were recorded between May 2012 and March 2016.

b) two species new to Turkmenistand were observed - Himalayan griffon *Gyps himalayensis* and common koel *Eudynamys scolopaceus*.

c) five of the eight globally threatened species known from the site were recorded - saker falcon *Falco cherrug*, Egyptian vulture *Neophron percnopterus* and steppe eagle *Aquila nipalensis* (all EN) and lammergeier *Gypaetus barbatus* and cinereous vulture *Aegypius monachus* (both NT).

d) ten of the eleven biome-restricted species were recorded – see-see partridge, *Ammoperdix griseogularis*, yellow-breasted tit *Parus flavipectus*, dark-grey tit *Parus rufonuchalis*, sulphur-bellied warbler *Phylloscopus griseolus*, eastern rock-nuthatch *Sitta tephronota*, white-throated robin *Irania gutturalis*, Finsch's wheatear *Oenanthe finschii*, variable wheatear *Oenanthe picata*, white-winged grosbeak *Mycerobas carnipes* and chestnut-breasted bunting *Emberiza stewarti*.

e) data was collected on 13 of the 17 species included in the Red Data Book of Turkmenistan (2011) - black stork *Ciconia nigra*, lesser kestrel *Falco naumanni*, saker falcon, peregrine falcon *Falco peregrinus*, barbary falcon *Falco pelegrinoides*, lammergeier, Egyptian vulture, cinereous vulture, short-toed snake-eagle *Circaetus gallicus*, steppe eagle, golden eagle *Aquila chrysaetos*, Bonelli's eagle *Aquila fasciatus* and Asian paradise-flycatcher *Terpsiphone paradisi*.

9 Mammals

a) annual monitoring by reserve staff since 1995 has shown an increase in the number of markhor *Capra falconeri* from 69 to 882 in 2013 and of urial *Ovis orientalis* from 164 to 250, with a peak of 320 in 2010. The markhor at Koytendag are the most western and isolated population of the species in the world.

A preliminary analysis of camera trap images has revealed the following:

b) confirmed breeding of Eurasian lynx *Lynx lynx*. Very little is known about the species' distribution in Central Asia.

c) numerous records of grey wolf *Canus lupus*.

d) numerous records of smaller predators such as wild cat *Felix silvestris*, red fox *Vulpes vulpes* and badger *Meles (meles) canescens* plus an unidentified mustelid, possibly *Martes foina*.

e) numerous records of tolai hare *Lepus tolai* and Indian crested porcupine *Hystrix indica,* with tolai hare being exceptionally common.

f) the presence of Eurasian lynx and grey wolf, both relatively numerous, and good numbers of prey such as urial is an indication that there is an intact predator-prey community at the site.

For all areas of research, recommendations for future work are presented.

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I COLORI DEL BUIO

Ebbene sì! La mostra al Vittoriano è finita. Il buio si è ripreso i suoi colori.
Fa un certa impressione guardare questi corridoi vuoti e spogli, quando solo poche ore prima erano pieni di pannelli multicolori, monitor e gente incuriosita. Una mostra durata 28 giorni, che ha visto probabilmente 50.000 visitatori, di tutte le età e di tutte le lingue. Cinque serate a tema, con conferenze e ospiti di qualità, hanno arricchito l'offerta di questa iniziativa. Ne è prova l'afflusso di gente crescente, sia alla mostra che alle iniziative ad essa connesse, e le tante manifestazioni di apprezzamento ricevute.
Una grande scommessa per la nostra associazione. Un grande sforzo organizzativo e a volte anche fisico. Ma soprattutto una grande esperienza. Forse la prima in cui come associazione ci confrontavamo con il grande pubblico.
Al di là dei numeri e del successo, che non sta a noi quantificare ne decretare, si è trattato di un vero banco di prova, che ci ha insegnato molte cose, che ci ha fatto crescere molto sul piano della comunicazione. Ma la storia non finisce qui. È nostra intenzione riproporre la, mostra, riveduta un po' nei contenuti, ad altri enti ed associazioni in giro per l'Italia. Il mondo sotterraneo e l'attività speleologica meritano di essere divulgate e fatte conoscere per quello che sono e rappresentano davvero e per il grande contributo che stanno dando alla conoscenza del nostra pianeta, anche sfatando certe raffigurazioni che della speleologia fanno a volte i grandi mezzi di comunicazione e di intrattenimento, come la televisione e il cinema.

THE COLOURS OF DARKNESS

Well then, the exhibit at Vittoriano is finally over; darkness has taken its colors back.
Looking at the bare and empty corridors feels kind of strange now, as just a few hours ago they were filled with multicolored panels, computer screens and intrigued visitors. The exhibit lasted for 28 days and was visited by some fifty thousand visitors of all ages and nationalities. The venture was enriched by five thematic evening sessions, with seminars held by eminent speakers. The increasing flux of visitors, both to the exhibit and to the conferences, and the many expressions of appreciation we received bespoke the success of our endeavor.
It has been a great gamble for our Association, which required intense logistic and, at times, quite physical efforts. Above all, however, this has been a great experience, possibly the first instance in which La Venta has faced the public at large.
Besides the numbers and the success, which is not up to us to quantify, this has been a real test-bed that has taught us many things and made us grow in terms of communication skills. The story does not end here, though, as we plan to offer the exhibit, upon partially revising its contents, to other organizations and associations around Italy. Speleological world and speleological activities deserve to be divulged and explained for what they really are and represent, as well as for the great contribution that they are bringing to the knowledge of our planet. In doing so, we also want to debunk certain depictions of speleology that have been created by mass media.

KOYTENDAG 2012

Il Koytendag è una catena di montagne in Turkmenistan, proprio al confine con Uzbekistan e Afganistan. La struttura principale è una monoclinale calcarea che si spinge dalle pianure solcate dall'Amu Darja, a 400 m slm, sino a creste ad oltre 3000 metri di quota, con immense ricoperture di gesso alle basse altitudini. Fu oggetto di ricerche geologiche negli anni '30 e poi di ricerche speleologiche negli anni '80 fatte da speleologi moscoviti, che vi esplorarono una grotta che da secoli era utilizzata per scopi minerari, la Kapp Koutan (Gapgotan, in Turkmeno), scoprendovi decine di chilometri di gallerie con concrezionamenti straordinari che ne hanno fatto la Lechuguilla asiatica. La dissoluzione dell'Unione Sovietica ha trascinato questi territori lontano dalle possibilità di visita e il Turkmenistan in un'indipendenza estremamente isolata, probabilmente lo stato meno accessibile al mondo. Qualcosa sta cambiando e l'attuale governo pare intenzionato ad aprire il paese a visite e ricerche. Per questo motivo sono stati invitati una quindicina di ricercatori di ogni parte del mondo per realizzare una ricognizione sulle eccezionalità geologiche e biologiche del Koytendag, con la prospettiva di crearvi un'area protetta e un geo-parco internazionale.
Vi hanno partecipato tre nostri soci che hanno potuto quindi apprezzare la sbalorditiva ospitalità turkmena e le ancor più eccezionali possibilità esplorative di quelle zone.

KOYTENDAG 2012

Koytendag is a mountain range in Turkmenistan, exactly on the border of Uzbekistan and Afghanistan. The main structure is a limestone monoclinal stretching from the plains crossed by Amu Darja, at 400 m asl, up to over 3000 m high ridges, presenting huge covers of gypsum at low altitudes. It was the object of geological researches in the '30ies and then of caving expeditions in the '80ies carried out by Moscow cavers who explored a cave, Kapp Koutan (Gapgotan, in Turkmenian) that had been mined for centuries; they discovered tens of kilometres of galleries with extraordinary speleothems that have made Kapp Koutan the Lechuguilla of Asia. The disintegration of Soviet Union has dragged these terri-

IL KOYTENDAG: PAESE DI DINOSAURI E DI GROTTE

Speleotemi di gesso / Gypsum speleothems, Gapgotan Gowangy, Turkmenistan

Giovanni Badino, José Maria Calaforra, Paolo Forti

Koytendag: a land of dinosaurs and caves

Il Koytendag è una remota valle del Turkmenistan, praticamente al confine con l'Afganistan e l'Uzbekistan, che rappresenta il naturale proseguimento verso Sud dell'area uzbeka in cui furono fatte le primissime spedizioni di La Venta (Bernabei & De Vivo, 1992).

A differenza dell'Uzbekistan, però, il Turkmenistan è una nazione molto chiusa in cui è difficilissimo entrare e praticamente impossibile fare attività speleologica se non chiamati dal Governo.

Per questo motivo quando ci è arrivato un invito ufficiale dall'Ufficio dell'UNESCO di quel Paese per partecipare ad una spedizione internazionale in quell'area per valutarne le potenzialità ai fini di una sua eventuale trasformazione in "geoparco", abbiamo accettato al volo.

Giunti nella capitale Ashgabat, assieme ad altri 17 colleghi provenienti da varie parti del mondo, siamo stati presi in carico dai responsabili del Governo e da quel momento non abbiamo dovuto pensare più a nulla: tutto era stato organizzato nei minimi particolari. L'organizzazione è perfetta e faraonica: per farci raggiungere [illegible]nte il Koytendag hanno predisposto addirittura un

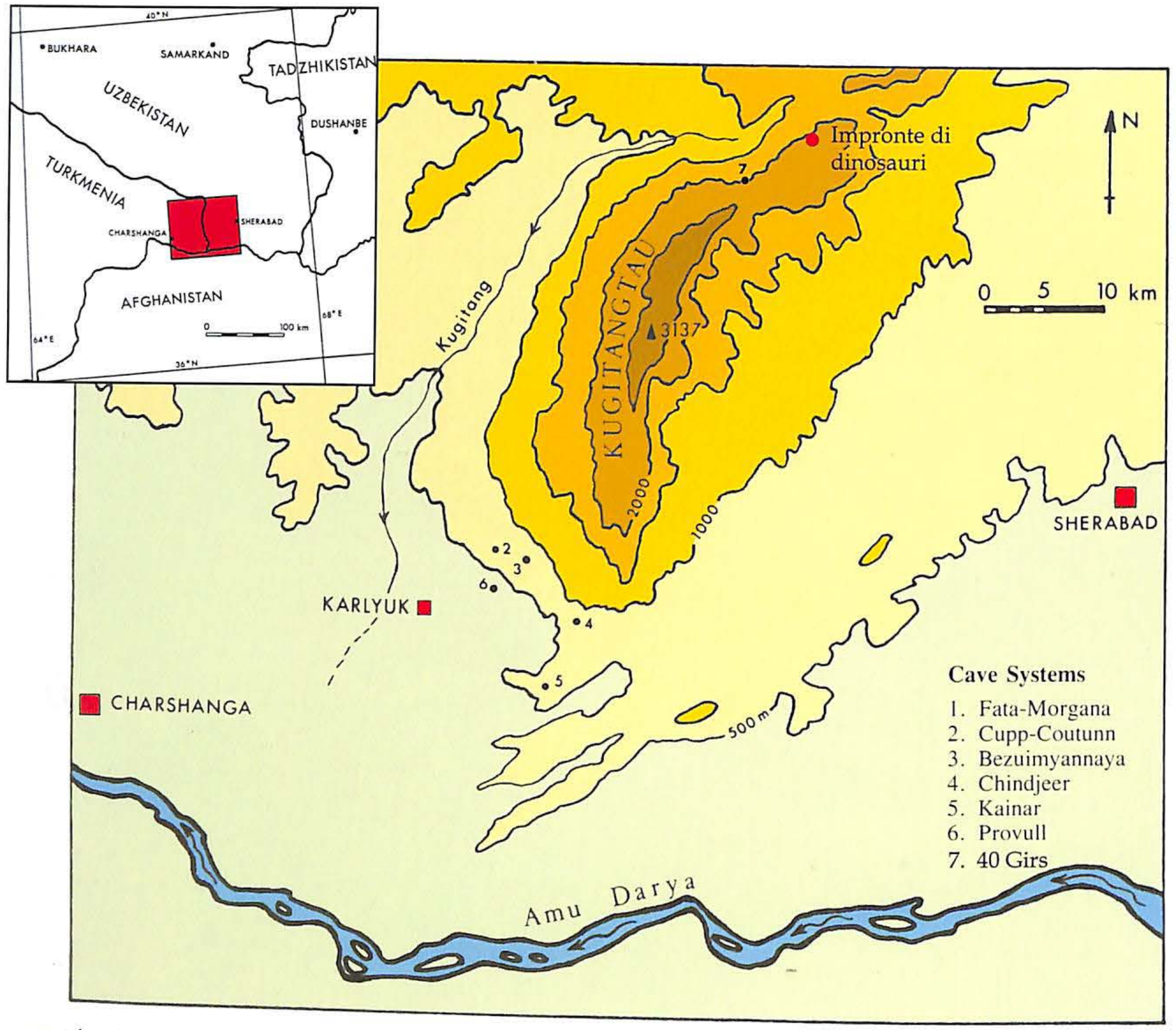
Koytendag is a remote valley in Turkmenistan, almost at the border with Afghanistan and Uzbekistan. It represents the natural southbound extension of the Uzbek territory where the very first La Venta explorations took place (Bernabei and De Vivo, 1992).

As opposed to Uzbekistan, though, Turkmenistan is a closed Country, into which it is almost impossible to enter and carry out speleological activities unless specifically invited by the Government.

For this reason, when we received an invitation from Turkmenistan's UNESCO office, to participate in an international expedition aimed at assessing Koyntendag 's potential to become a "geo-park", we wasted no time in accepting.

Upon arriving in the Capital city, Ashgabat, with seventeen other colleagues from all over the world, we were greeted by the Government's envoys and from that moment on we did not need to concern ourselves with anything. Everything had been planned to the tiniest detail.

The organization was grandiose and flawless. A special train with special luxury sleeping cars had been organized for us; a plethora of government officials, six TV crews and a dozen journalists were also on board. The journalists were to interview us several times a day until the



treno speciale solo per noi con carrozze letto di lusso...

Sul treno oltre a noi e ad uno stuolo di funzionari governativi trovano spazio anche sei troupe televisive e una diecina di giornalisti che, da quel momento e per tutta la durata della spedizione, ci intervisteranno diverse volte al giorno in modo che la televisione ufficiale del Turkmenistan possa passare dalle due alle tre ore al giorno di notizie sulla spedizione.

Nelle dieci ore di viaggio in ogni cittadina in cui transitiamo ci sono folle festanti a salutarci e all'arrivo siamo festeggiati da tutte le autorità del luogo e da un nutrito gruppo folklorico con balli e canti e simboliche offerte di roba da mangiare...

Questo tipo di accoglienza sarà una costante per tutto il periodo della nostra permanenza.

Ma veniamo allo scopo del nostro viaggio: dovevamo visitare alcune località che potrebbero permettere a questa regione di diventare un "geoparco". Le zone geologicamente più importanti sono l'area con le impronte di dinosauri, la Grotta delle 40 Fanciulle e la Grotta di Kupp Coutun.

La passeggiata dei dinosauri

Il primo giorno con un percorso in fuoristrada di circa un'ora arriviamo al sito principale dove sono state scoperte le impronte di dinosauri. È un posto assolutamente incredibile con migliaia di orme perfettamente conservate (fino a 40 cm di diametro!): tra queste è possibile seguire lo spostamento di un singolo animale per oltre 300 metri. Attualmente i paleontologi dell'Università di Bologna stanno svolgendo ricerche su questo sito e su altri non distanti.

Le impronte sono state scoperte pochi anni fa a seguito di una frana ed è assai probabile che molte altre si trovino ancora sepolte.

end of the expedition, so that Turkmenistan's official TV could broadcast updates on the expedition that lasted for a good 2-3 hours a day.

During the ten-hour trip we stopped at several towns and in each one we were welcome by cheering crowds, local authorities and large traditional folk groups, dancing and singing for us. We were also given symbolic food offerings... This kind of greeting was going to be a constant trait of all our stay.

The purpose of our trip was to explore certain areas that could change the whole region into a "geo-park"; the most important of them were the dinosaur footprint area, the Cave of the Forty Maidens and the Kupp Coutun Cave.

The Dinosaurs' Stroll

On day one, a one-hour off road drive took us to the main site where dinosaur footprints had been discovered. It is a truly incredible place, with thousands of perfectly preserved footprints, some as wide as forty centimeters! Among them, one particular trail shows the path of a single animal for more than three hundred meters. At present, paleontologists from the University of Bologna are carrying out researches on this and other sites nearby. The footprints were discovered few years ago after a landslide and it is likely that many others are still buried. This might actually be a good thing, given that the site is rapidly deteriorating due to superficial erosion prompted by the rigid weather and the steepness of the mountain face. Some of the damage is also due to vandalism, as the site is very famous but there are no protective measures in place.

The Cave of the Forty Maidens

A thirty-minute off-road drive separates the dinosaurs' site from a fairly deep canyon, inside which a one hour walk leads to an impressive large cave containing a perennial water spring. Seen from afar, it looks like


Orme di dinosauri nei pressi di Kugitan
Dinosaur footprints nearby Kugitan

Questo forse è un bene, dato che il sito si sta deteriorando abbastanza in fretta a causa dell'erosione superficiale che è favorita sia dal clima rigido dell'area che dalla forte acclività del versante.

Un po' di degrado deriva da vandalismi umani dato che il sito è diventato famosissimo ma, al momento, non è stata messa in atto alcuna azione pratica di protezione.

La Grotta delle 40 Fanciulle

A circa 30 minuti di fuoristrada dal sito dei dinosauri si apre un canyon abbastanza profondo, dove con una facile camminata di un'ora circa si raggiunge un maestoso grottone al cui interno sgorga una sorgente perenne.

Da lontano sembra che tutta la volta della grotta, parzialmente illuminata dai raggi solari, sia tappezzata da stalattiti policrome, ma non è assolutamente così: avvicinandosi infatti si scopre che si tratta di migliaia di nastri di stoffa "fissati" alla volta con una pallina di fango. Questa cavità è ritenuta una "grotta sacra" sia per la presenza della sorgente perenne sia perché si tramanda che, in un tempo remoto, 40 vergini si uccisero qui dentro per evitare di essere violate dagli invasori di turno.

Le persone del luogo vengono in pellegrinaggio alla grotta e raccolgono del fango dal pavimento a cui attaccano una fettuccia di stoffa che poi lanciano verso il soffitto cercando di farla attaccare il più in alto possibile, formulando un desiderio...

Se la fettuccia rimarrà appesa, il loro desiderio sarà esaudito tanto più rapidamente e meglio quanto più in alto sarà arrivata.

Sulla base delle persone che effettivamente abitano la regione, studiosi del folklore locale hanno calcolato che questo rito deve risalire almeno a 2-300 anni fa.

La Gapgotan Gowangy

Circa trenta anni fa apparvero alcuni articoli russi che parlavano di una favolosa grotta ai confini dell'Unione Sovietica dove si trovavano incredibili concrezioni di gesso e una quantità, quasi assurda, di strani minerali di grotta, già in parte descritti nell'antichità da

that the cave's ceiling, partially lit up by sunlight, appears to be covered in multicolored stalactites. This is not the case, though; a closer look reveals thousands of fabric strips hang from the vault, kept in place by tiny mud balls.

This cave is considered "sacred", because of the perennial water spring and because, as legend has it, in the remote past forty virgins killed themselves inside it to avoid being raped by the invaders of that time. Locals go to the cave in a sort of pilgrimage; they gather some mud from the floor and attach it to a strip of fabric, which then they throw towards the ceiling while making a wish... If the strips sticks to the ceiling the wish will come true and the higher the strip reached the sooner it will happen. Going by the number of people who live in the region, the researches who study local folklore estimated that the rite probably began at least 200 to 300 years ago.

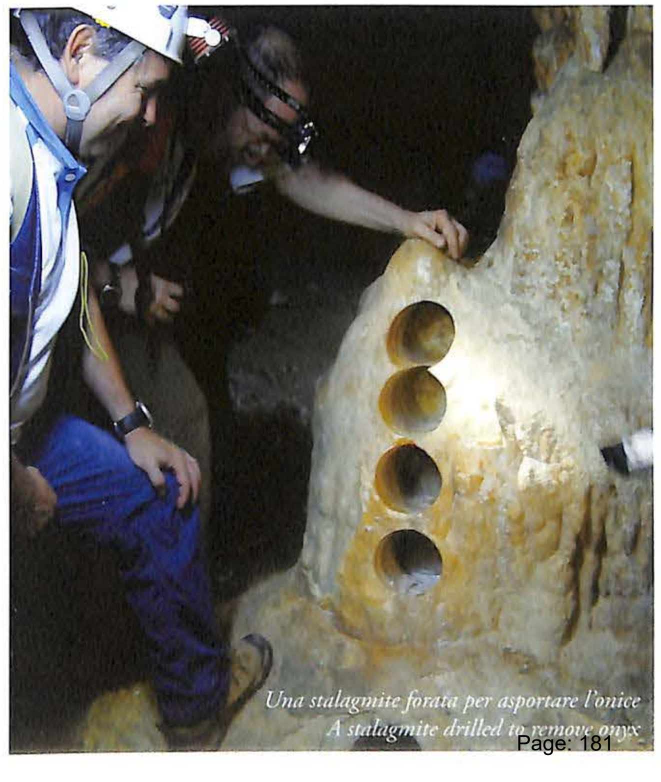
Gapgotang Gowangy

Approximately thirty years ago Russians Authors published some articles describing a cave at the borders of the Soviet Union, which allegedly contained incredible gypsum concretions and an almost absurd amount of strange cave minerals, partially described in ancient times by Diodorus Siculus, approx. 40 b.C. For those interested in cave minerals it became a kind of "Eldorado"... From that moment on, Gapgotan Gowangy (or Kupp Coutun, when transliterated into English) became a sort of a dream. Our second day in the Koytendag was completely dedicated to this cave. To reach it, we had to clear a military checkpoint, as we were really close to the border with Uzbekistan. That was the only time our convoy was ever stopped and checked.

After passing the checkpoint we proceeded upwards to a karstic plain, crossed by a very deep canyon.

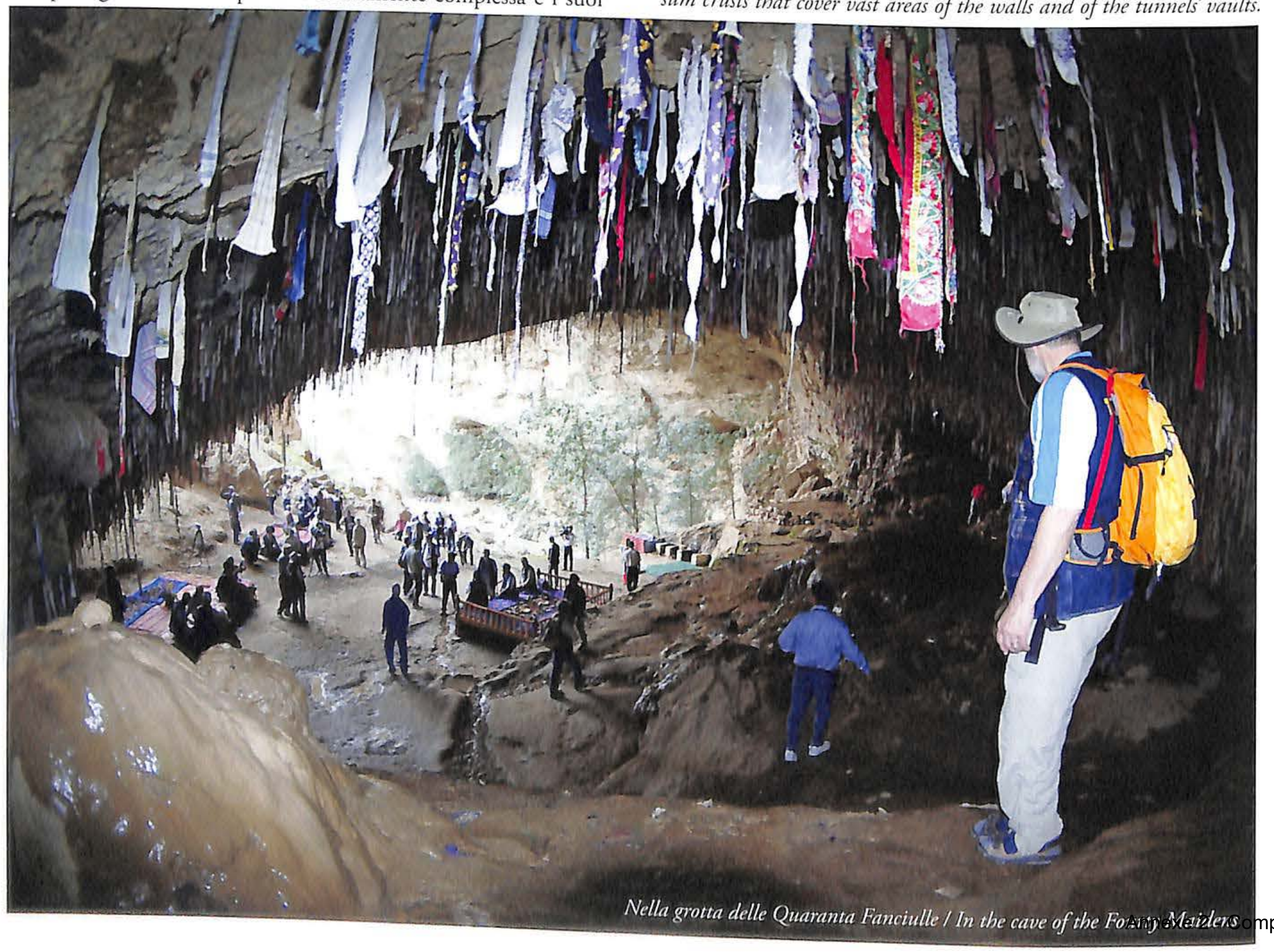
One of the five artificial entries to the cave is located right at the bottom of the canyon; it is a sub-horizontal tunnel that stretches for about three hundred meters before it reaches a huge collapse chamber. Gapgotan Gowangy is a complex karstic system, of which approximately 56 kilometers are known thanks to explorations carried out in the early 1980s. Much is still waiting to be explored, though. Advancing through the tunnels is quite easy, something that unfortunately contributed to the partial destruction of its concretions, at times carried out even with industrial methods.

While inside, we recalled how the Russian speleologists had described the cave many years ago, which at the time sounded excessive. Instead, they were all true, and if anything, even underestimated. Most of the walls are covered by a deposit of gypsum that creates unique shapes:


Una stalagmite forata per asportare l'onice
A stalagmite drilled to remove onyx

Diodoro Siculo (ca. 40 a.C.): una specie di "Eldorado" per un appassionato di minerali di grotta...
Da quel momento la Gapgotan Gowangy (il cui nome è stato trascritto in inglese come Kupp Coutun) era diventata un sogno...
Il secondo giorno nel Koytendag è completamente dedicato a questa grotta. Per raggiungerla bisogna passare un posto di blocco militare, dato che si trova vicinissima al confine uzbeko. Sarà l'unica volta che la nostra carovana viene fermata e controllata.
Dopo il posto di blocco si sale su un pianoro carsico solcato da un profondo canyon. Uno dei cinque ingressi artificiali alla grotta si trova esattamente al fondo di questo canyon: è una galleria mineraria suborizzontale in cui si cammina per circa 300 metri sino ad un enorme salone di crollo.
La Gapgotan Gowangy è un complesso sistema carsico di cui oggi si conoscono circa 56 km di sviluppo grazie alle esplorazioni effettuate nei primi anni '80 del secolo scorso (Maltsev & Self 1992), ma molto altro resta da esplorare al suo interno. La progressione è abbastanza facile e questo purtroppo ha causato la parziale distruzione del suo concrezionamento, portata avanti anche con metodologie industriali.
Durante la visita ci ritornano alla mente le descrizioni fatte, tanti anni prima, dagli speleologi russi, che allora erano sembrate eccessive. E invece era tutto vero, e anche di più.
Buona parte delle pareti è ricoperta da uno strato di gesso che da luogo a forme del tutto uniche: candelieri che protendono i loro bracci dal soffitto per diversi metri, stalagmiti cave, più simili a vulcani in miniatura che a normali concrezioni di grotta e poi bolle cave e tanto altro...
Ma sono i minerali che vi si trovano che rendono questa grotta un vero scrigno mineralogico: fluoriti viola o celestina azzurra su bianchissime aragoniti coralloidi e ancora minerali quasi sconosciuti quali la metacinnabarite, la fraipontite o il mumjo (quest'ultimo complesso materiale di decadimento organico).
E non solo...
La speleogenesi del complesso è sicuramente complessa e i suoi

chandeliers with meters-long arms, hollow stalagmites, looking more like miniature volcanoes than normal cave concretions, hollow bubbles, etc...
Still, it is because of its minerals that this cave is a real treasure chest: purple fluorites or blue celestite onto pure white, coral-like aragonite. And more, little known minerals like metacinnabarite, fraipontite or mumjo, this latter being a complex material derived from organic decay.
The system definitely originated from complex speleological phenomena and its evolution has not been characterized yet. One thing known for certain is that the cave has gone through a significant hydro-thermal stage, the effects of which can be seen both in the corrosion patterns and in the concretions. The terminal phase of the hydro-thermal stadium was characterized by the presence of hydrogen sulfide, which led to the hypogeal iper-karstic development.
The presence of hydrogen sulfide could be put in relationship with the high pyrite content and the presence of organic material that can be found in the highly fractured black dolomite rock. Other sulfur sources could have originated the gypsum speleothems, though. Right above the carbonate formation, in fact, lies the Gurduck Formation, consisting mainly of gypsum and anhydrite. It hence seems logical that, at least in the most recent phases of speleogenesis, solubilization of the sulfites carried out by meteoric water could have been responsible for adding large amounts of calcium sulphates to the cave. Besides, reduction of sulphates into sulphides that took place deep underground could have fed the rising to the surface of thermal sulphuric waters. At present, however, one cannot establish the relative role played by the different processes.
The complexity of these phenomena is also reflected by the incredible richness and diversity of the speleothems.
These include large calcite flows, some of which are macro crystalline, with internal laminas probably created during the hydrothermal period. Yet, gypsum speleothems display the most variety: from the imposing chandeliers (quite similar to the best known ones found in the Lechuguilla Cave, in New Mexico) to the large hollow stalagmites and gypsum crusts that cover vast areas of the walls and of the tunnels' vaults.



Nella grotta delle Quaranta Fanciulle / In the cave of the Forty Maidens

stadi evolutivi non ancora ben chiari.
È comunque certo che la grotta è stata interessata da un importante stadio idrotermale i cui effetti sono visibili sia nelle forme di corrosione che in quelle di concrezionamento.
La fase terminale dello stadio idrotermale fu caratterizzata dalla presenza di acido solfidrico con conseguente sviluppo di cavità di natura ipogenica.
La presenza di acido solfidrico può essere relazionata all'alto contenuto in pirite e materiale organico della roccia incassante costituita da dolomia scura spesso molto fratturata, anche se vi possono essere anche altre fonti per lo zolfo che ha dato luogo agli speleotemi gessosi. Infatti direttamente sopra la formazione carbonatica si trova la Formazione di Gurduck, costituita principalmente da gesso e anidrite.
È quindi logico che, almeno nelle ultime fasi speleogenetiche, la dissoluzione di questi solfati ad opera delle acque di infiltrazione meteorica, possa aver apportato una grande quantità di solfato di calcio nella grotta.
E ancora la riduzione in profondità dei solfati a solfuri potrebbe anche aver alimentato la risalita delle acque termali solfuree. Allo stato attuale delle conoscenze, però, non è possibile definire l'importanza relativa di questi differenti processi.
La loro complessità è anche riflessa nell' incredibile ricchezza e diversità degli speleotemi presenti: tra questi vi sono grandi colate di calcite anche macrocristalline, le cui lamine più interne si sono probabilmente sviluppate durante il periodo idrotermale. Ma sono gli speleotemi di gesso a presentare la maggiore variabilità: imponenti candelieri (praticamente analoghi a quelli più famosi della Lechuguilla Cave, in New Mexico), grandi stalagmiti cave e croste di gesso che coprono grandi porzioni delle pareti e delle volte delle gallerie.
In queste ultime sono particolarmente interessanti le bolle di gesso, spesso forate, che permettono di vedere differenti fasi di sviluppo al loro interno.
Dal punto di vista fisico, la grotta presenta anomalie di temperatura.
È noto che la roccia profonda, e quindi le grotte, hanno all'incirca la temperatura delle acque di infiltrazione.
Nei nostri climi piove nelle stagioni intermedie e quindi c'è ben poca differenza fra la temperatura media annuale e quella media delle precipitazioni. In altre, come nel nord Messico, piove soprattutto d'estate e quindi le grotte sono ben più calde della media esterna.
In Turkmenistan succede l'opposto, le precipitazioni sono concentrate alla fine dell'inverno e quindi la roccia è "fredda".
Nell'area della grotta la temperatura media annuale è di 13,5 °C, quella delle precipitazioni circa 4 °C in meno, e quindi ci si aspetta che la grotta sia a circa 9-10 °C. No, dalle misure che abbiamo improvvisato lì risulta essere a circa 18 °C nelle zone con corrente d'aria, per salire sino a 21 °C nei rami superiori che agiscono da trappole d'aria calda. Un'anomalia da capire.
La corrente d'aria è abbastanza debole (0.5 m^3/s all'ingresso e 2-3 m^3/s nei punti più ventilati, zero nelle zone alte) per una grotta di tale vastità e inserita in un contesto carsico così immenso.
Conviene proprio estendere le ricerche sulle parti alte del massiccio, che si spinge sino a oltre 3100 m d'altitudine.
Dopo appena 4 ore siamo costretti a risalire, non senza avere prima individuato un piccolo insetto cavernicolo che letteralmente "cammina" sulle acque: si tratta di uno ptinide (una famiglia di coleotteri noti anche come "insetti ragno" per la loro forma tondeggiante) attualmente allo studio e che potrebbe rivelarsi anche nuovo per la scienza.
Considerato che la Gapgotan Gowangy non è stata più esplorata dagli anni '80 del secolo scorso e già allora gli speleologi russi sostenevano che ancora moltissimi rami dovevano essere scoperti, è

In Gapgotan Gowangy

In the latter, the gypsum bubbles are particularly interesting; they are often punctured and when looking inside them one can see the different phases of their development. From a physical point of view, the cave presents temperature anomalies. It is known that deep rocks, and hence caves, have about the same temperature of the waters that seep through them. In our climate most precipitations happen during intermediate seasons and therefore there is a little difference between the annual average air and rain temperatures. In other places, like in northern Mexico, most precipitations happen in the summer and therefore caves are quite warmer than average external air temperature.
In Turkmenistan, on the other hand, the situation is reversed as most rainfall takes place in the winter and hence the rock is "cold". The area where the cave is located has an annual average temperature of 13.5 °C, whereas the average temperature of rainfall is about 4 °C lower. One would hence expect that the air in the cave had a temperature of about 9-10 °C, and yet our preliminary measurements showed a temperature of 18 °C in the presence of air drafts, which reached 21 °C in the upper branches, where the hot air gets trapped. This is an anomaly that will need to be studied and understood.
The air speed is rather slow for a cave of that size that is part of a huge karstic environment (0.5 m^3/sec at the entrance, 2-3 m^3/sec in the windiest spots and zero in the upper parts). We will have to extend our researches to the higher areas of the massif, which reaches an altitude of 3100 meters.
After just four hours we had to go back to the surface, but we still had the time to spot a tiny cave-dwelling insect that can "walk" on water. It belongs to the ptinidae family, also known as "spider beetles" because of their roundish shape; it is now being studied and it might turn out to be a previously unknown species. The Gapgotan Gowangy Cave had not been explored since the 1980s and already at the time Russian

evidente che questi sistema carsico occuperà un posto preminente nelle prossime esplorazioni speleologiche in Asia Centrale.

Le grotte in gesso e il pesce cieco

Durante i trasferimenti da un sito all'altro ci rendiamo conto che il Koytendags non è solo importante per le impronte di dinosauro o per le grotte in calcare, ma vi sono presenti anche grandi fenomeni carsici in gesso che, almeno esteriormente, sembrano essere assolutamente identici a quelli presenti da noi in alta Val Secchia (Emilia Romagna).
A pochi metri dalla strada che percorriamo giornalmente si scorgono imponenti portali di grotte in gesso, doline di crollo e anche karren in sale!...
Purtroppo non essendo stato previsto in precedenza non è possibile visitare questi luoghi, che pure sarebbero importantissimi anche per lo scopo della missione…
In una delle poche visite ad una di queste grotte (la Provull cave) effettuate dal team russo all'interno di un grande lago sotterraneo è stato trovano nientedimeno che un pesce cieco, l'unico che ancora oggi si conosca da una grotta in gesso!

Le possibilità future

Finita la parte sul terreno, il treno riservato ci riporta a Turkmenabat, dove nel grandioso teatro nazionale si tiene un convegno internazionale di due giorni per promuovere la candidatura del Koytendag a geoparco dell'Unesco.
Al termine del convegno ci viene richiesto specificatamente di presentare un progetto di ricerca speleologica che, se accettato, ci permetterà di ritornare in forze in questa splendida regione non solo per completare le ricerche nelle grotte in calcare, ma anche, e forse soprattutto, iniziare lo studio di quelle in gesso.

speleologists said that many branches had not yet been discovered. It is therefore quite clear that this karstic system will be a pre-eminent target for future speleological explorations in Central Asia.

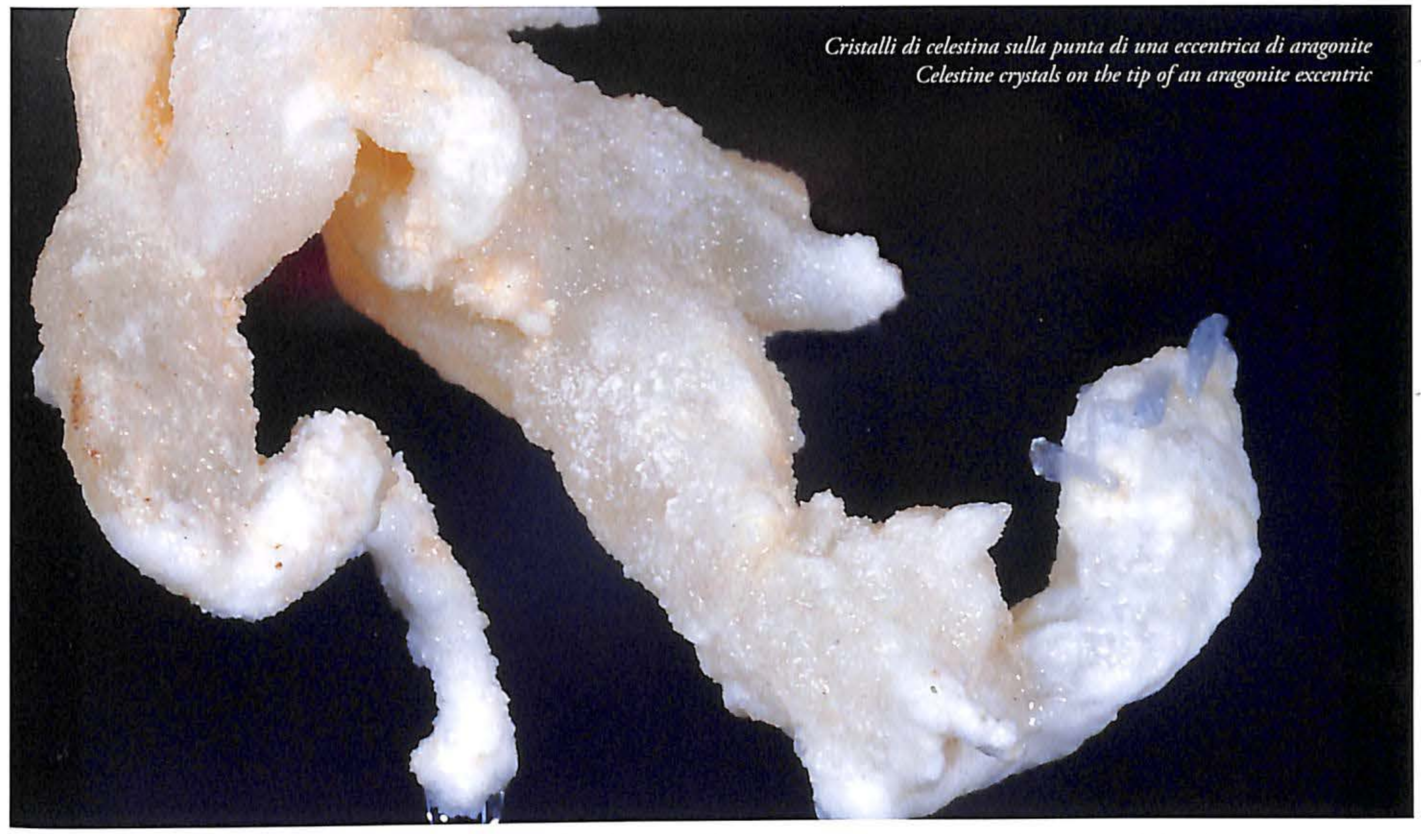
Gypsum caves and the blind fish

While traveling from the different sites we realized that Koytendag's importance does not derive just from dinosaurs' footprints and limestone caves. It also features large gypsum karstic phenomena, which, at least from the outside, look identical to those found in the upper part of Val Secchia, Italy. Just few meters away from the roads we traveled on a daily basis we could glance at imposing portals of gypsum caves, sinkholes and even salt-made karrens!... Unfortunately, we could not go and see those places up close, even though they would have been of paramount relevance for the aim of our mission, as that was not included in the original plan.
During one of the very few explorations carried out inside one of those caves (Provull cave) by the Russian team, they found a large underground lake that was home to a blind fish, nothing less, the only species of this kind ever found inside a gypsum cave.

Future possibilities

Once we completed our field activities on the ground the train took us back to Turkmenabat. There, an international two-day conference aimed at promoting Koytendag as a UNESCO geo-park was held in the grandiose National Theater.
At the end of the conference we were specifically asked to present a speleological research project that, if accepted, will allow us to get back in full gear to this fantastic region, not only to complete our researches in the karstic caves but also, or mostly, to begin the study of the gypsum caves.

Discesa nel canyon verso l'ingresso della Gapgotan / Descent in the canyon to the entran[illegible]



Cristalli di celestina sulla punta di una eccentrica di aragonite
Celestine crystals on the tip of an aragonite excentric

LA CONSERVAZIONE AMBIENTALE DELLA GAPGOTAN GOWANGY

Da oltre 20 anni l'accesso alla Gapgotan Gowangy è controllato, gli ingressi chiusi e non è possibile accedervi senza il permesso delle autorità. Purtroppo però la situazione non è stata sempre questa: infatti per un lungo periodo (anche prima della dominazione russa) queste miniere erano praticamente facilmente accessibili a tutti.
Conseguentemente le zone della grotta più vicine agli ingressi e comunque più facili da raggiungere sono molto deteriorare, soprattutto per quel che riguarda gli speleotemi, anche a seguito delle attività minerarie che sono state eseguite al suo interno. Non solo quella relativa all'estrazione di metalli, ma anche quella per l'estrazione dell' "onice" (concrezioni di calcite con alternanza di bande bianche e marron utilizzate come elemento decorativo e per produrre piccole sculture) che ha distrutto una grande quantità di grandi colate. I depositi di gesso invece hanno indirettamente sofferto per l'attività mineraria. Infatti in tutte le aree raggiunte dalla miniera gli speleotemi gessosi sono ricoperti di una patina nera probabilmente causata dalla polvere e dai fumi generati dalle varie attività estrattive. Questa ipotesi sembra essere confermata dal fatto che nelle zone più remote del sistema, raggiunte solamente dagli speleologi, le concrezioni di gesso conservano il loro brillante bianco candore. Nel futuro di questa interessantissima cavità dovrà per forza esserci la turisticizzazione, che però dovrà tener ben presente il suo rapporto strettissimo con la attività mineraria e contemporaneamente rendere evidente e chiara la sua complessa storia speleogenetica. Insomma bisognerà combinare la presentazione dei principali aspetti antropici (coltivazione dei solfuri metallici e estrazione dell'onice) con quelli naturali (concrezionamento complesso e cristallizzazioni di gesso nonché forme particolari delle gallerie) per far comprendere al futuro pubblico l'eccezionalità di questa grotta forse unica al mondo.

ENVIRONMENTAL PRESERVATION OF GAPGOTAN GOWANGY

The access to the Gapgotan Gowangy Cave has been strictly regulated for the past twenty years; accesses are sealed and no one can enter without an official permit. Unfortunately, things were not always this way.
For a long time (even before the Russian ruling) these mines were accessible to just about anybody.
As a consequence, the areas of the cave that are closer to the entrances, or are otherwise easy to reach, are heavily deteriorated, especially for what concerns the speleothems.
Such damages were also caused by the mining that was carried out inside the cave, to extract metals as well as "onyx" (calcite concretions, with alternating white and brown stripes, used as decorative elements and to carve small sculptures); such activities destroyed a great deal of flows.
Gypsum deposits, on the other hand, suffered indirectly because of the mining activities.
In all the areas in which mining took place, gypsum speleothems are covered by a black film, likely produced by the dust and fumes released by the different phases of extractive activities.
This hypothesis seems to be confirmed by the observation that the most remote areas of the system, reached only by speleologists, still have their bright white color.
The future of this very interesting cave will have to include tourist activities, which however will have to be well aware of its close relationship with mining activities and at the same time highlight its complex speleogenetic history.
In summary, in order to let the visitors appreciate the uniqueness of this one of a kind cave tourist development will have to combine the display of anthropic (farming of metal sulfides and onyx extraction) and natural effects (formation of complex gypsum concretions and crystallizations, peculiar shapes of the tunnels).

Maltsev, Vladimir A. and Dmitriy I. Malishevsky—On Hydrothermal Phases During Later Stages of the Evolution of Cup Coutunn Cave System, Turkmenia, U.S.S.R.: *NSS Bulletin* 52: 95-98.

ON HYDROTHERMAL PHASES DURING LATER STAGES OF THE EVOLUTION OF CUP COUTUNN CAVE SYSTEM, TURKMENIA, U.S.S.R.

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(English translation re-written with added notes, by Derek Ford.)

Recent researches in Cup Coutunn system and other caves of Kugitangtau Ridge, Turkmenia, have revealed that the early caves were modified by thermal water activity in three distinct phases: first, *deposition of calcite crystals up to 2 m in length;* second, *deposition of fluorite crystals (≲ 10 cm) with minor quartz, galena and calcite;* third, *dissolution of the fluorite. Limestone walls and breakdown were altered to depths of 0.5 m. Thermal minerals have since been attacked and reworked by H_2S-rich condensation waters, with deposition of barite and celestite.*

Recent mineralogical researches in the Cup Coutunn System and other caves of the Kugitangtau Ridge, Turkmenia (Fig. 1), have yielded an unexpected result—the caves have been affected by thermal waters. This was not known before because (1) thermal water erosional effects upon the bedrock morphology are very minor and any thermal minerals have been destroyed where later meteoric waters flowed; thus, evidences of thermal activity are confined to a few places in upper levels, (2) the caves are beautifully decorated with conventional speleothems so that the speleologists readily overlook the less prominent thermal deposits. For example, in 1981 the first author took the leading Soviet cave mineralogist, Victor Stepanov, to the Promeszutochnaya Cave section of the system; both walked past a display of large fluorite crystals in the floor without even noticing them. (However, in the same expedition Stepanov did discover evidences of thermal activity in a different system in these mountains, Fata Morgana Cave, near Gaurdak; see Fig. 1.)

The Promeszutochnaya fluorite crystals (CaF_2) were the first thermal deposits to be reported, being noted by the Gorky caving group in 1984 (Moroshkin, 1984; Maltsev, 1987). The crystals were displaced from their growth sites and their genetic relationships could not be established. There were several similar finds by different groups during 1985–88 but no special studies were undertaken.

This note presents preliminary results from our research in 1988 and 1989 in Promeszutochnaya. Many of the observations are supported by findings of other groups in other parts of the system, chiefly Cup Coutunn Cave and Tush-Jyruck Cave. The results may be of great significance in the understanding of speleogenesis in this particular region, and perhaps in many other karst areas. The scientific resources of our caving groups are not sufficient to solve many of the problems; other cave scientists are invited to collaborate if they would like to.

Following creation of the caves themselves, thermal water activity in them appears to have occurred in three successive phases, followed by a distinctive post-thermal phase of reworking:—

Phase 1; crusts of gigantic calcite crystals were deposited. Crystals may be up to 2 m in length. They contain inclusions with sulfides (metacinnabar, HgS, has been recognized) and manganese oxides (Fig. 2). The calculated temperatures of deposition are 100–150° C.

Phase 2; deposition of fluorite crystals up to 10 cm in length, with galena (≲ 0.5 mm), quartz (≲ 1.0 mm) and tiny calcite crystals (Fig. 3). Fluorite depositional temperatures are estimated to be 70–100° C. Interesting features of the fluorite include high concentrations of strontium (up to 4%), high internal stress in the crystals, the absence of any luminescence, or of any gas phase in the fluid inclusions.

Phase 3; was marked by strong dissolution of the fluorite; it penetrates to depths of 4 cm along crystal boundaries.

During all three phases apparently, there was alteration of the limestone walls. Alteration zones are up to 0.5 m in depth. We have studied several rock falls that occurred before the thermal water deposition and found the blocks to be altered to the same depth on all of their faces. Yet the

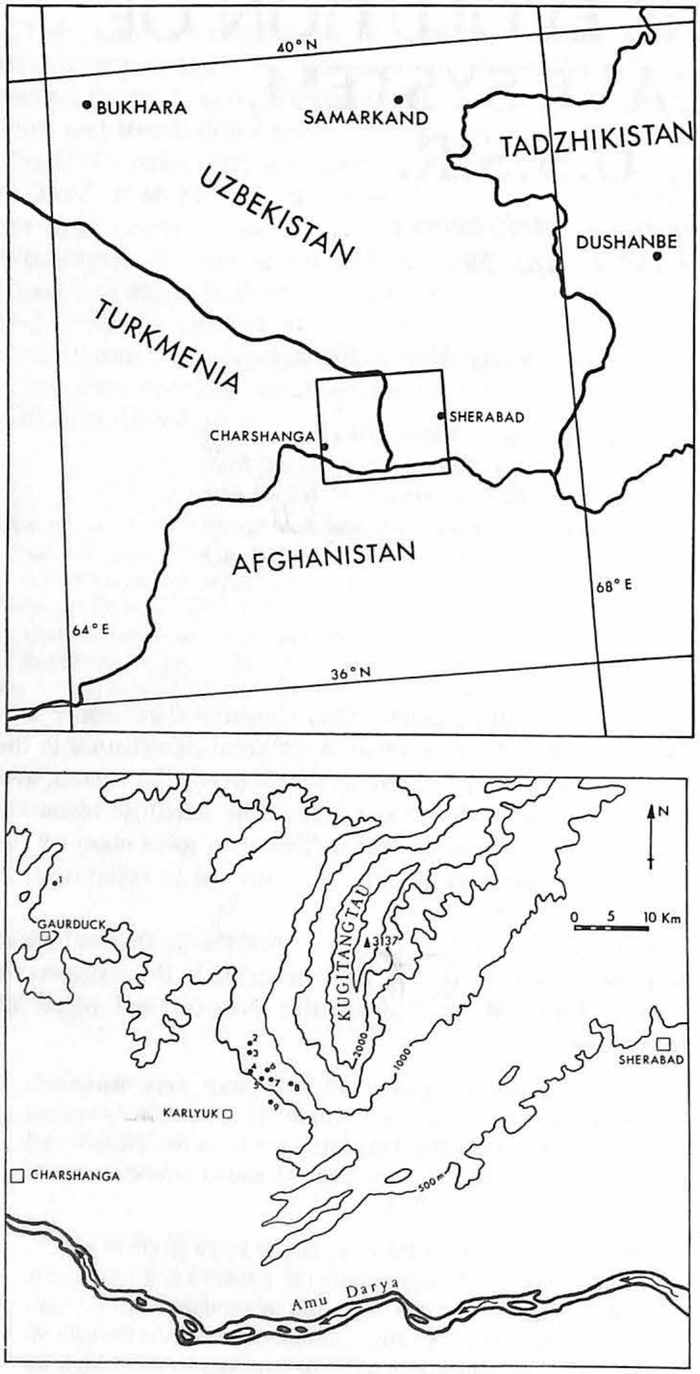

Figure 1. **A) Location of the Kugitangtau cave region, Turkmenia, U.S.S.R. B) 1—Fata Morgana Cave. 2—Verticalnaya Cave. 3—Geophyzicheskaya Cave. 4—Hushm-Oyeek Cave. 5—Promeszutochnaya Cave. 6—Tush-Jyruck Cave. 7—Cup Coutunn Main Cave. 8—Bezvimyannaya Cave. 9—Provull Cave.**

Figure 2. **Remnants of large calcite crystals covered by coatings of sulfides. The crystal exposed at right center is 45 cm in length, now reduced to 1 cm in thickness.**

Figure 3. **A large crystal of fluorite (2nd thermal phase), with a surface that has suffered strong dissolution (3rd thermal phase).**

morphology of these rock falls cannot be distinguished from that of falls occurring after the thermal phases. This is the basis for our contention that the thermal waters cannot have contributed significantly to the erosional sculpturing of the caves (above).

The thermal mineral phases have not been dated but it may be supposed that they are younger than the middle Quaternary because the principal phases of enlargement of the caves themselves are believed to be of that age (Kucheriavyh and Abduszabarov, 1982). We have not been able to find any source tectonic structures for the thermal activity, such as faults displaying the same sequence of mineralization. Such young thermal activity has not been recognized by students of the geology of the Kugitangtau Mountains. It appears to us that the entire period of thermal activity in the caves was quite short, but it was also vigorous.

Effects that followed the thermal phase are most interesting. As noted, thermal deposits are preserved only where there could be no significant flow of meteoric water subsequently. In such areas there is corrosion by condensation waters from the atmosphere only. Such corrosion has weathered the limestone walls to depths up to 10 cm. The calcite is partially gone and fluffy residual clays remain that preserve the limestone texture. The clays range from yellow to red or black in color, and contains such ore-associated minerals as galena, metacinnabar and manganese oxide. Their concentration in the weathered zones is 15–20% by weight/volume, compared to only 2–6% in the parent limestone. Hydrohematite (fine grained hematite, Fe_2O_3) and hydromuscovite (or illite, $KAl_3Si_3O_{10}[OH_2]$) have been reported in similar residual clays in Fata Morgana Cave (Lazarev and Philenko, 1976).

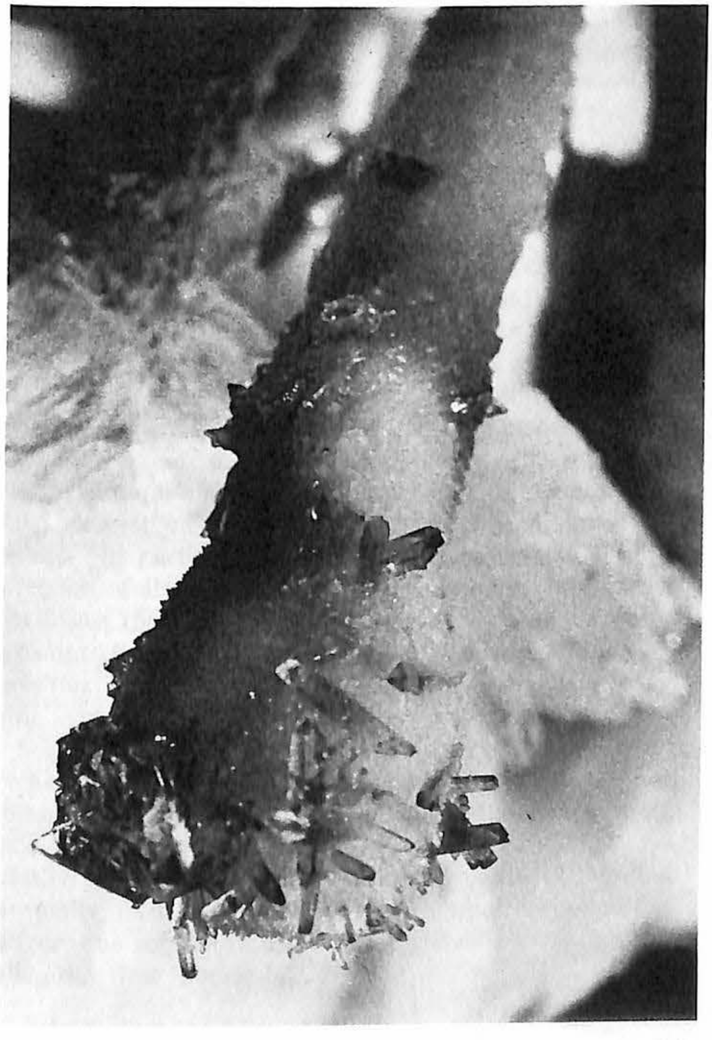

Figure 4. **Reworking and redeposition of thermal minerals in post-thermal phases—celestite crystals grow from a normal calcite helictite. Larger crystals are 1.5 cm in length.**

The gigantic calcite crystals of the first thermal water phase have also been attacked by condensation waters and almost dissolved away, many being reduced to relicts 0.5 to 2.0 cm thick. A distinctive feature is that very thin (1–5 μm) overgrowths of sulfides that formed during the second thermal phase are not dissolved; they are now very fragile sheaths enclosing the surviving crystals. From spectral analysis, the sheaths consist chiefly of metacinnabar. There may also be some metallic mercury but this cannot be proven because the crystals are too small for X-ray analysis. There are similar, but thicker, sheaths in Fata Morgana Cave that have not been linked to any thermal water activity as yet. Lazarev and Philenko (1976) suggested that these may have been deposited at the same time as gypsum crusts formed upon other calcite surfaces, but we believe that such gypsum developed when H_2S-rich condensation waters oxidized and reacted with the calcite.

In some areas of Promeszutochnaya seeping groundwaters (i.e., the type that normally deposit calcite dripstones, etc.) flow over the thermal precipitates and rework them. Individual crystal rosettes of celestite ($SrSO_4$) and barite ($BaSO_4$) are found; they are up to 3 cm in diameter (Fig. 4). There is also sokonite, a zinc-rich clay mineral of the montmorillonite group that is colored green by the presence of ~ 2% Ni, and other minerals not yet identified. Their scale and location indicates that all are derived from alteration of the earlier thermal minerals.

There are evidences of other possible thermal water effects in areas of the Cup Coutunn System that are intersected by a series of upthrown faults termed the Chilghaz Zone. This zone is considered to be a source structure for Pb-Zn mineralization elsewhere in the mountains. In Cup Coutunn, young flowstones in it contain up to 1% of Pb and Zn. There are also large deposits of aragonite (which is rare in all other regions of the caves) and some deposits of cerussite ($PbCO_3$). However, there are no morphological or other features of direct thermal water activity.

In conclusion we suggest that:

(1) There was hydrothermal activity in the Cup Coutunn System. However, it cannot be classified as a hydrothermal system in its origin because the thermal phases appear to have been quite brief and to have done little work to enlarge already existing caves.

(2) Thermal contributions to, and effects upon, the secondary mineral suites in the caves, however, are quite considerable. Their study is only just beginning.

(3) The residual clays in the altered wall rocks may be particularly significant because they should concentrate the products of the thermal activity. We have yet to study them.

(4) These thermal phases were not known in the Cup Coutunn area before. They are probably similar to those recognized previously in the Fata Morgana area.

[*Editor's Note.* The sequence of events proposed above is basically similar to that suggested by Dr. D. E. Deal for Jewel Cave, South Dakota, i.e., a phreatic cave system excavated by earlier, presumably cool meteoric, waters is invaded by hot waters that do little erosional work but alter the wall rock and precipitate characteristic mineral deposits. Following the thermal phase the caves drain and are not, thereafter, re-occupied by cool waters. M. Bakalowicz and I have questioned such sequences on the grounds that evidence of early, *erosional* thermal water phases will not be preserved, only the late, depositional or alteration phases. See Deal, 1961, M.S. thesis, University of Wyoming; Bakalowicz et al., 1987, Bulletin, Geol. Soc. Am., pp. 729-738]

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REFERENCES CITED

Kucheriavh, V. I. and Abduszabarov, M. A. 1982. Cup Coutunn 2—a large cave system in Central Asia, in *Some aspects of the physical geography of southwest Uzbekistan*. Samarkand, pp. 29-30 (in Russian).

Lazarev, K. S. and Philenko, G. D. 1976. Geology and mineralogy of the Gaurdak caves. *Caves* (Karst Institute, Perm), vol. 16 (in Russian).

Maltsev, V. A. 1987. Results of mineralogical investigations in caves of the Cup Coutunn System, in *Problems of karst study in mountainous regions*. Metsniereba, Tbilisi, p. 21 (in Russian).

Moroshkin, V. V. 1984. Minerals of the Cup Coutunn caves. *Priroda* ("Nature") *3*, pp. 45-50 (in Russian).

Epidemic dangers in the caves of Middle Asia

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Abstract

A microbiological study of the Kupp-Koutan-2 and Tash-Yurak caves (Kugitangtow ridge, Turkmenistan) showed that pathogenic and conventional pathogenic microorganicms found in the caves could be dangerous for humans. *Staphylococcus, Enterobacteria, Penicillus, Aspergillus, Nanizzia*-like from Gymenoascaceae fungi were isolated from sediment samples and air. The most dangerous places are connected with subentrance sediments consisting of organic dust where the main part is faeces of animals. Deep parts of caves are safe. However, we have discoveried a pollution by enterobacteria near the cavers base existing for a long time. Also we have discovered that a group of 6 cavers increase the concentration of microorganisms in the air by three times because the dry dust and the spores rise to the air very easily.

Аннотация

Микробиологическое обследование пещер Кап-Кутан-2 и Таш-Юрак (хр.Кугитангтау, Туркменистан) показало, что встречающиеся там патогенные и условно-патогенные виды бактерий и микромицетов могут представлять опасность для человека. Среди таких организмов были выделены *Staphylococcus, Enterobacter, Penicillus, Aspergillus*, гименоасковые грибы близкие к *Nanizzia*. Отмечено, что места наибольшей опасности связанны с привходовыми отложениями рыхлой органической пыли, значительная часть которой представлена сухой фекальной массой грызунов и копытных. Объемы и отложения глубинного карста в достаточной степени стерильны от условно патогенных организмов, исключая районы длительно существующих подземных стоянок, где было выявлено загрязнение бактериями кишечной группы. Было также установлено, что передвижение группы из 6 человек по рыхлым органическим отложениям увеличивают микробную обсемененность воздуха в 3 раза из-за того, что сухая пыль и споры легко поднимаются в воздух.

The caves of Kugitangtow ridge were studied for pathogenic and conventional pathogenic species of microorganisms contained in different kinds of the sediments and in the caves' air.

We think that the caves of Kugitangtow ridge is an ideal model of other Middle Asian Caves, because they contain all main elements of underground landscapes typical for Asian regions: sediments connected with bats, porcupines, gnawers, unguligraders etc., and also the deep part of the caves contain mineral sediments only.

We worked with samples of sediments which were studied by cultural technique on Levin (for enterobacteria) [3], Chapeck (for micromycetes) [2], blood agar (for hemolythic bacteria) [3], egg yolk salt agar (for pathogenic coccus) [3] and beef-extract agar (for summary saprothrophic bacteria) media. The air was studied by Kokhs sediment method [3] during our expedition in the caves. Incubation was fulfilled between 24°C and 35°C.

As a result of studies the **Table 1** was made.

samples	sum of saprophytes bacreria	sum of saprophytes fungi	sum of conventional enterobacteria	pathogenic enterobacteria	Staphylococcus	hemolyth. bacteria	pathogenic fungi
Organic sediments near entrance of Kupp-Koutan Cave	$1 * 10^7$	$1,8 * 10^4$	$8 * 10^3$	$0,3 * 10^3$	++	NO	++
Organic sediments near entrance of Tash-Yurak Cave	$9 * 10^6$	$0,5 * 10^4$	$1,2 * 10^3$	NO	NO	$1,5 * 10^3$	++
Flood mineral sediments in Snezhny Korolevy Chamber	$3,2 * 10^6$	$5,1 * 10^5$	$7 * 10^3$	NO	+	$2 * 10^3$	NO
Flood mineral sediments in Skazka Chamber near cavers base	$2,4 * 10^6$	$3 * 10^4$	$5 * 10^4$	$5,5 * 10^3$	++	$4 * 10^3$	NO
Red-color ocher from Snezhny Korolevy Chamber	$7,6 * 10^6$	$1,2 * 10^5$	NO	NO	NO	$0,5 * 10^3$	NO
Faeces of bats from Ozerny Khod Passage	?	?	?	?	?	?	+++

Table 1: Concentration of microorganisms in the organic sediments and in the clay (CFU - colony forming units/gr)

It's necessary to give some explanations:

Pathogenic enterobacteria. This is a type of organisms isolated by classic medical techniques and biochemical tests. Pathogenic enterobacteria were distinguished as forming the uncoloured colonia on media with lactose, eosine and methilthioninchloride. On the other hand natural microflora is painted in blue or red colours [3]. We didn't study our cultures in medical-biological tests.

Pathogenic fungi. Fungi were studied in pure culture and also by microscopy in samples. Identification was made by morphology of reproductive organs. We have found many species of fungi which could be an agent of infection and allergy. *Aspergillus flavus, Aspergillus fumigatus*-like, *Penicillum funiculesum, Penicillus purpurogenum. Aspergullus sp., Penicillus sp.* are isolated from samples of sediments. Also we have discovered *Gymenoascaceae* fungi like *Nanizzia* which could cause dermatomycosis infection. There were some cases of dermatomycosis in caver groups after expeditions [Korshunov, pers. comm]. Characteristic for this infection is the fall of skin density. *Hystoplasma capsulata* as one of the most dangerous microorganisms wasn't found in the caves yet.

Hemolythical bacteria. Those are bacteria having ability of growth in blood media and forming hemolysis zones in agar.

Staphylococcus. The discovery of many Staphylococcus in the caves [1] is a real fact. We also have found them in sediments samples and air. 95% of those bacteria are *Staphylococcus albus*-like organisms. However, the conclusion about their pathogenic property is rather doubtful. We suppose that we usually find a free-living form in the caves.

It's evidently that subentrance chambers containing the organic matter of gnawer's and unguligrader's faeces are the most dangerous parts of the caves. Moderate dry conditions and a variety of organic substrates are a reason for the high stability of saponoze infection agents and other epidemic infectiones types. A big role in the support of infection agents lifecycle is played by the zoological factor. The subentrance parts are the environment for animals (mainly gnawers) which can be the natural reserve for some infections. And also, the most part of carriers is dwelling in the similar environment. As an example, we have calculated a quantity of mites which are carriers of Human Return Typhus (*Ornithodorus sp.*). In the subentrance chambers of Tash-Yurak Cave we could calculate about 2-3 mites/m^2. In the part of this cave where organic sediments are absent we have calculated 1 mite/10 m^2 and less. In the deep parts of other caves *Ornithodorus* mites were not found.

We studied also caves' air in the subentrance chamber (with organic sediments) and in the Baobab Chamber (with mineral sediments mainly) "before" and "after" the pass of group of 6 cavers. It was discovered that concentration of microorganisms in the air had become three times higher **(Table 2)**.

The point of tests	The sum of saprothrophic bacteria	The sum of enterobacteria	The sum of Staphylococcus	The sum of micromycetes
Subentrance chamber of Kupp-Koutan Cave "before" cavers	$4{,}5 * 10^3$	NO	NO	$8 * 10$
Subentrance chamber of Kupp-Koutan Cave "afterwards" cavers	$1{,}2 * 10^4$	NO	$0{,}7 * 10$	$3{,}1 * 10^2$
Baobab Chamber of Kupp-Koutan Cave "before" cavers	$3{,}2 * 10^2$	NO	NO	$0{,}3 * 10$
Baobab Chamber of Kupp-Koutan Cave "afterwards" cavers	$9{,}8 * 10^2$	NO	NO	$0{,}7 * 10$

Table 2: ***Concentration of microorganisms in the cave's air (CFU - conoly forming units/m^3)***

References

Volodin A.P., Pshenichkov V.A., 1949. Microflora of Kungur Ice Cave. - The proceedings of Permsky stomatological insitute. v.8. p.393-402 (in Russian)

Semenov S. M., 1990. Laboratory media for actynomycetes and fungi. - Moscow. p.172 (in Russian)

HANDBOOK OF MICROBILOGICAL AND VIRUSOLOGICAL METHODS OF RESEARCHES. 1982. edit. by M.O.Birger. Moscow (in Russian)

Cave chemolithotrophic soils

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Abstract

Geochemical and microbiological studies in the Cupp-Coutunn cave (Turkmenistan) show, that the fluffy red-colored coverings on the cave walls and roof, 1-20 cm thick, are not a kind of a residual sediment, but a complex organomineral media. This media, named "okher", has a very high biochemical activity. Okher appears to be a result of both strong corrosion and weathering of the rock, and a formation of secondary minerals. It also appears to be a basis of the feeding chain for higher organized flora and fauna.

Introduction

The biological redox processes are already proved to be a significant karstification factor, and the reason for some specific features of caves mineralogy. The so far studied cases mostly concern phreatic areas in caves where the sulfate reduction proceeds in deep phreas. Sometimes full bacterial sulfuric cycle was reported, with sulfatereduction in phreas, and sulfuroxidizing in dry areas [FORTI, 1988; BALL & JONES, 1990].

In spite of this, there are several caves known, that have no phreatic areas, but have active sulfuric processes in them. One of these caves is the Cupp-Coutunn cave in Turkmenistan, and it was selected as an object of the study.

Okher

The term "okher" came from the caver's jargon, as a name for red fluffy coverings on the floors and roofs of the cave, and is based on an untranslatable game of words. Up to 1993 it was taken as a residual of atmospheric corrosion [MALTSEV & SELF, 1992], but even the first studies shown, that it can't be so [SEMIKOLENNYKH & KORSHUNOV, 1994].

Okher vs. corrosion residues

If we compare okher to classic corrosion residues (for example, from Lechuguilla cave), we'll easily see two main differences:

a) In the corrosion residues we always see unaffected carcass of non-soluble minerals (especially alumosilicates), in which the original texture of the rock is saved recognizable. For the corrosion residues, known from Guadalopean caves, we can even see, that these residues are more likely simply weathered limestone - the texture has completely survived, so the volume of these "residues" is equal to the volume of the affected parent rock [CUNNINGHAM et.al., 1993; M.QUEEN, pers.comm.].

On the contrary, okher never keeps unaffected carcass of the limestone, because of much more acid conditions. All minerals, even silicates, completely re-crystallize, mostly forming new minerals, which were never found in the parent limestone. For example, fig. 1. shows rather large gibbsite crystals, generated in okher. The texture of the rock is lost completely, and the volume is changed greatly. For example, concentration of Fe_2O_3 in different layers of okher is 5.7%-28.3%, and in the parent limestone it never exceeds 0.5%. Even when converting volumes to weights (okher is fluffy, density of dried okher is about 0.2-0.6), the difference still remains great. The same is seen for silicates.

b) The corrosion residues are mineralogically passive. Okher, growing on pure carbonate substrate, is almost always covered by gypsum efflorescences, and even coatings. Disturbed okher noticeably smells of sulfuric gases, including H_2S. In spite of this, there are no visible mechanisms for transportation of sulfur to the okher location along the cave (no water flows, and no sulfuric gases in the air).

Figure 1. Gibbsite crystal in okher, 0.1 mm large, diagnosed via X-ray microzond. SEM photo by A.Semikolennykh.

These two features already allow to separate residues (passive product) form okher (active strata with complete re-working of everything).

Structure and morphology of okher

Okher is spread almost all over the cave, and its morphology and structure is variable, depending on the limestone composition, humidity, air circulation, etc.. But some generic features and typical structure exist.

Okher has no definite boundary with the limestone. Appearing as something fluffy and very porous on the surface, it becomes much more dense and sandy in the middle, then consequently transforms into altered limestone, and so on. The okher covering can be from a couple of millimeters thick up to 20cm and even more.

Okher is always well structured and has several layers. The main layers, listed below, have specific properties and can be found in almost any kind of okher (fig. 2).

a) The outer layer is thin (1-3mm.), and consists of gypsum sand, rarely forming a crust. This layer is usually present in thin okher (up to 2-3cm), and absent in thicker one. In the last case gypsum sand doesn't form a separate layer, but exist in next layers. The boundary to the next layer is fuzzy. In places of strong seasonal humidity cycles, the gypsum may also be reworked into filamentary crystals [MALTSEV, 1996]

b) The second layer is red, extremely fluffy and porous, 1mm to 10cm thick. In thick okher this layer has a color trend - from browny inside to bright red outside. The boundary to the next layer is sharp. pH in this layer is in the range of 7-8.

Figure 2. General view of the okher cross-section. Photo by V. Korshunov.

c) The third layer is yellow or browny-yellow colored. Usually it's the thickest layer, and can be up to 20cm thick. It's much more dense than the previous, sandy, and usually contains pieces of altered limestone.

d) The fourth layer is dark gray up to black. This layer is thin and unstable, possibly seasonal (appearing due to overmoistening during corresponding seasons). It has a sharp boundary to the previous layer, and a fuzzy one to the next.

e) The last layer consists of strongly altered limestone. The limestone here keeps its structure, but looses density. In the outer part of this layer the limestone becomes very soft, and strongly smells of sulfuric compounds when being broken. Deeper it consequently transits into normal limestone. pH on the contact of this layer with the previous is about 3.5-4, maybe even lower. The problem is, that the spatial distribution of pH is irregular, due to irregularity of bacterial communities, and all the measurements are to be made in situ - otherway the results are strongly distorted.

The pH data of the okher layers is to be compared to the pH data of the cave water. The meteoric water, coming along fractures, has pH about 6.5 in all the cases. The water in the pools has pH 7-7.5, the same as the water in the springs and in the artesian basin, both fed from the karst.

Okher covering is so delicate, that sometimes a thick red layer disconnects from the roof and falls, forming thick deposits. In these deposits only the top 10 cm look like the original okher, and in the deeper layers it changes into some dense, fat and plastic brown clay, and consequently - into also dense, fat and plastic blue clay.

Microbiology of okher

The key question - the source of the H_2S gas in the okher, in fact stays unresolved. There are many indirect evidences of SRB (sulfate reducing bacteria) activity in the deep layers of okher, but no direct ones. At the studied depth SRB (***Desulfotamaculum***) were found only in one sample. The source of the sulfur are bituminous inclusions in the limestone. Bacterial activity is the only known mechanism, due to which the sulfur is partly returned (see below). Therefore, SRB must be the main type of bacteria, utilizing the source sulfur. The question mostly is whether the SRB activity proceeds in limestone themselves, or only in the limestone near the cave. The first supposition has two

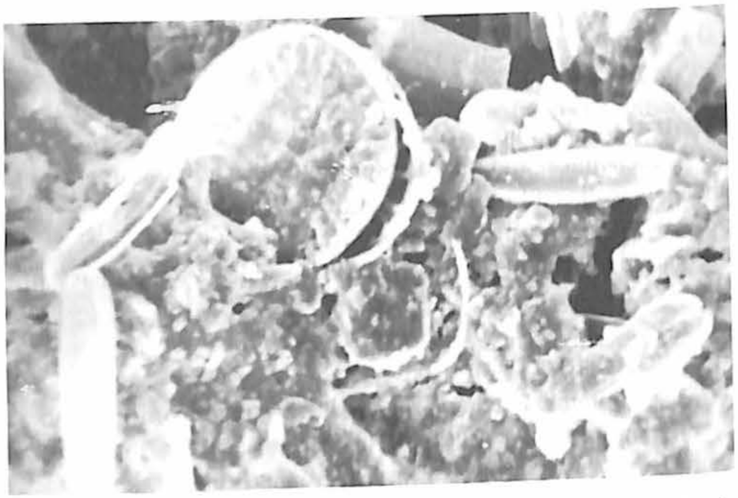


Figure 3. Diatomea in the outer layer of okher. Completely re-crystallized surrounding shows, that it's not residual. SEM photo by A.Semikolennykh.

pieces of evidences against it: No traces of the sulfur was found in springs, unloading from limestone; okher morphology too weakly correlates with fractures, which collect the H_2S gas, and this means, that it mostly appears near the cave, and is transported along the pores of the weathered limestone to deeper layers of the okher (porosity of the source limestone is extremely low). So, SRB must be mostly found in deeper layers, than it was sampled. Some evidences (mostly, studies of microflora, growing

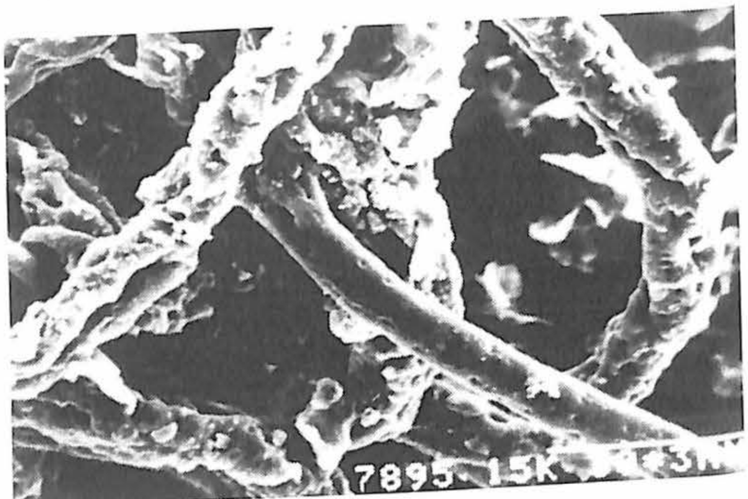


Figure 4. Simbios of mycoplasma and fungi (both undiagnosed) in the outer layer of okher. SEM photo by A.Semikolennykh.

on the candles left in caves), show, that utilizing of bituminous inclusions must be due not only to SRB, but also to ***Arthobacter, Rhodococcus, Mycobacterium***, found in all such samples.

On the contrary, another half of the sulfuric cycle is "opened", and proved. From the samples, taken from outer okher layers, using the Vacksman, Tausson and Birs media, there were exposed sulfuroxidating bacteria, particularly ***Thiobacillus ferrooxidans***, ***Th. thioxidans***, and similar microorganisms. Their activity is enough for partial return of sulfur into the corrosion cycle, and for enriching of the outer okher layers by Fe, providing the red coloring.

The sulfuroxidizing activity in the outer layer, returning the significant part of sulfur into the cyclic sulfuric corrosion of limestone, is an additional indirect evidence of SRB activity somewhere inside, because inside the okher pH falls to about 3, and free H_2SO4 exists, reacting with limestone, that consequently results in gypsum generation inside. Absence of this gypsum in middle layers of okher shows, that it must be destroyed by SRB.

The bacterial biomass from the okher is utilized by other organisms, giving a start to a long feeding chain. Immediately in okher several kinds of fungi (detected ***Penicillus sp., Aspergillus niger, Scopulariopsis sp.***), several protozoa, diatomea (fig.3, 4), etc. were found. In the massifs of fallen okher several kinds of mites and insects cab be found. It's possible also, that this chain

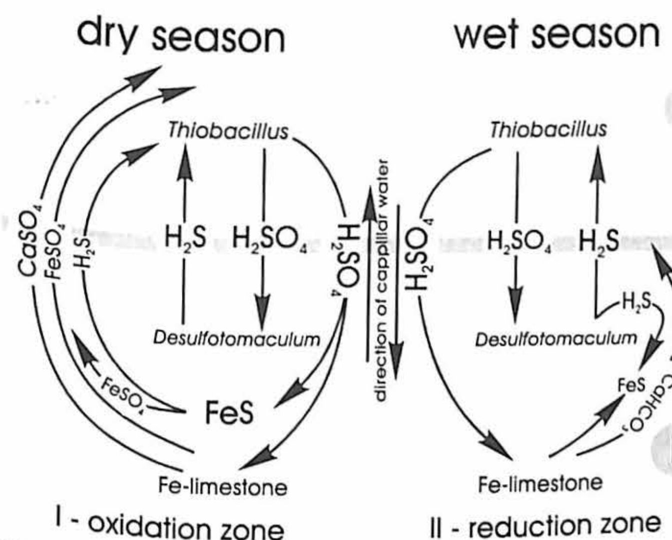


Figure 5. The seasonal iron and sulfur migration.

appears to be the chain, leading up to blind fishes, found in the under-plane drainage of the cave system (Kugitangtou blind loach), but some elements of this chain are still absent.

Looking at the details of the okher spatial distribution, we can find out, that there is some optimum between general high humidity of the cave area, and the oscillations of the humidity, caused by the seasonal cave wind inversions. Okher, developing within this optimum, is about one order more active, than the okher, developing in other areas of the cave. The diagram on fig. 5 illustrates the main relations between activities in the okher and the microclimatic conditions of the location.

Mineralogy of okher

Due to the fact that the okher layers have very different pH, and that the seasonal humidity cycle (and microbiology-driven cycles) result in cyclic migration of various ions through the pH barriers, all the matter is reworked. This reworking has several variants, but the general scheme is like the following.

Silicates, present in limestone mostly as quartz and micas, are transformed into kaolinite-like minerals in the middle layers of the okher, and further to gibbsite and illite in the outer layers. Gibbsite and illite co-existance may be explained with high-pH conditions, separating Si and Al. The same effect is known from the other parts of cave, where gibbsite and serpentine co-growth are known.

Iron is concentrated in the outer layer, mostly in the form of microcrystalline oxides - hematite, goetite, etc..

Gypsum (fig.6) is generated both in deep layers (metastabil), and outer layers (final). Calcite mostly disappears in the middle layers, and appears again in the outer layers, where it forms, together with gypsum, specific "sand". This sand, falling from

Figure 6. Okher corrosion. The white stripes are calcite veins, completely turned to gypsum in the outer layer of okher. The image height is about 40 cm. Photo by V.Maltsev.

the roofs, sometimes makes up sediments up to several metres thick, appearing as the product of the limestone corrosion by the okher.

High acidity in the deep okher layers causes some side effects when the cave intersects veins, or the cave wall is covered by products, which survived from the hydrothermal phase. Interactions between sulfuric acid, fluorite druses, silicate matter, and ore veins leads to generation of minerals, exotic for caves, like saukonite, fraipontite, serpentine, etc.

Okher as a kind of soil

So, okher is an active strata, providing the corrosion of limestone, gas and water exchange with atmosphere, alteration of the residual material, and biomass generation, that is used by other organisms. Due to this, okher certainly is to be classified not as a sediment, but as a special type of a soil, based on chemilititrophic bacteria.

Okher appears to be a significant corrosion factor. In some cave passages it provides up to 90% of the total corrosion. This can be estimated through the total quantity of the Fe and Si in the okher, compared to their contents in the parent limestone in the full volume of the passage. In such localities the okher corrosion forms specific morphologic types of the cave landscape - syr, red chinks, red tubes [SEMIKOLENNYKH et.al., 1996].

Okher exists not only in the Cupp-Coutunn cave. There are evidences of it's existance in Snezhshnaya deep cave in Caucasus, and also in some minor caves within ore mines, but this needs to be studied very carefully. In the Guadalopean caves the visual similarity appeared to be a visual convergence of very different phenomenas.

Related effects in the Cupp-Coutunn cave

The microbiological studies in the Cupp-Coutunn cave have not only shown the okher's microbiological origin. Some other corrosion and mineral generation factors definitely are also related to the activity of microorganisms. For example, it's the gypsum replacement by silicates in the Vodopadnyi chamber.

Figure 7. Gypsum replacement from inside by a foam-like silicate substance. Photo by V.Maltsev.

The gypsum gemmiforms (fig.7) are replaced from inside by some very porous foam-like silicate substance.

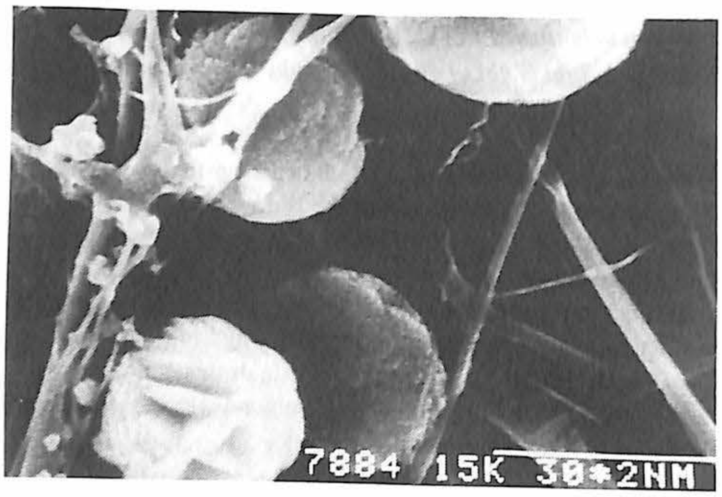


Figure 8. Celestite globules (those, where crystals are seen), silicate globules and threads from the foam, replacing gypsum gemmiforms from inside. SEM photo by A.Semikolennykh.

This substance, if studied closely, consists of celestite spherolites, amorphous silicate globules, amorphous silicate threads. The first of them may have any origin, but the last two - can only be biological. It can clearly be seen from the SEM photo on the fig. 8. There is no idea, what bacteria it could be. No growth in vitro was received, and no bacteria are known, leaving carcasses of Fe - Mg - silicate composition, very close to olivine.

There are several more similar phenomenas known, but all are completely unstudied. Certainly, microbiology must become one of the main trends in studying the cave systems like Cupp-Coutunn.

References

T.K.Ball & J.C.Jones, 1990. Speleogenesis in the Limestone Outcrup Worth of the South Wales Caalfield//Cave Science, 17(1), London

K.I.Cunningham., D.E.Northup, A..M.Pollastro, W.J. Wright, E.J.LaRock, 1995. Bacteria, fungi and biokarst in Lechuguilla Cave, Carlsbad Cave National Park, NM // Environmental Geology, No. 25, p.2-8.

P.Forti, 1988. The role of sulfide-sulfat reaction in speleogenesis//First FEALC, Belo Horizont, Brasil

V.Korshunov, A.Semikolennykh, 1994. The model of speleogenetic processes connected with bacterial RedOx in sulfuric cycles in caves of Kugitangtou Ridge//Breakthroughs in Karst Geochemistry and RedOx microbiology, Karst Waters Inst. NY, p.43.

V.A.Maltsev 1993. Minerals of the Cupp-Coutunn cave system, Southeast Turkmenistan // World of Stones, No.2, Moscow, p.5-30.

V.A.Maltsev 1996. Sulfate filamentary crystals and their aggregates: Proc. Univ. Bristol Spelaeol. Soc., 20(3), pp 171-185

V.A.Maltsev & C.A.Self, 1992. Cupp-Coutunn cave system, Turkmenia, Central Asia//Proc. Univ. Bristol Speleol.Soc., 19(2)-29

A.A.Semikolennykh, V.A.Maltsev, V.V.Korshunov, 1996. The processes of biogenic sulfuric weathering in the caves of the Kugitangtou Ridge, Turkmenistan. In: Mineralogy and Life: Biomineral Interactions. Syktyvkar., p. 61.

Proc. Univ. Bristol Spelaeol. Soc., 1992 **19** (2) 117-149

CUPP-COUTUNN CAVE SYSTEM, TURKMENIA, CENTRAL ASIA

by

V.A. MALTSEV and C.A. SELF

ABSTRACT

Cupp-Coutunn/Promeszutochnaya is the longest limestone cave in the (former) Soviet Union. The cave is part of an extensive area of palaeokarst, perhaps of Middle Cretaceous age, rejuvenated by tectonic movement in Neogene times. During the Middle Quaternary the cave was invaded by thermal waters which deposited calcite, fluorite and metallic sulphides. Post-thermal and modern re-working of these deposits has produced a stunningly decorated cave, with a unique mineral assemblage. The quality and unusual nature of these speleothems matches that of any cave in the world. In 1991, the caves were placed on the Global Indicative List of Geological Sites (GILGES) by a working group of the UNESCO World Heritage Convention.

INTRODUCTION

The Kugitangtau is a mountain ridge some 50 km long in Soviet central Asia (Figures 1, 2 and 3). The ridge is aligned north/south and forms the boundary between the republics of Turkmenia (Turkmenistan) and Uzbekistan. Immediately south of the ridge, the Amu Darya river marks the border with Afghanistan. In broad geographical terms, the Kugitangtau may be regarded as an outlier near the south-western end of the higher Baysun ridge, which connects directly with the Gissar range of mountains at the western end of the Tien Shan mountain chain. The well-known mineral cave Fata-Morgana (also known as Gaurduckskaya) lies on the independant Gaurduck ridge to the west of Kugitangtau (Figure 3). The name Kugitangtau is a combination of both Tadjik and Uzbek words and means literally ''mountain-canyon-mountain''. The local people normally use only the Tadjik part of the name — Kugitang — but since this abbreviated version is also used for a village, a river and a lake the full version specifies the mountains themselves. This is the form normally used on maps.

The Kugitangtau is geologically an anticlinal dome whose core comprises Pre-Cambrian gneisses into which a Hercynian granite batholith has been intruded (Figure 4). Unconformably overlying the gneisses are a 300 m sequence of Triassic and Lower Jurassic flysch, with locally some material of volcanic origin. The flysch leads up into the main limestone sequence, the 400 m thick Kugitang Series of Upper Jurassic age. The Kugitang Series passes conformably up into the 200 m thick gypsums and limestones of the Gaurduck Series, also of Upper Jurassic age. Cretaceous rocks, of both shallow sea and continental type, disconformably overlie the Gaurduck beds but do not outcrop on the Kugitangtau ridge itself. Similar deposits of Palaeogene and Neogene age may be found some 40 km from the ridge.

Tectonic structures dominate the topography of the region. A major fault, the

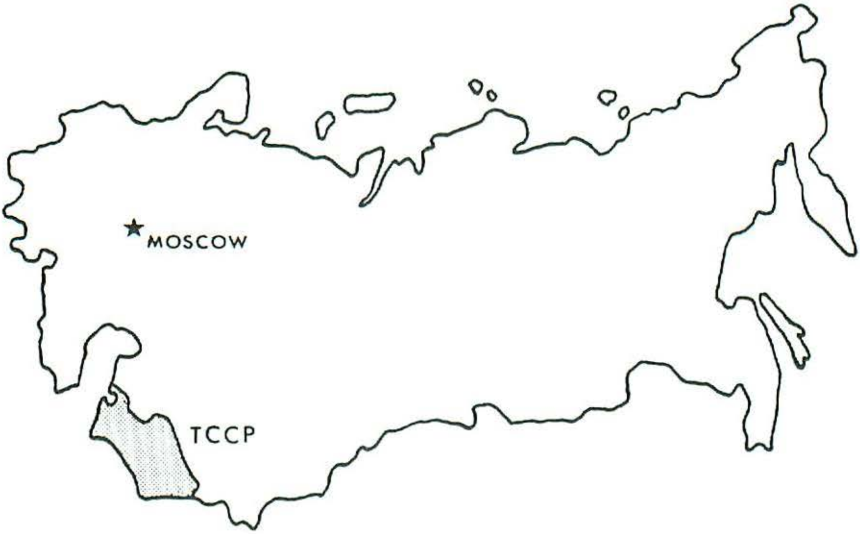


Figure 1. *Turkmenia and the Soviet Union.*

Eastern Kugitang Upthrust runs within the granite along the long axis of the anticline, and it is the uplifted western side which forms the Kugitangtau cuesta. The cuesta presents a scarp face over 1 km high, the upper limestone wall of which is near vertical and dominates the Uzbek plain to the east. The anticlinal dome is not symmetrical across the fault line, the dip to the west varying between about 7° and 15°, being much steeper to the east at about 60°. As a result, the western (Turkmenian) flank of Kugitangtau is an extensive limestone dip slope, while on the Uzbek plain the steeply dipping limestones form only low hills (though in the north-east there are two larger hills with caves of archaeological importance).

The Turkmenian dip slope of the cuesta is cut by a second major fault, sub-parallel to the Eastern Kugitang Upthrust but smaller and with opposite throw. The central spine of Kugitangtau may thus be regarded as a horst block, mostly gently sloping, but with a central mountain group culminating in a peak of over 3000 metres. The dip slope of the horst block is known as the "upper plateau" and, though made of limestone, it has few karst features. Surface weathering forms dominate, with spectacular canyons which give the region its name. At the northern end of Kugitangtau, another small fault within the horst block raises an area of limestone as the "top plateau". Active modern karst seems to be restricted to this small area, where there are vertical cave systems.

To the west of the sub-parallel fault, flanking the horst block, the lower ground is a narrow ribbon of sloping land comprising the uppermost beds of the Kugitang Series. In the south and south-west this ribbon becomes a more extensive dip slope known as the "lower plateau" (see Figure 4, section). Like the upper plateau, surface weathering forms dominate but here the cliff-walled canyons have intersected caves from an earlier cycle of erosion. Most speleological study has been concentrated on the south-western flank of the lower plateau, where access has been made easier by the building of mining roads. Here Cupp-Coutunn and

Figure 2. *Regional map.*

its associated caves are found, comprising Cupp-Coutunn (main), Promeszutochnaya, Tush-Yurruck, Hushm-Oyeek, Geophyzicheskaya, Verticalnaya and some minor caves. To the east lie the separate drainage systems of Bezuimyannaya, Chindjeer and Kainar. The cave entrances are all found in the walls of canyons, with the single exception of Hushm-Oyeek which has a collapse entrance from the plateau. Cupp-Coutunn is a locally common cave name, so the term Cupp-Coutunn (main) is sometimes used to designate the main cave of the region. In some references, particularly in mining journals, the name Karlyukskiye Caves is used (see Figure 3 for location of Karlyuk village).

To the south-west of Cupp-Coutunn, the sloping limestone plateau passes beneath the (Gaurduck Series) gypsum beds of the surrounding alluvial plain. Along the lower margin of the limestone there are often small flanking hills capped by gypsum beds, with some small gypsum caves unrelated to the drainage in the

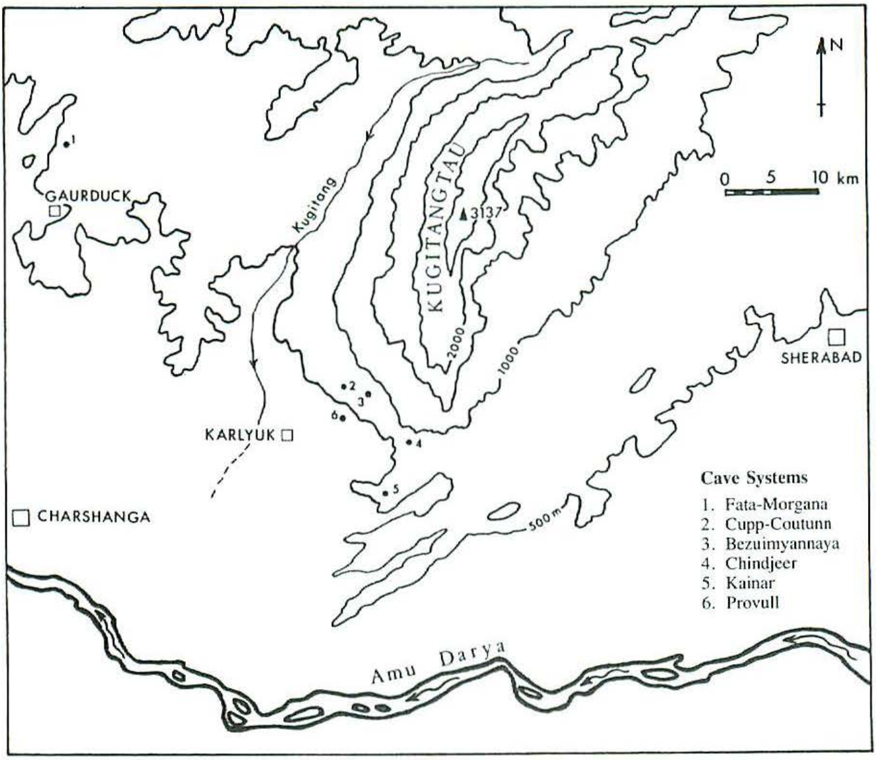
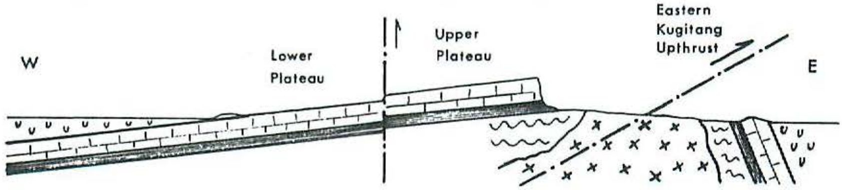


Figure 3. *Kugitangtau.*

limestone. There are also subaqueous caves in the gypsum karst of the plains (eg. Provull), but there is no proven hydrological connection with the underlying limestone.

The climate of the region is semi-desert, with rain for only a short period during the spring and autumn. Flowing water in either caves or canyons is unusual, though major floods do periodically occur. The temperature in the caves varies with altitude, from 17°C in Geophyszicheskaya to 22°C in the southern part of Promeszutochnaya. In some parts of the cave there are high concentrations of hydrogen sulphide and carbon dioxide gases. Radon is present in low concentrations, mostly in the vicinity of middle Quaternary clay infills. Apart from a few isolated pools of water the caves are very dry, though the cave air remains humid. In areas of weak air circulation the humidity is usually 100%. Along the windier galleries it varies with the season. When air is being drawn into the cave, the humidity at 300 metres from the entrance, can fall to as low as 70%. When the wind is flowing from the cave, the humidity is normally 100% at 100 metres from the entrance. New (mined) entrances have seriously affected the humidity and airflow patterns in the caves and are already having a deleterious effect on speleothem growth. Late in the year 1991, the mined entrances to Cupp-

Coutunn and to Promeszutochnaya were gated by the Gaurduck Geological Service, greatly reducing the problems of both airflow and casual visitors. Access for responsible cavers is still available by arrangement.



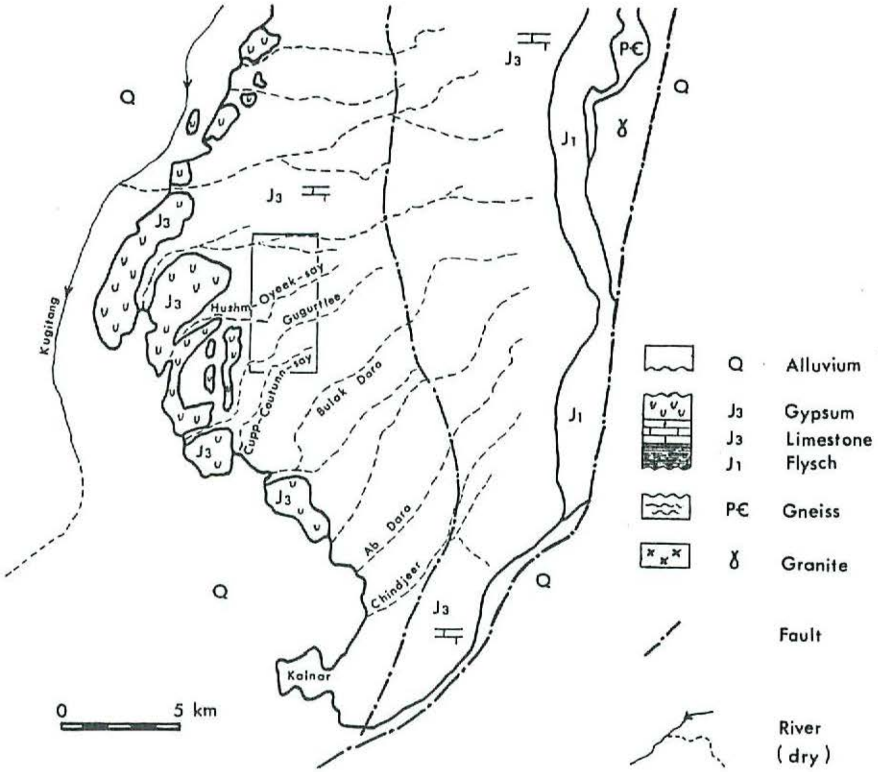


Figure 4. *Geology of southern Kugitangtau.*

HISTORY OF EXPLORATION

Hushm-Oyeek cave has been known from ancient times and may, according to Gvozdetsky (1981), correspond to a cave recorded in the "Bibliotheka Historica" of Diodorus Siculus (c. 40 BC). Other caves of the area have probably been known to local shepherds, but the earliest proof of exploration is a bottle left in Cupp-Coutunn (main) cave, some 700 m from the entrance. The bottle, found some forty five years later, contained a piece of paper dated 1932 left by a party of tourists from Moscow. Unfortunately the names of this party were at the bottom of the page and this part of the paper had already begun to disintegrate.

The first proper study of the caves was by Sultan Yalkapov of Ashkhabad during the period 1956-64. Cupp-Coutunn (main) cave (originally named by Yalkapov Cupp-Coutunn II, to distinguish it from the gypsum karst cave Cupp-Coutunn I, also in this region) was explored for a length of 2 km. Hushm-Oyeek was explored to 3 km and early explorations made in Tush-Yurruck, Bezuimyannaya and Dalnaya (part of the Bezuimyannaya system of caves). Yalkapov first described the karst drainage of the area and suggested that the caves are older than the canyons (Baikalov et al, 1970). The canyons are generally agreed to be of mid-Quaternary age (Geology of USSR, vol XXII, 1972).

During the 1970s some geological studies and explorations were made by Samarkand cavers led by V. Kucheryavuih. Cupp-Coutunn (main) was extended to 5.6 km, Hushm-Oyeek to 7 km, and some small caves also found. Kucheryavuih generally agreed with Yalkapov's karst drainage model (Kucheryavuih and Abdujabarov, 1982) but thought the caves and the canyons to be of the same age.

From 1970 to 1982, several of the caves were mined for calcite speleothems which were then made into wall tiles and ashtrays. Gypsum formations were sawn off and taken as souvenirs. Cupp-Coutunn (main), Hushm-Oyeek and Tush-Yurruck were affected and during this phase the cave Promeszutochnaya was discovered and also mined. At this time the known length of Promeszutochnaya was 1.5 km. The mining was eventually stopped by adverse public opinion, following a campaign led by Moscow and Ashkhabad cavers.

In 1981, the systematic study of the Cupp-Coutunn system was started by our group, then called the speleological section of the Institute of Mineral Resources. (This team has an amateur and informal membership and currently works under the aegis of the USSR Geological Society.) During the first expedition in 1981, the blind fish *Noemacheilis starostini parini* was collected by V. Maltsev in the gypsum cave Provull. This new species, of the stone loach family (Figure 5), lacks even the relics of eyes and two fish were sent alive to Moscow for further study by S. Smirnov and V. Parin (referred to in Zalesskaya and Golovatch, 1989). During the second expedition, V. Stepanov identified hydromagnesite in Cupp-Coutunn (main) and since then mineralogical studies have become an important part of our expedition programmes.

In 1982, the Gaurduck Geological Service (GGS) took over responsibility for the caves, ostensibly for their preservation. By 1986, however, the GGS were preparing to mine Geophyzicheskaya and only the action of one of their engineers prevented them. Y. Kutuzov blocked himself inside the cave with two friends and stayed there for six weeks. He lost his job as a result of this action, but the cave was saved. The stunning speleothems of Geophyzicheskaya (Frontispiece) give some impression of the former beauty of the main galleries of other caves before mining.

Between 1983 and 1984 the length of Cupp-Coutunn (main) was increased to

19 km, mostly as a result of detailed surveying, though some new areas were also found. In 1985, a breakthrough was made into the most interesting part of the cave, increasing the length to 23 km. The new areas contained very unusual speleothems with concentrations of many different minerals in one region — calcite, aragonite, cerussite, hydromagnesite, celestite and manganese oxides (Maltsev and Bartenev, 1989). During this period the gypsum karst cenote Provull was dived by E. Voidakov to a depth of 58m. Promeszutochnaya was resurveyed by A. Vyatchin of Gorky and new areas discovered, increasing the length of the cave to 17.5 km. Two new caves were found in 1985: Y. Chernuish of Moscow found Geophyzicheskaya with a team of schoolboys, and a cave of 2.5 km, as yet still unnamed, was found by Shakhmatova of Krasnoyarsk in Ab-Dara canyon (Figures 3 and 4). This cave is part of the Chindjeer system and lies to the east of both the Cupp-Coutunn and the Bezuimyannaya cave systems.

Figure 5. *Blind fish* Neomacheilis starostini parini.

In the years 1986 and 1987, Cupp-Coutunn was extended to 27.5 km and a connection made with Promeszutochnaya. Unfortunately, the connection gave easy access from Promeszutochnaya to one of the most beautiful areas of Cupp-Coutunn, so the passage was immediately resealed. In 1991, a new link was made via the strenuous B-podval series. After several years of work by one of our teams in Cupp-Coutunn, and by a Krasnojarsk team in Promeszutochnaya, the first traverse of the two caves was made by a combined group of Moscow, Bristol and Siberian cavers. In 1988 the Kugitangtau National Park was established and control of the caves is now contested between the Kugitangtau National Park and the Gaurduck Geological Service. Since 1988, the focus of attention for most of our group and that of S. Volkov (Balashikha) has been Promeszutochnaya, which has been extended to 25.5 km.

Since our first brief report in 1982 (Maltsev, 1982), a number of papers have been published in Russian on specialist topics concerning this cave system (Maltsev, 1987a; Bartenev and Veselova, 1987; Bartenev, 1987; Maltsev, 1987b; Bartenev and Maltsev, 1989; Maltsev and Bartenev, 1989; Maltsev, 1989; Maltsev and Malishevsky, 1989). The present paper is the first broad over-view and general description of the caves.

With local official bodies now competing for the right to manage the caves for tourism, it is to be hoped that the mining of the caves has ended for ever. There are, however, still many other problems for conservation. Traditionally, local people have used gypsum stalagmites (which are hollow) as lampshades, and even among cavers there is a problem of souvenir-collecting. Worst of all are visiting geologists who are able to recognise rare and unusual mineral deposits. Having picked clean Fata-Morgana (an inevitable loss since it underlies at shallow depth the encroaching Gaurduck sulphur mine) they are now visiting the Cupp-Coutunn caves. In April 1990 our team found a unique occurrence of fluorite crytals growing on helictites. Returning two days later for photography, we found the formation vandalised. It is for conservation reasons that a description and survey of the caves has never before been published. Even in this report, published outside the Soviet Union, we feel that a general rather than a detailed description serves better to preserve the beautiful and often unique formations in this cave.

CAVE SYSTEMS OF SOUTHERN KUGITANGTAU

In this section only the limestone caves of the southern part of the lower plateau are considered. Beneath the sloping limestone surface, which here follows the gentle 7° dip of the strata, there appears to be an extensive network of ancient sediment-filled caves. The caves are planar phreatic mazes, each one developed on several levels aligned with the dip of the limestone. Passage dimensions can be quite large, but the accessible cave is often much smaller due to ancient infil material and modern alluvium. At the present state of knowledge, it is impossible to prove that these caves were once all part of a single phreatic network, but this is certainly a possibility.

The accessible caves have all been reinvaded by meteoric waters and have lost, at least in part, their ancient argillaceous filling. The major caves with extensive open passages are all to be found to the west of small sub-meridional (sub-north/south) faults, as shown in Figure 6. At their northern end these faults split off from the major fault that marks the boundary with the upper plateau, but they have the opposite throw (10-20 metres upthrow to the west is typical). They vary a little in orientation but generally follow the direction of the dip at first, then curve to the south. They were formed during the same uplift period as the major faults of the Kugitangtau central spine. The canyons mostly have a north-northeast/south-southwest trend and are crossed by these minor faults, usually with springs at the lowest point of intersection. The faults appear to be the main groundwater route, both now and in the past, and to have been responsible for the rejuvenation of the caves (see Karst History section). A group of much smaller faults of the Chilgas tectonic zone, oriented about 330°, are also present but do not carry water. These Chilgas faults are tear faults with a small displacement (usually less than 10 metres) but where there is vertical movement, the upthrown block is to the east, the opposite throw to the more significant sub-meridional faults. The Chilgas faults sometimes have lead/zinc mineralisation.

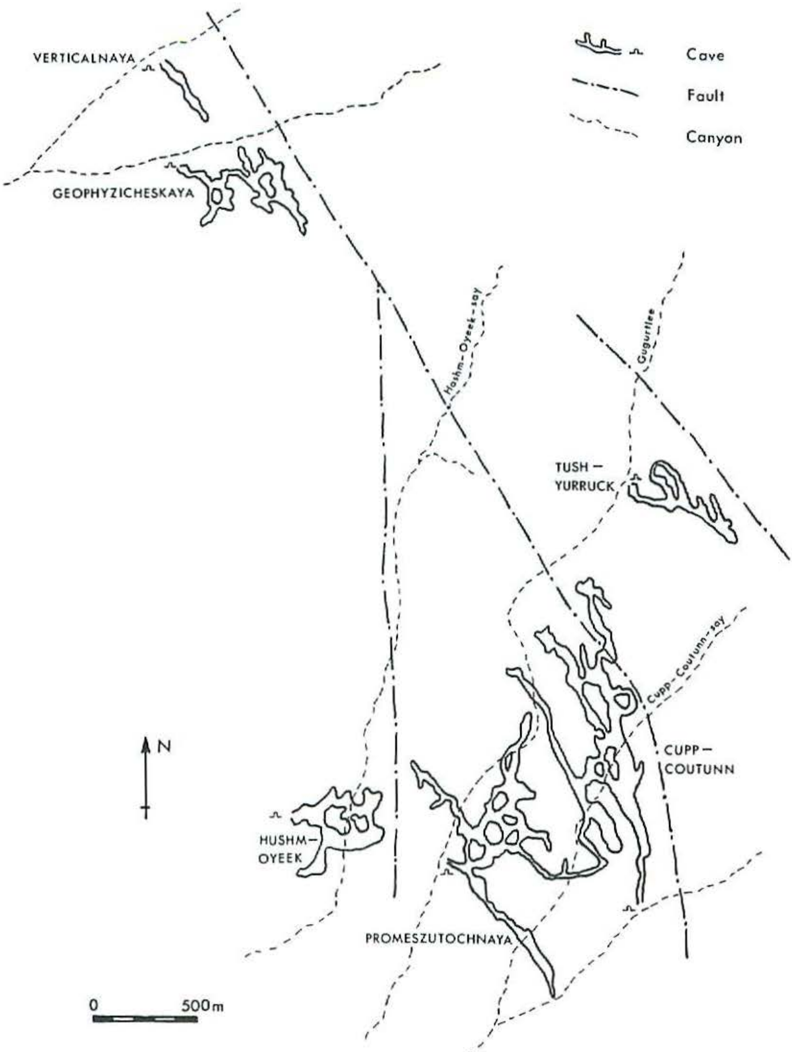


Figure 6. *Sketch map of the Cupp-Coutunn system.*

The caves of southern Kugitangtau appear to be grouped into systems (as shown in Figure 3) each associated with (and rejuvenated by) a sub-meridional fault, but since the caves are older than the faults (see Karst History) we cannot say that the systems do not interconnect. The cave systems are here treated separately and described below in order from north to south.

The Cupp-Coutunn system has a total explored length of 72 km, of which the longest cave is Cupp-Coutunn (main)/Promeszutochnaya at 52 km. The system is based on one major sub-meridional fault (Figures 6 and 7) with a spring of 15 l/s in Bulak-Dara canyon. This fault was responsible for most of the rejuvenation of the cave, but a smaller fault to the west has influenced Hushm-Oyeek. The cave Promeszutochnaya traverses between both these faults. A second small fault has affected Tush-Yurruck and Yalkapova Chamber in the north-eastern part of Cupp-Coutunn (main) (see Figure 6).

Figure 7. *Cupp-Coutunn-say canyon viewed from the plain. The near skyline is the surface expression of Cupp-Coutunn's sub-meridional fault. The far skyline is the upper plateau.*

The Bezuimyannaya system length is only 5 km, divided between Bezuimyannaya and some smaller caves. The system is controlled by a fault whose spring of 10 l/s is in Ab-Dara canyon. The explored length of the Chindjeer system (by Shakhmatova in 1985) is 2 km in one cave as yet un-named in the upstream part of Ab-Dara canyon. The fault controlling the system drains to Chindjeer spring, which has a flow of 20 l/s. The spring is accessible for 10 m but is blocked underwater by collapse.

The Kainar system probably covers the largest area, and has a more complicated tectonic structure. Two small anticlines, with axial direction east-southeast and bedding angles up to 40° are separated by a graben. These structures control the surface relief, producing a pair of small ridges 1 km apart and extending for 3 km. Only a few small caves of up to 200 m are as yet explored, some of which have strong air flows. Kainar spring has a flow of 1000-1500 l/s emanating from a large collapse, but digging is impossible without undermining a nearby road. 50 metres beyond the main resurgence there is a second resurgence, gushing up from small holes in the plain at 30 l/s and with a high hydrogen sulphide content. Similarly foul water is seen at a cenote in the gypsum karst 1.5 km south-east of Provull, with hydrogen sulphide probably derived from bacterial activity in the gypsum phreas. The two Kainar springs feed into Kainar lake, where troglobitic fauna (*Stenasellus asiaticus*) sometimes appears.

The discharge from the Kainar springs does not significantly alter during the year, suggesting that the aquifer is sufficiently large to balance seasonal input variations. The small springs associated with the faults to the north are, by contrast, very variable and respond quickly to rainfall. In the caves, dripping water in passages close to sub-meridional faults also responds rapidly to rainfall, being appreciably colder than cave temperature when snow has fallen on the upper plateau.

It should be stressed that flowing water is seldom observed in the caves, which are very dry except during major floods recurring at intervals of about ten years. The springs are thus drainage from diffuse flow groundwater systems draining to the faults, and rising to the surface in the floors of the canyons near the boundary of the limestone plateau and the gypsum plains. The small springs are overflow outlets, while Kainar is a major resurgence at the hydrological base level.

Beneath the plains at a depth of 10-40 metres there are large diameter conduits entirely water-filled and phreatic in form, such as can be seen at the cenote Provull. At greater depths (200-300 m) boreholes have yielded artesian water in the limestone beneath the plains. Chemically, the waters in pools inside the caves and the artesian waters are similar, but the phreatic water of the caves beneath the plains is dissimilar. This is however to be expected as the caves beneath the plains are in gypsum and there is no noticeable water flow. Chemically there is no way of determining whether the limestone cave water feeds the sub-plains phreas or goes deeper to the artesian zone.

The plains phreas may be quite old because of the fauna it contains. The blind cave fish seen in Provull is more cave-adapted than normal, lacking even the relics of eyes, and must have had a stable environment for a considerable time to so evolve. Though it is possible that the fish evolved elsewhere and only subsequently colonised the gypsum phreas, we favour the theory that the plains phreas is a single common collector for the water of the region, both from the faults and from the caves. At present we have no idea whether the water eventually drains to the Amu-Darya, the major river to the south, or evaporates through the porous surface rocks. The evaporation model is attractive because there are no springs near the Amu Darya noticeably contaminated by hydrogen sulphide. Boreholes in the gypsum rocks of the plains phreas often reach such contaminated water. The range of the troglobitic fauna would in this case be limited to those parts of the collector near to the drainage points of the caves and/or faults, where the water is still fresh. Further limits to this range are suggested by the presence of normal river fish in cenotes close to the Kugitang River to the west.

THE CAVES OF THE CUPP-COUTUNN SYSTEM

CUPP-COUTUNN (Main)

Also known as Cupp-Coutunn II

Length 27 km Vertical range 203 m

The natural entrance is a hole at the top of a large collapse, 40 m high, in the north wall of a small canyon, tributary to Cupp-Coutunn-say (Figure 6). There is evidence of a continuation of the cave in the south wall of the canyon, but access has not been made.

The entrance leads to a great gallery (Figures 8 and 16), up to 20 m high and 50 m wide, which heads north for 1500 metres until it is blocked by alluvial sediments as it approaches Gugurtlee Canyon (Figure 6). This main gallery of Cupp-Coutunn rises steadily to the north, but has a number of flood channels in its floor that enter from the east and leave to the west, sometimes flowing south along the gallery floor for a short time. The

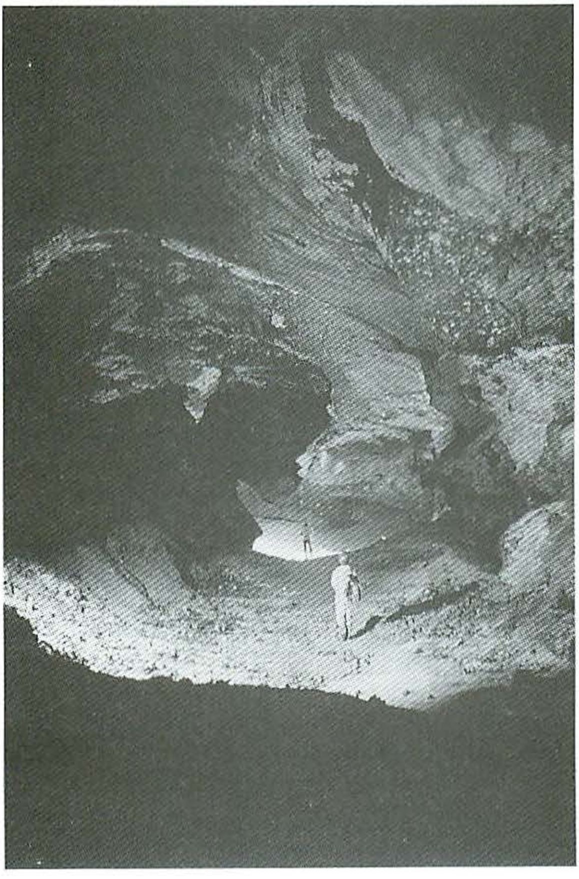


Figure 8. *Cupp-Coutunn. Main Gallery near Fontyan Chamber.* (Photo: J.T. Griffiths)

flood channels are contemporary, the water entering the cave from a sub-meridional fault that parallels the main passage at a distance of 150 metres to the east.

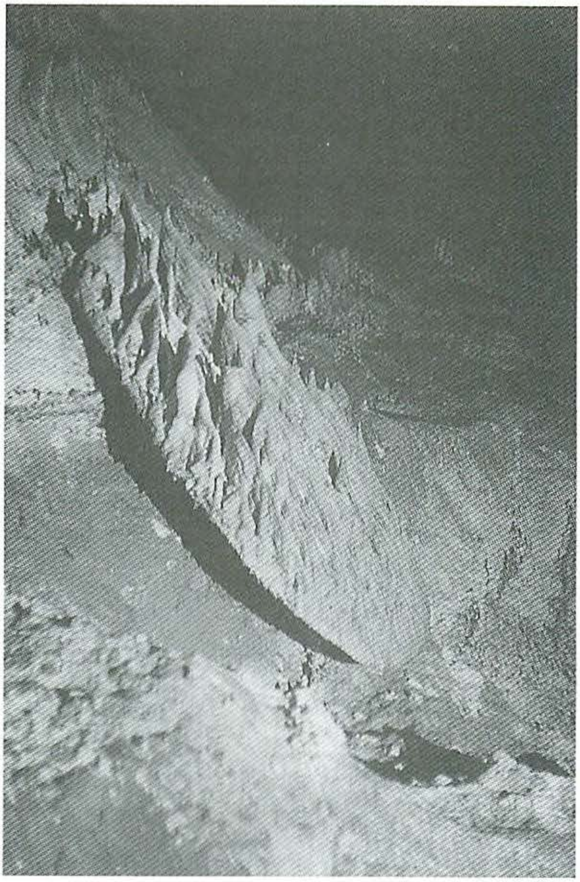


Figure 9. *Calcite shield in Cupp-Coutunn.*

Between the main gallery and the fault there are some minor mazes, generally of quite large passages and chambers, with an unusual spherical morphology (discussed in Karst History). Closer to the fault these passages divide into much smaller tubes. These eastern mazes have a connection, via Dvukh Kolodtsev (''Two Shafts'') chamber, to the eastern part of the system located beyond the fault in the same structural block as Tush-Yurruck cave. (Note: though this series appears from the survey to be the northern end of the cave, it is described as ''eastern'' because it lies to the east of the main gallery). These passages lead to the very large Yalkapova chamber, but are then blocked by alluvial sediments in the region of the surface Gugurtlee canyon. Dvukh Kolodtsev chamber lies at the crossing of a Chilgas fault and the sub-meridional fault, the cave showing 10 metres displacement across the Chilgas fault. The main fault is not seen in this chamber and the tentative evidence we have for this crossing is mineralogical — a plot of the location of calcite shields (Figure 9), which can only grow where the percolating water has a hydrostatic head and in this cave occur only in the close vicinity of this fault.

Cupp-Coutunn (main) also has an extensive lower series, below and to the west of the main gallery. This lower series also contains roomy galleries oriented north/south, usually with evidence of southerly water flow along them. In many places they have a distinctly vadose appearance, unlike the collapse chambers that are typical of this system. On closer inspection these ''vadose'' walls are seen to be ancient sediments in a larger phreatic passage.

The connection between the upper and lower levels is via a low labyrinth whose walls are part rock and part ancient infill material. The roof has been strongly affected by condensation corrosion and the floor is covered with recent alluvium and gypsum sand. The main gallery of this labyrinth is crossed by a zone of east/west fissures. These fissures are 10 metres high but only one is passably wide. This chimney climb, Soochy Dety (''Children of a Bitch''), provides the only access from the upper to the lower cave.

The lower cave consists of a central maze with some large chambers (eg. MGRY, Baobab) and four main galleries. The northern gallery has four levels and is very extensive, leading from Zazavallny (''After Boulder Choke'') chamber to Plasznaya (''Beach'') gallery where it ends in a mud blockage. The passage has been blocked, for conservation reasons, near Bolshoi Geophyzicheskaya (''Big Geophysical'') chamber. For two thirds of its length, the northern gallery takes flood water from the main gallery of the upper cave. In Bolshoi Geophyzicheskaya chamber, stoping has exposed some small palaeokarst cavities in the roof containing a distinctive yellow clay. Similar clays in palaeokarst pockets of Fata-Morgana cave (Gaurduck) are a mixture of illite and haematite. In all the caves, palaeokarst pockets are only seen in areas of breakdown, which suggests that they have the same age as the main cave passages.

The second gallery, Strana Durakov (''Country of Fools'') and Kuzkina Mutt (''Bad Beetle's Mother''), is in beds 15 metres deeper. This passage heads north-west in a very direct line, suggesting that a structural control along its left wall (perhaps a small fault) has limited the rejuvenation of this part of the cave. The gallery has at least two levels, the lower of which is a flood channel. The upper level is not continuous and consists of large chambers, much collapsed, with some side mazes. In the middle of the lower level, just beneath Gugurtlee Canyon, there is a short syphon with stalactites underwater. In this region there is an air and voice connection with Promeszutochnaya and an air connection with Vorony Sir (''Crow Cheese'') in the northern gallery. The far part of this gallery appears to be a maze of at least three parallel passages, much collapsed and partly filled with mud.

The third gallery contains Nadeszda (''Hope'') chamber, one of the largest chambers in the cave. The chamber ends with a structural drop caused by a Chilgas fault, and considerable collapse.

The final gallery is Makaronnaya Rechka (''Macaroni River''), which heads south at the level of the end of Nadeszda Chamber. The gallery turns to the west into a maze, somewhat similar to the one between Cupp-Coutunn main gallery and the lower levels, and enters the B-podval (''Very Bad Basement'') area. The B-podval maze takes the flood drainage of 20% of Cupp-Coutunn and 15% of Promeszutochnaya, with its outflow to the south blocked by mud. It is also the deepest part of the cave, 170 metres below the natural entrance. In the north-west part of the maze a connection has been found to Promeszutochnaya.

Cupp-Coutunn also has an artificial entrance to the main gallery. This mined entrance, and the mined entrances to Promeszutochnaya, have greatly altered the circulation of air, both within and between the caves. The most obvious effect has been to draw in cooler and drier air, which reduces floor sediments to dust and gives an ''abandoned'' appearance to nearby parts of the cave.

PROMESZUTOCHNAYA

Length 25.5 km Vertical range 95 m

The cave has a natural entrance in the bottom of Gugurtlee Canyon and two artificial (mined) entrances, the most northerly of which is the normal point of access. The natural entrances of Promeszutochnaya and Cupp-Coutunn (main) are 1 km apart in adjacent canyon systems.

Promeszutochnaya generally consists of a net of northwest/southeast and northeast/southwest passages with some mazes and with extensive clay fills. No lower level series is known, probably because the passages are blocked by clay. Large collapse chambers and collapse mazes along the eastern side could be an indication of lower level passages that are not completely infilled. The cave passes under both Gugurtlee Canyon (in the Skazka ("Fairy Tale") region, and in the north) and also the Cupp-Coutunn canyon (Oksanochka chamber).

The large size of passages in the central part of the cave are due to invasion by surface water from the canyons, with removal of sediment and subsequent collapse. The water drains to the southern part of the cave, access to which is sometimes blocked by alluvium after floods. The shifting alluvium causes ephemeral lakes in some passages. The Kanalizatsia ("Sewage") region is the lowest part of the southern series and there is probably a (temporarily choked) hidden passage here which takes the flood water and its sediment to the west, since alluvium does not reach the most southern part of the cave. A narrow fissure on the south-western side of Oksanochka chamber allows access to the far south, via a low passage containing calcite formations. The southern end of the cave is a great ancient collapse with condensation corrosion on all faces of the constituent boulders. The bottom part of this collapse, 7-10 metres below the main level, is accessible and also shows evidence of periodic flooding. The low corrosional activity of such flood water can be demonstrated by the similar morphology of the boulders at the top and bottom of this collapse. Only gypsum formations are corroded.

The northern part of the cave, beyond Kaskidniy ("Cascade") chamber, is generally low and wide with recent alluvium choking the western margins. Where the cave passes beneath Gugurtlee canyon a coarser infill, up to cobble size, is seen with deeply incised flood channels. This is well displayed in the upper part of the Gallery Fanatikov. The northern termination is an area of collapse where tectonic fractures cross the line of the cave. The eastern margin of this part of the cave is passable at several different levels within the collapsed beds but no route can be followed far. There is a wind connection from here to both levels of Strana Durakov in Cupp-Coutunn. Fortunately, the extensive nature of the collapse should deter attempts to dig an easy route to the vulnerable lower series of Cupp-Coutunn.

The western branch, comprising Zyelonykh Zmiev ("Green Snakes") and OSKHY passages, is not well understood. The passages are generally of small dimension with strong evidence of condensation corrosion. The circulation of air is variable but usually from the west, where the cave Hushm-Oyeek lies at a few hundred metres distance.

One unusual feature of this cave is an apparent structure oriented northwest/southeast, governing not the cave passages themselves but the general accessibility to some of the mazes. This is best seen in the western branch, where there is no main gallery linking the mazes. The nature of this feature is unknown, but it appears to be tectonic and may indicate the line of a major drainage route in Mid-Quaternary times. To the northwest this structure points directly towards Geophyzicheskaya and Verticalnaya; to the southeast it points to the spring in Bulak Dara canyon and beyond it to Provull, the gypsum cenote.

HUSHM-OYEEK

Length 7 km Depth 170 m

Hushm-Oyeek is a very complicated cave consisting (in plan) of an isometric maze of gigantic chambers (up to 270 m long, 95 m wide, 25 m high) and large collapses (up to 120 m deep). One of these collapses reaches all the way to the surface and is the entrance to the cave. The extensive nature of the collapses has foiled attempts to find continuations at the main level of the cave. 10-15 metres above the main level there is an upper level of small tubes which have partially collapsed into the chambers. Beyond the perimeter of the chamber maze these tubes all become impassably small.

A lower level in the western part of the cave, Shakhterov passage, provides the modern drainage of the cave, but is blocked by mud. One kilometre further west there are a large group of gypsum karst caves, the largest of which is Cupp-Coutunn I (length 250 m, depth 46 m). These gypsum caves are at about 100 m lower altitude than the bottom level of Hushm-Oyeek.

Hushm-Oyeek is probably the modern drainage route for half of Promeszutochnaya (250 m distant) and for Geophyzicheskaya (3 km away). Seven hundred metres north of the cave there is a large drainage area in the floor of Hushm-Oyeek-say canyon, but this almost certainly enters Promeszutochnaya.

The hollow gypsum stalagmites of Hushm-Oyeek have traditionally been used by the local people as lampshades. Most of the smaller ones have now gone, but there are larger gypsum stalagmites (up to 20 m tall) and gypsum stalactites (up to 5 m long) remaining. There is a currently a plan to develop Hushm-Oyeek as a show cave. (Gypsum stalagmites are polycrystalline structures that normally grow from a gypsum floor crust. The humidity is higher within the hollow structure, causing gypsum to dissolve in the surface water film and then be re-deposited on the top and outside.)

GEOPHYZICHESKAYA

Length 4.5 km Depth (not measured, c. 100 m)

The cave has a collapse entrance in the wall of a canyon and has two main galleries, oriented SE directly towards Zyelonykh Zmiev in the western branch of Promeszutochnaya, 3 km distant. The cave also has mazes between the two galleries and a maze to the north. The chambers and passages of this cave have some interesting features, in part due to the location of the cave very close to the main water-bearing fault, in part because of drainage from the canyon into the cave. As a result, the galleries are much taller than in other parts of the system (up to 30 metres high). Some of the chambers are of the same spherical morphology as are seen to the east of Cupp-Coutunn main gallery.

Flood water from the canyon has considerably modified the cave, moving boulders from areas of collapse and introducing large quantities of alluvium. As a result, the main galleries end in clay blockages, and the presumed lower levels of the cave are not accessible. The potential exists for side passages to the main galleries, and for upper level passages. The relatively recent discovery of this cave, plus access restrictions, means that Geophyzicheskaya is one of the best preserved caves of the region. The cave lies beneath a plateau remnant of the Guarduck gypsum beds, and so contains the best gypsum chandeliers in the area. (Gypsum chandeliers are branching stalactites formed of large crystals (see Frontispiece). Gypsum swords are stalactites formed by a single crystal.)

VERTICALNAYA

Length 1.6 km Depth 95 m

The cave entrance lies near the top of a canyon to the north-west of Geophyzicheskaya. A short horizontal passage opens abruptly at the limit of daylight onto a vertical drop of 80 m, a danger to the unwary, to gain a gallery 600 m long oriented southeast. At the end of this gallery a large collapse separates the cave from Geophyzicheskaya. There are minor mazes to the side of the main gallery. The upper level of this cave has not been explored, but part of it can be seen in Nosorog cave whose entrance is in the wall of the canyon opposite Geophyzicheskaya. Nosorog cave is 120 m long and ends in a clay blockage.

TUSH-YURRUCK

Length 3.2 km Depth (not measured, c. 40 m)

The cave entrance is in Gugurtlee Canyon 600 m beyond the northern end of Cupp-Coutunn (main). The cave in plan is an isometric maze (like Hushm-Oyeek) but also has main passages oriented west-northwest/east-southeast. Because there is active drainage from the canyon, the passages are blocked by sediment and there is little hope of connection to Cupp-Coutunn (main). The cave is normally very dry and has no air circulation. No lower levels are known.

MINOR CAVES

There are at least twenty minor caves of length 100-500 metres associated with the Cupp-Coutunn system.

KARST HISTORY

The first estimate of the age of the Kugitangtau karst was made by Yalkapov (Baikalov *et al.*, 1970), who recognised that the caves were older than the canyons and so declared the karst to be pre- Middle Quaternary. Kucheryavuih (1982), however, thought that the caves and canyons were of a similar age. His ideas were based on the Middle Quaternary date of the last activation of the Chilgas faults which control the largest chambers of Cupp-Coutunn (main) and Hushm-Oyeek. Kucheryavuih thought that these faults were responsible for initiating cave development. It is now recognised that the caves are relict from an ancient palaeokarst and that the Middle Quaternary was merely a period of rejuvenation and excavation. There were several major phases of development:

Ancient Karstification.

In central Asia a very old period of karstification has been recognised, which predates the mountain-building that gives the area its present topography. Bosak (1989) in his study of the Karjantau karst proposes a Middle Cretaceous age for the main karst phase. Because of the similarities of palaeoclimate and post-Cretaceous geology, a similar age can be postulated for the Kugitangtau karst, though later dates are equally possible.

Within the caves there is clear evidence that they were formed before the raising of the Kugitangtau ridge. The caves seem to have developed as an extensive maze under planar phreatic conditions, the different levels reflecting different positions of the water table in what were, at the time, horizontally bedded limestones. In Cupp-Coutunn three main levels can be recognised, with the lower level often further sub-divided. For example, the Yo maze in the north gallery of Cupp-Coutunn's lower series has four levels that seldom interconnect, yet the thickness of rock separating them is less than one metre. If the (modern) 7° bedding angle had been present during the formation of the cave, one would expect to see phreatic loops and a more organised drainage pattern. With three distinct levels one would expect to find vadose passages, but this is not so. The plan survey of Cupp-Coutunn/Promeszutochnaya (Figure 16) is typical for a cave formed near the water table. At the end of this phreatic period all levels of the caves were completely filled with sediments. This ancient filling became consolidated and now forms the walls and roof in several parts of the modern cave. In the Svynyachy Siar ("Pig Cheese") maze, at the beginning of the northern branch of Cupp-Coutunn's lower series, an area of ancient argillites 150 x 100 metres can be seen with a marked yellow zone 2 cm thick, having the same bedding angle as the limestone. This proves that the cave infill is also older than the phase of mountain-building. Other examples of bedding-oriented ancient clays are known both in this cave and in Promeszutochnaya. In the surface canyons, Bulak Dara for example, horizons of palaeokarst pockets are also parallel to the bedding.

The Cretaceous palaeogeography of this area has not yet been determined in detail, but there are many similarities between the Kugitangtau cave mazes and the (small diameter) cave mazes currently forming in the salt water/fresh water mixing zone on the Ust-Urt shore of the Caspian Sea. These mazes have four levels, reflecting changing levels of the Caspian Sea. Perhaps the Kugitangtau caves also developed close to a large body of salt water. If the Middle Cretaceous age of the karstification is correct, a marine transgression during the Upper Cretaceous may have been responsible for ending the karst episode.

Regeneration

During uplift of the Kugitangtau ridge, which began in Neogene times and is still continuing, the planar cave passage mazes were tilted and then disrupted by faulting. Uplift had largely been completed by Middle Quaternary times, when the karst process restarted, accompanied by the formation of a dendritic pattern of canyons on the inclined plateau surface. Four phases of canyon incision are recognised, perhaps related to regressions of the Caspian Sea. A high water table in the caves during the early regeneration phase prevented underground drainage of the developing canyon systems.

Fluvial erosion has destroyed all traces of ancient surface karst forms and also parts of the upper levels of the caves. A cave remnant modified by such erosion is Tunnel Cave, part of the Bezuimyannaya system, where a canyon 100 metres deep enters the cave and re-emerges after 50 metres; the cave has some side mazes blocked by alluvial sediments. During the regeneration phase, the direction of underground drainage changed from the original south-southeast, as shown by clay and silt deposits in the main galleries, to the modern southwest. Three sequential sub-phases have been recognised for the underground karst process.

Rejuvenation. During this first phase the caves were in part freed from their ancient argillaceous filling. This was almost certainly as a result of water from the "upper plateau" being transmitted by the sub-meridional faults. With an altitude difference between cave and upper plateau of approximately 1 km, it is possible that the water was under pressure. All the major caves now made accessible by sediment removal lie on the western (downhill) side of such faults. In Cupp-Coutunn's eastern mazes, the passages leading to the fault divide into smaller phreatic tubes on several levels. These invasive tubes are younger than the rest of the cave. This rejuvenation phase appears to have been brief, with a quick transfer from phreatic to vadose to dry conditions. Erosion was mainly confined to the infill materials, with little dissolution of the limestone itself except near the faults. It is unfortunate that at no point can a sub-meridional fault be seen underground, though they form distinct surface features (Figure 7).

Chambers near the fault in the eastern mazes of Cupp-Coutunn are characteristically spherical and without collapse. Tintilosov (1983) has found that similar chambers in a Caucasus cave are the result of rapid seasonal flooding, where conditions change from dry to phreatic without a vadose river phase. In Cupp-Coutunn, such flooding may have been caused by a seasonally high water table during cold stages of the Quaternary. Alternatively, the chambers may have been formed during the subsequent hydrothermal phase of the cave's history, with slightly aggressive water entering via the fault. No thermal minerals have been found in this part of the cave.

Thermal Sub-phase. The air-filled passages of the caves were now invaded by thermal waters, entering from faults, which caused a chemical alteration of both the limestone of the cave walls and the ancient cave sediments. No ancient speleothems appear to have survived the thermal process. The water seems not to have been very aggressive and no evidence of cave enlargement by corrosion has been found, except (perhaps) in the immediate vicinity of the fault. The thermal waters deposited minerals in the cave, particularly calcite, fluorite and metallic sulphides. The mineralogy is described in detail in the next section.

The thermal process in the Kugitangtau caves appears markedly different from that of other, better known, hydrothermal systems. Carlsbad and Lechuguilla caves in New Mexico (Hill, 1987), Jewel and Wind caves in South Dakota (Bakalowicz *et al.*, 1987), the caves of Budapest in Hungary (Bolner, 1989) were all formed by the corrosive action of the thermal water. Mineral deposition occurred later, as the thermal waters lost their power to dissolve calcite. The Kugitangtau thermal water had already lost its aggressive potential before it entered the caves. The exotic Cupp-Coutunn mineralogy may represent the final evolution of the thermal water, with greater concentration of rare elements than in the American or Hungarian caves. A thermal karst cave may even be present, at depth beneath Cupp-Coutunn.

Activisation of Chilgas Faults. During the Middle Quaternary (according to non-published reports of the Gaurduck Geological Service) there was some movement of the small northwest to north-northwest oriented Chilgas faults. These Chilgas faults can be seen underground where there is a displacement of cave passages (structural drops). Most of this displacement took place during the Neogene uplift period when the faults were formed. Movement during the middle Quaternary had an even more profound effect, causing collapse in what were by then air-filled passages, and the formation of large collapse chambers in the vicinity of these faults. Subsequent enlargement of the main galleries by collapse through the upper levels postdates this movement.

Modern Phase

In the caves, the Modern Phase is marked by condensation corrosion of the cave walls and roof. The cave air contains a mixture of acidic gases (CO_2, H_2S and SO_2) which are taken up in thin films of water which condense from the vapour phase onto the cave walls. Dissolution occurs and the thin water film carries away the soluble material, leaving insoluble material as a crust that may eventually fall to the ground. This surface crust of residual clays is particularly evident in zones of thermal alteration of the parent limestone. Condensation preferentially occurs in depressions of the wall relief and the ensuing corrosion exaggerates such irregularities to give the cave a characteristically "rugged" appearence (e.g. Figure 10).

Figure 10. *Condensation corrosion enhances the jaggedness of the Vorony Sir maze in Cupp-Coutunn.*

Another feature of the Modern Phase is the irregular floods of surface water which enter the caves from the points where they cross under the canyons. These floods have had a considerable influence, bringing fresh alluvium into the cave, reworking the original argillaceous deposits, and both blocking and unblocking passages. Where large quantities of the original fill have been removed, roof collapse may occur, as seen in the central parts of Promeszutochnaya. Otherwise, these floods do not seem to have caused any significant enlargement of the cave, either by abrasion or by corrosion of the limestone. The Modern Phase has seen considerable deposition of both calcite and gypsum. V. Stepanov has studied the gypsum speleothems in the main level of Hushm-Oyeek and found six cycles of wet to dry conditions during growth. In other caves, decorated passages have been partially filled by coarse stream debris, with younger formations overlying both. The Modern Phase would appear to extend some way back into the glacial phases of the Quaternary.

In the surface canyons and on the lower plateau, there is little evidence of new karstification. Modern karst processes are represented by the development of caves in the gypsum beds (Gaurduck Series) that form small hills at the foot of the limestone plateau. The longest known is Kaptyarkhana, 1.5 km long and located on the middle-west flank of the ridge. These caves are not beautiful and are dangerously prone to collapse. Most are unexplored. The origin of these caves is interesting. Their lower levels are usually connected to the sub-plain phreas and may be quite old. Above the water table condensation corrosion is vigorous and the cave grows very quickly, soon collapsing through to the surface. The process is helped by a thin and porous roof, very warm water temperature and cold surface temperature in winter.

MINERALOGY

Mineralisation of Cupp-Coutunn and its associated caves may be divided into three phases, though there is some overlap particularly between the second and third phases. The first phase is thermal in origin, when the cave was filled with hot mineralised water. The second, post-thermal phase featured the destruction of the thermally altered limestone, mostly by the process of condensation corrosion. The mineral products of this second phase were concentrated in the residual clays or reworked into speleothems. The third phase of mineralisation is of normal speleothem growth. Nothing is known of pre-thermal phase mineralisation dating from the early history of the cave, and if there are any surviving samples of minerals from this period they will be buried in the remnants of the original argillaceous infill.

Thermal Phase

The first part of the thermal phase featured the deposition of giganto-crystalline white calcite (Plate 1). The calcite is of sub-aquatic crystal form and was deposited at a temperature of 100-150°C (determined from the homogenisation temperature of gas/liquid inclusions in the crystals). Mineral inclusions within the calcite, identified by X-ray diffraction, include galena (PbS), metacinnabar (HgS) and manganese oxides, the exact composition of which has not been determined. These inclusions normally comprise less than 0.25%. Subaquatic fluorite (CaF_2) crusts were then deposited under slightly cooler conditions, usually not more than 80°C. The fluorite is normally purple in colour with crystals up to 10 cm in diameter. The crystals (unusually) have no luminescence and lose their colour within a year when exposed to sunlight. In Dvuketajniy "Two Levels" chamber in Promeszutochnaya, a "hot" fluorite has been identified with a homogenisation temperature up to 170°C. Crystals of galena (up to 1.5 mm size) and quartz (SiO_2, up to 1 mm size) have been identified by binocular microscope on the surface of this "hot" fluorite. In other cases calcite is seen to be growing paragenetically with the fluorite. The fluorite has a high strontium content (up to 4%), but no rare elements. The strong colour of the fluorites in the western branch of Promeszutochnaya (Plate 2) seems to be concentrated on the outer part of the crystals, and may be a dissolution effect. Thermal minerals also entered the palaeokarst pockets, with calcite deposition seen in pockets exposed in Bulak Dara canyon and fluorite in Geophyzicheskaya.

During a late part of the thermal phase substantial dissolution of fluorite took place, with an etched relief on some crystals of as much as 3 cm. During this period (and also the post-thermal period) the giganto-crystalline calcite was also corroded. The ore mineral inclusions were not dissolved and so became concentrated on the surface of the crystals, giving them a metallic lustre (Plate 1). This surface coating is normally 0.02 to 0.1 mm in thickness. Metacinnabar surface coatings in Fata-Morgana cave (Gaurduck) are thought to have a quite different origin due to erosion caused by pressurised steam, lost into the cave during sulphur extraction from the nearby Gaurduck sulphur mine (D. Belyakovsky, pers. comm.).

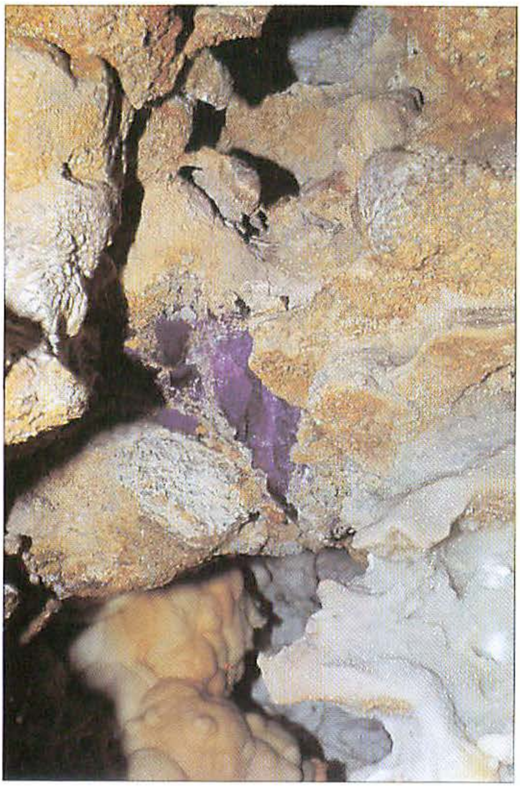
During the thermal period, the limestone of the cave walls was substantially altered, to a depth of 0.5 to 1.0 m. In fresh limestone, the non-soluble component is 2-5%, but in altered limestone this can be as much as 30%. Alterations include recrystallisation of calcite and partial replacement by other minerals, mostly sulphides and silicates. Small amounts of quartz and plagioclase feldspar also grew in the limestone during this period. The presence of plagioclase is unusual, since it is normally formed at much higher temperatures. This suggests there may have been a very hot phase at the beginning of the thermal process, most products of which did not survive later phases. Temperature variations during a thermal episode are difficult to prove, but may be quite common. Bakalowicz et al (1987) propose cyclic warm episodes for the hydrothermal process in Jewel Cave (South Dakota), to cause degassing and so bring the mineralising solutions to supersaturation.

Post-thermal Phase

During this period residual clays were formed by dissolution of the thermally altered limestone (seen in Plate 1). The clays contain clearly visible sulphides and what appears to be mica but detailed studies have yet to be undertaken. The similarity of the Cupp-Coutunn residual clays to those of Fata-Morgana suggests the mica may be illite; for the same reason, the iron oxide haematite is probably present (Lazarev and Philenko, 1976). The main component of the residual clays still attached to the cave roof is goethite (X-ray identification by M. Tranteev of Bulgaria, pers. comm.). Normal clay minerals are usually less common, perhaps because of leaching of Al and Si during the thermal process. In the Dvuketajniy region of Promeszutochnaya, the orange-red clays have been found to contain zinc-based analogues of the alumino-silicates muscovite and chlorite. In southern Promeszutochnaya, the main component of the clays is kaolinite, but up to 5% lead oxide is present near the point where a galena vein is exposed in the cave wall.

In some of the cave mazes which were deeply corroded during the post-thermal period "mostly-gypsum sands" have been found. Analysis by Tranteev shows that these sands contain, in decreasing concentrations, gypsum ($CaSO_4.2H_2O$) crystals up to O.5 mm size, iron oxides and hydroxides, clay minerals, calcite, dolomite, sulphur, silicates and sulphides. The gypsum sand develops in regions of high atmospheric H_2S concentrations, where more gypsum forms than can be removed by condensing water. A bacterial process is probably involved, for free

Calcite deposited during the thermal phase in Cupp-Coutunn. The grey lustre is caused by metal sulphides. The limestone has an orange crust coating of residual clay.



"Hot" fluorite from western Promeszutochnaya.

Green sauconite within calcite flowstone in Promeszutochnaya.

Celestite crystals on a calcite helictite in Promeszutochnaya.

sulphur is found both within and as a dust layer upon the sand (these sulphur patches can be as much as 1 metre across). Some of the clay minerals are reworked within the sand, with reduction of Fe^{3+} to Fe^{2+}.

Some of the products of the thermal phase were also reworked into speleothems. This reworking of material has continued into the third (modern) phase, but for convenience the unusual minerals are all described in this section. Cerussite ($PbCO_3$) paragenetically grows as crystals of up to 2 mm size with aragonite ($CaCO_3$). The aragonite forms under normal cave conditions but its growth is governed by trace concentrations of lead, which in the northern branch of Cupp-Coutunn lower series can be as high as 1%.

Isolated spherulites of sauconite, a zinc montmorillonite clay, are found both upon and underneath normally deposited calcite (X-ray diffraction, Belyakovsky, pers. comm.). The sauconite is usually coloured green by the presence of nickel (Plate 3). The mineral appears here not as a clay (typical for all montmorillonites) but as structured aggregates of clear mineral. An interesting feature of the sauconite is that it is often found near occurrences of an unusual orange aragonite. The aragonite has either a branching, coral-like morphology or grows as a spherulite sector within the surface of a calcite flowstone. In both cases the aragonite has small holes where a second, more soluble mineral once resided. A sample of this aragonite cannot be taken without very visible damage. A reported visual identification of copper sulphate (in Maltsev and Bartenev, 1989) is now questionable. A sample taken from the cave was washed in the laboratory and immediately dissolved. Recent discoveries in other parts of the system suggest the mineral was more likely to have been a nickel salt. The specimen was found in a region that was then sealed for conservation, but another team re-opened the passage and ignorantly trampled the remainder of the mineral.

In Promeszutochnaya, a very green mineral has been found which on analysis proved to be a mixture of sauconite, fraipontite (a zinc analogue of serpentine) and a third mineral of the fluorite group (as yet not identified). Fraipontite is a very rare mineral, with only a handful of occurrences worldwide; this is the first time it has been found in a cave. The green colour is almost certainly due to partial substitution of zinc by nickel. A colour photograph has been recently published in a mineralogical magazine (Maltsev and Belyakovsky, 1992).

Some minerals grow as isolated crystals upon calcite helictites or are found inside gypsum crystals. Celestite ($SrSO_4$) grows as blue to colourless crystals up to 1.5 cm size (Plate 4), individually or as rosettes, and always on calcite or paragenetically with gypsum. It is never found in association with aragonite, except at one location where it is in asociation with orange aragonite and sauconite. Stepanov (pers. comm.) reports some very old celestite in Hushm-Oyeek, predating all other minerals, but no other such occurrence is known. In one part of Cupp-Coutunn (main) celestite is a cementing material for the floor deposits. Yellow-coloured isolated crystals with a more elongated crystal form, growing on helictites, proved also to be celestite. The celestite may be thermal in origin, but could alternatively derive by normal groundwater flow from the strontium-rich Gaurduck beds which overlie parts of the cave system (Belyakovsky, pers. comm.). Clear crystals of a typically celestite crystal form in one location were, on analysis, found to be barite ($BaSO_4$).

Tyuyamunite, a vanadium-uranium mineral, has been visually identified in Geophyzicheskaya (Belyakovsky, pers. comm.). Radioactivity in the nearby cave air is 300-500 micro-Roentgens per hour, about ten times higher than in other caves of the area. Ordinary montmorillonite has also been found on (modern phase) calcite helictites, where it occurs as milky-coloured crusts 1-2 mm thick together with celestite crystals (X-ray diffraction, Belyakovsky, pers. comm.).

Modern Phase

After the post-thermal phase the cave returned to a more normal regime of speleothem growth, though the abundance and variety of the minerals must owe something to the previous thermal history. The calcite group of minerals are particularly interesting. Staining techniques showed that what appeared to be calcite speleothems contained zones of calcite, high-magnesium calcite, mangano-calcite, dolomite ($CaMg(CO_3)_2$), ankerite ($(Ca,Mg,Fe)CO_3$) and ferro-calcite. Thin crusts of orange to red ankerite crystals, 1-4 mm in size, were also identified by staining. Siderite ($FeCO_3$) flowstone crusts up to 1 mm thick also occur. Other unusual speleothems include polycrystalline crusts of calcite (occasionally aragonite) containing manganese oxide dendrites.

Two major types of aragonite speleothems are also present, one paragenetic with sauconite, the second with hydromagnesite ($Mg_5(CO_3)_4(OH)_2.4H_2O$). The hydromagnesite mostly occurs as spherulites on the ends of aragonite frostwork (Figure 11).

The cave also has very large quantities of gypsum, mostly occurring as wall crusts and as floor debris derived from these crusts. In places gypsum speleothems occur, often of very large size. These take the form of mono-crystalline stalactites, chandeliers, both mono-crystalline (Figure 12) and the normal hollow stalagmites, shelfstone and efflorescences (hair and beards, needles and flowers). The gypsum is probably derived from two sources: the overlying Gaurduck beds (remnants of which still exist on the Kugitangtau plateau) and as the product of the reaction of atmospheric hydrogen sulphide with the limestone during the post-thermal and modern phases. Growth of gypsum with dolomite and celestite is common.

In the driest areas of the cave, soluble minerals such as epsomite ($MgSO_4.7H_2O$), halite (NaCl) and mirabilite ($Na_2SO_4.10H_2O$) form speleothems. These crusts, flowers, needles and small chandeliers were for several years mistakenly thought to be gypsum. In one such case a halite-epsomite flower has grown to a size of 40 cm. Epsomite is also found as a thin grey efflorescence. Other efflorescent deposits prove to be saltpetre (KCl) growing as thin crusts with halite and gypsum.

During the 1990 expedition a cold phase (21°C), second generation purple fluorite was discovered in Promeszutochnaya (colour photograph in Maltsev and Belyakovsky, 1992). Crystals of up to 0.3 mm length were seen growing on both calcite helictites (Figure 13) and gypsum crystals. Gypsum tends to recrystallise because of humidity changes, so fluorite growing on gypsum is probably less than 100 years old. This modern fluorite may be the product of chemical attack on both calcite and gypsum by atmospheric HF gas, but as yet no gas tests have been made on the present cave air. Fluorine is thought to have been a component of the deep thermal fluids. A possible second modern fluoride mineral may be forming. In one part of Cupp-Coutunn, aluminium survey station markers have been corroded in only four years to form a glassy spherulitic mineral deposit.

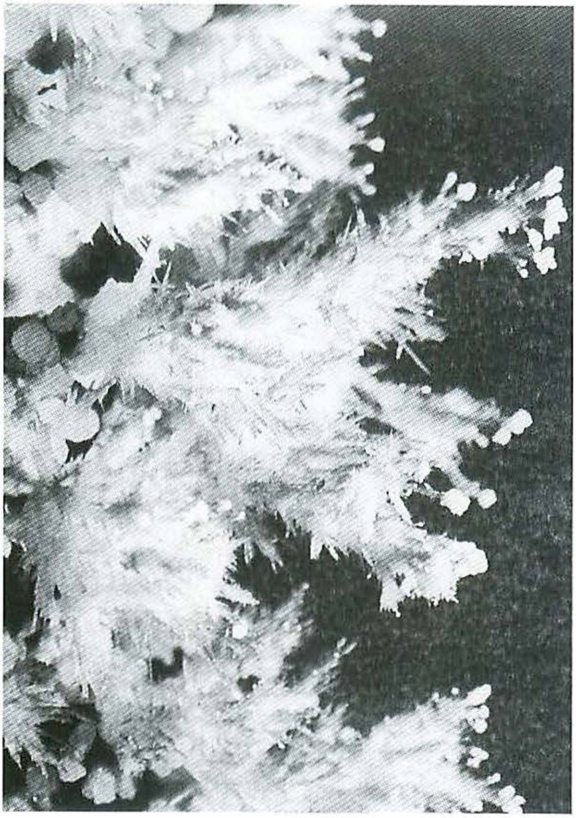


Figure 11. *Hydromagnesite spherulites growing upon aragonite frostwork, on rounded calcite crystals on the side of a calcite stalactite (Cupp-Coutunn lower series).*

Unidentified Minerals

One of the most interesting unidentified minerals comprises two silicates growing together in a highly porous arrangement inside gypsum clouds. The minerals may possibly be a result of a reaction of sulphuric acid on montmorillonite, but the individual fibrous crystals are too thin for X-ray analysis. In one of the conserved parts of the cave there is a single highly-reflective and colourless crystal of 2 cm size, growing on a calcite helictite. There is no other occurrence of this mineral, which was left in place. In Cupp-Coutunn (main), there are five crystals of up to 1 cm size that have the crystal form of aragonite, but on colour staining gave the reaction of dolomite.

Figure 12. *Monocrystalline gypsum stalagmites in Promeszutochnaya.*

MAIN SPELEOTHEM FORMS

The speleothems of the Cupp-Coutunn system are mostly eccentric in form; helictites (Figure 13) and corallites are far more common than normal stalactites and stalagmites. A full list of speleothems is beyond the scope of this paper (the cave has ''almost everything'', according to those who know it well) but some form of classification of the main types may be useful. Speleothems are here grouped by the process defining their morphology, in order of decreasing amounts of free water needed for their formation.

Subaquatic. Most of these forms are thermal in origin, notably the fluorite and the massive calcite spar. There are also cold-origin shelfstone deposits in rimstone pools formed by calcite. In rare cases aragonite and even gypsum shelfstones have been found.

Sub-aerial gravitation controlled. These are mostly calcite stalactites, stalagmites and flowstones. In rare cases they may be made of aragonite or gypsum.

Sub-aerial near-gravitation controlled. To this group are assigned the hollow gypsum stalagmites, which can reach 20 m in height, and the gypsum chandeliers, which can be 5 m long. The morphology of these gypsum forms is controlled both by gravitation and by seasonal changes in humidity. To the same group are assigned some stalactite-like aragonite aggregates of very strange morphology: sectors of spherulites hang one from another in the manner of a daisy-chain (Figure 14).

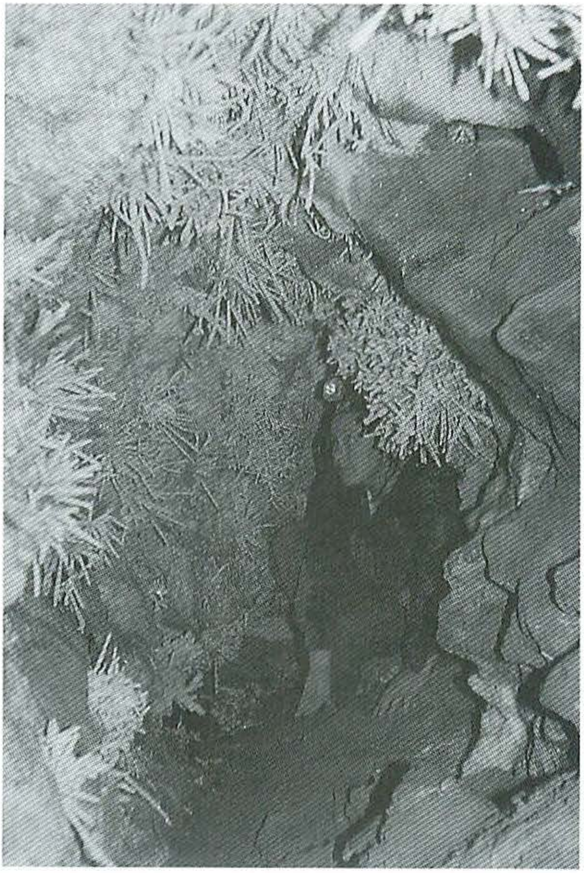


Figure 13. *Difficult caving conditions in Promeszutochnaya.*

Subaerial gravitational-capillary controlled. To this group we assign vertically directed helictite bushes, which can be 2 m long and 0.5 m thick.

Capillary controlled. Various forms of helictites, corallites and crystallites have a capillary channel origin or are formed from capillary films.

Capillary-airflow controlled. Calcite and aragonite anemolites are assigned here, as they are airflow directed.

Humidity controlled. This group comprises the speleothems whose morphology is controlled by humidity changes, such as gypsum hair and flowers, gypsum crusts, and efflorescences of soluble salts.

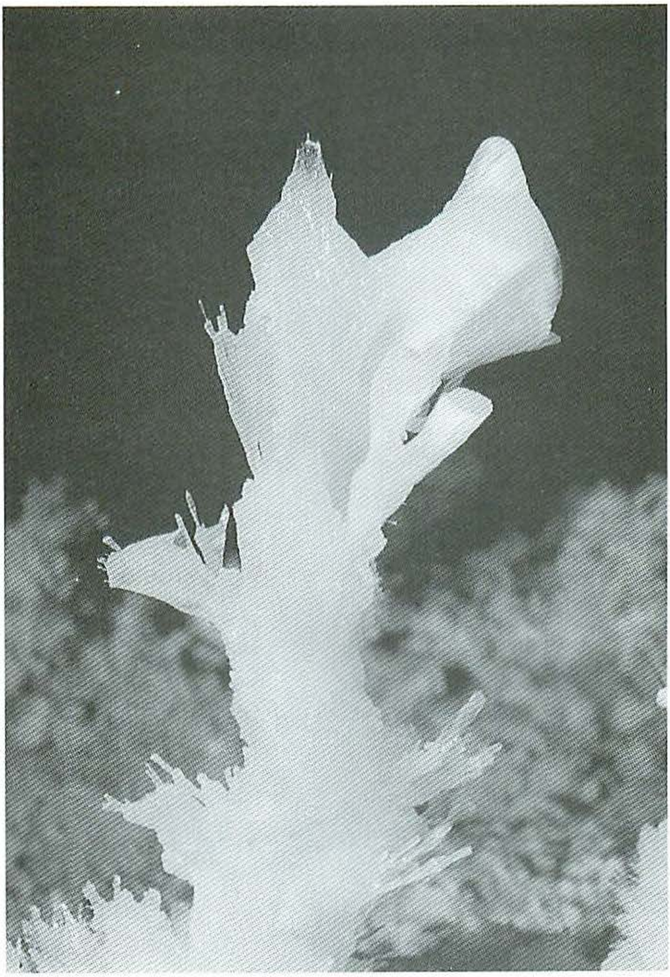


Figure 14. *Aragonite pseudostalactites of needle aggregates in Cupp-Coutunn.*

Special speleothem forms

Pseudohelictites. These look similar to acicular anthodites. Controlled by crystallisation pressure, they are formed when calcite and aragonite grow together (Figure 15).

Isolated crystals, rosettes and spherulites. These speleothems are formed of various minerals, as described earlier in this section, but we can offer no explanation why an otherwise uncommon cave mineral should be concentrated in one place. Examples include a lone spherulite of sauconite sitting on a calcite flowstone, many metres from any other, and a calcite helictite with many celestite crystals on its sides, when other helictites in the same bush are bare.

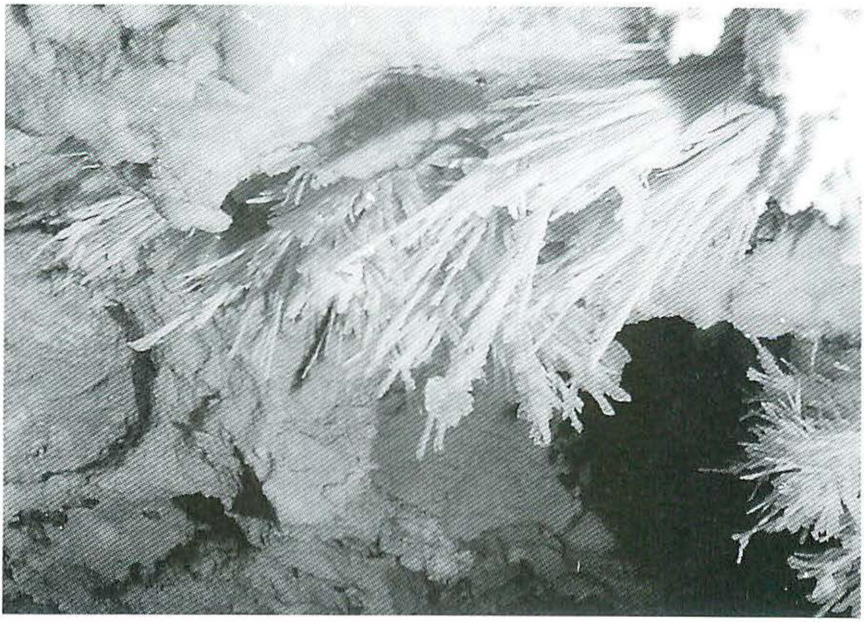


Figure 15. *Calcite/Aragonite needle pseudochelictites with gypsum crystals in Promeszutochnaya.*

CONCLUSIONS

The Cupp-Coutunn system is one of the most scientifically interesting caves in the world. Its mineralogy, fauna and microclimate features make it unique, yet until very recently it was considered only as a natural resource to be mined. The threat of mining has now receded (hopefully for ever) but individual geologists are still a serious menace to the cave. Such deliberate vandalism is fortunately decreasing, as more people become aware of the value of conservation, but this greater awareness of the beauty of the Cupp-Coutunn system brings a corresponding increase in the number of visitors. As visits by geologists have now dropped below 200 per year, caver visits have increased to 500 and tourist (casual caver) numbers have reached 3000 per year. Such tourist parties commonly number more than 40 people, usually with less than this number of working lights. This is far too many people for the safety of the cave environment, particularly when so many of them are not experienced cavers. Heat, dust and accidental damage are all on the increase. By contrast, the number of serious cavers, those involved in exploration or scientific work, has remained steady at 50 visitors per year.

At present, no viable scheme exists for regulating visitors to the caves. We hope this will change in the future, but in the meantime we ask that NO CARBIDE be used in the caves. The residual clays attached to the walls are a very effective temperature insulator and temperatures as high as 60°C have been recorded at roof level above carbide lamps. Underground camps using liquid fuel can also cause thermal damage to speleothems: at one microclimate study station, in a chamber 600 metres from the campsite, an air temperature of 37°C was recorded.

There is very little standing water in the caves and visitors are recommended to carry water with them; the cave water is needed by explorers operating from underground camps. Cave divers visiting the gypsum cenotes are asked to limit their attention to the sites that do not have troglobytic life, until more is known about the nature of the aquifer.

APPENDIX

FAUNA, ARCHAEOLOGY AND SURVEY

Fauna

The Cupp-Coutunn caves have only one true troglobite, a microscopic insect that lives in the clays. As yet unstudied, the insect was discovered by S. Smirnov. The clays in which the insects live are high in organic material (up to 20%).

A number of troglophiles, both insects and mammals, make use of the caves. The mammals include bats, mice, porcupines, foxes and a member of the ferret family (*Martes foina*) — the farthest travelling of all the visiting species. The presence of water in some parts of the cave appears to be the main reason for the visits of these animals, even the mice routinely travelling 150 metres down (vertically) into the cave to drink. The mice can be a problem if an underground camp is placed too near a water supply, the smell of food attracting them in 2-3 days. The routine precautions of hanging up the food sacks and daily re-packing one's sleeping bag are necessary. The foxes and ferrets probably use the caves as a hunting ground for mice.

The porcupines also travel long distances underground and often have their nests within the cave. Unfortunately they carry a very unpleasant skin parasite, *Argazida*, which can cause a serious relapsing fever in man. Prompt and intensive treatment with a spirocheticidal antibiotic is needed to prevent a prolonged illness. The danger is in the dry parts of the cave where fallen parasites can survive for up to three years.

Aquatic troglobites can be found in the phreatic cave systems beneath the plains. A cave-adapted shrimp, *Stenasellus asiaticus*, is locally common. The blind cave fish, *Noemacheilis starostini parini*, is unique to the cave Provull.

Archaeology

No archaeological material has been found in the main parts of the Cupp-Coutunn system, but some remains have been recovered from Verticalnaya. The horizontal entrance soon opens onto a pitch, at the foot of which the bodies of two travellers with money and baggage were found. Also found were the remains of several animals, including wild goats and a leopard. This material is in the collection of the Ethnographic Museum in Leningrad, but further details are not available.

Survey

The caves were surveyed in two phases, to determine the plan and elevation. The plan was made with hand held compass (±1° accuracy) with internal plumb-bob clinometer (±5° accuracy, used only for correction of length) and fibron tape (measurements to the nearest 10 cm). The first survey was drawn manually from these notes while in the cave. A second survey was then made in Moscow, line drawn by computer with error distribution using the electric resistance nets algorhythm (Orevkov,1987).

The vertical survey was made independantly by hydrolevelling (accuracy 10 cm, length of tube 15-30 m). A theodolite (accuracy of angles 0.5°, distance 50 cm) survey was made on the surface and in the main gallery of Cupp-Coutunn (main). When Cupp-Coutunn and Promeszutochnaya were connected via the B-podval series, the closure error was only 20 metres horizontally, but 60 metres vertically. The vertical error almost certainly indicates problems with the surface survey between the two caves.

Permanent metal survey stations have now been installed in all the main caves of the Cupp-Coutunn system except Verticalnaya and Hushm-Oyeek. The original survey at 1:1000 has been greatly reduced for publication. Some detail has necessarily been omitted.

Spelling of Place Names

The names of towns, villages and caves in this part of Central Asia are normally found written in the Cyrillic alphabet. In converting to Roman letters we have tried to indicate local pronunciation of the names, rather than a strict transliteration. Occasionally, English language texts may be found using a different spelling, particularly of the main cave Cupp-Coutunn (eg Kap-Kutan). These differences are not important since the only ''correct'' spelling is in Cyrillic script.

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REFERENCES

BAIKALOV, A.A., YALKAPOV, S.D. and SEDLETSKY, V.I. 1970. A deposit of marble onyx. *Razvedka i ohrana nedr (Estimating and conserving underground resources)*, Soviet Ministry of Geology, **2**, 14-16. (in Russian)

BAKALOWICZ, M.J., FORD, D.C., MILLER, T.E., PALMER, A.N. and PALMER, M.V. 1987. Thermal genesis of dissolution caves in the Black Hills, South Dakota. *Bulletin of the Geolological Society of America*, **99**(6), 729-738.

BARTENEV, O.S. 1987. Secondary karst deposits of the Cupp-Coutunn system and the method of studying its development. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 58. (in Russian)

BARTENEV, O.S. and MALTSEV, V.A. 1989. A concept of three stages of speleogenesis as a basis for creating models of evolution of karst systems. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 88-90. (in Russian, English abstract)

BARTENEV, O.S. and VESELOVA, N.V. 1987. Dust caused by people in the cave system Cupp-Coutunn. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 159. (in Russian)

BOLNER, K.T. 1989. Regional and special genetic marks of the Pal-Volgy cave, the largest cave of thermal water origin in Hungary. *Proceedings of the 10th International Congress of Speleology*, Budapest, **3**, 819-822.

BOSAK, P. 1989 Mountainous karst of the Karjantau ridge (Southern Kazakhstan, USSR) :Phenomena and Development. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 99-102.

DIODORUS SICULUS. c40 B.C. *Bibliotheka Historica*. 12 vols. (Loeb Classical Library, Harvard University Press, 1933-1967. (Classical Greek with English translation)

FRIEDMAN, J.M. 1959. Identification of carbonate minerals by staining methods. *Journal of Sedimentary Petrology*, **29**(1), 87-97.

GAURDUCK GEOLOGICAL SERVICE. 1960-75. Unpublished reports kept in Geological Fund. (in Russian)

GEOLOGY OF U.S.S.R., **XXII**, TURKMENSKAYA S.S.R., 1972. Moscow. (in Russian)

GVOZDETSKY, N.A. 1981. *Karst*, Moscow, 65. (in Russian)

HILL, C.A. 1987. Geology of Carlsbad Cavern and other caves in the Guadalupe Mountains, New Mexico and Texas. *New Mexico Institute of Mining and Technical Bulletin*, **117**, 79-80.

KUCHERYAVUIH, V.I. and ABDUJABAROV, M.A. 1982. Kapkotan-2 the biggest cave in Central Asia. *Nekotoriye aspectiy fizicheskoy geografy yugo- zapadnogo Uzbekistana (Some physical aspects of the geography of south-western Uzbekistan)*, Samarkand University, 29-30. (in Russian)

LAZAREV, K.S. and PHILENKO, G.D. 1976. Geological-mineralogical peculiarities of the Gaurduck cave. *Peshcheriy (Caves)*, University Press, Perm, **16**, 45-63. (in Russian)

MALTSEV, V.A. 1982. Carbonate karst of the south-western slope of the Kugitangtau ridge. *Proceedings of the 3rd U.S.S.R. Conference on Karst Studies*, Moscow, 153. (in Russian)

MALTSEV, V.A. 1987a. Heat pollution of caves during underground expeditions. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 158. (in Russian)

MALTSEV, V.A. 1987b. State of study of the underground karst hydrosystem Cupp-Coutunn. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 104. (in Russian)

MALTSEV, V.A. 1989 The influence of season changes of the cave microclimate to the gypsum genesis. *Proceedings of the 10th International Congress of Speleology*, Budapest, 3, 813-814.
(Extensively revised and reprinted in 1991 as: The influence of seasonal changes of cave microclimate upon the genesis of gypsum formations in caves. *National Speleological Society Bulletin*, **52**, 99-103.)

MALTSEV, V.A. and BARTENEV, O.S. 1989. Results of minerallogical studies in the Cupp-Coutunn cave system in Turkmenia. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 209-211. (in Russian, English abstract)

MALTSEV, V.A. and BELYAKOVSKY, D. 1992. The Kap-Kutan cave system in the Kugitang mountains in East-Turkmenia. *Mineralien Magazin Lapis* **17**(2), 13-18. (in German)

MALTSEV, V.A. and MALISHEVSKY, D.I. 1989. About the hydrothermal stage on the later part of evolution of the Cupp-Coutunn cave system. *Proceedings of the 10th International Congress of Speleology*, Budapest, 3, 815-816.
(Extensively revised and reprinted in 1991 as: On hydrothermal phases during later stages of the evolution of Cup Coutunn cave system, Turkmenia, USSR. *National Speleological Society Bulletin*, **52**, 95-98.)

MOROSHKIN, V.V. 1984. Minerals of the Kugitang caves, *Priroda (Nature)*, **3**, 45-50. (in Russian)

OREVKOV, S.Y. 1987. Using the solution for the task of electric network design for the task of processing survey data in caves. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 190. (in Russian)

TINTILOSOV, Z.K. 1983. *Novaphonskaya cave system*, Metsniereba, Tbilisi. (in Russian)

ZALESSKAYA, N.T. and GOLOVATCH, S.I. 1989. The condition of biospeleology in the USSR. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 240-242. (in Russian)

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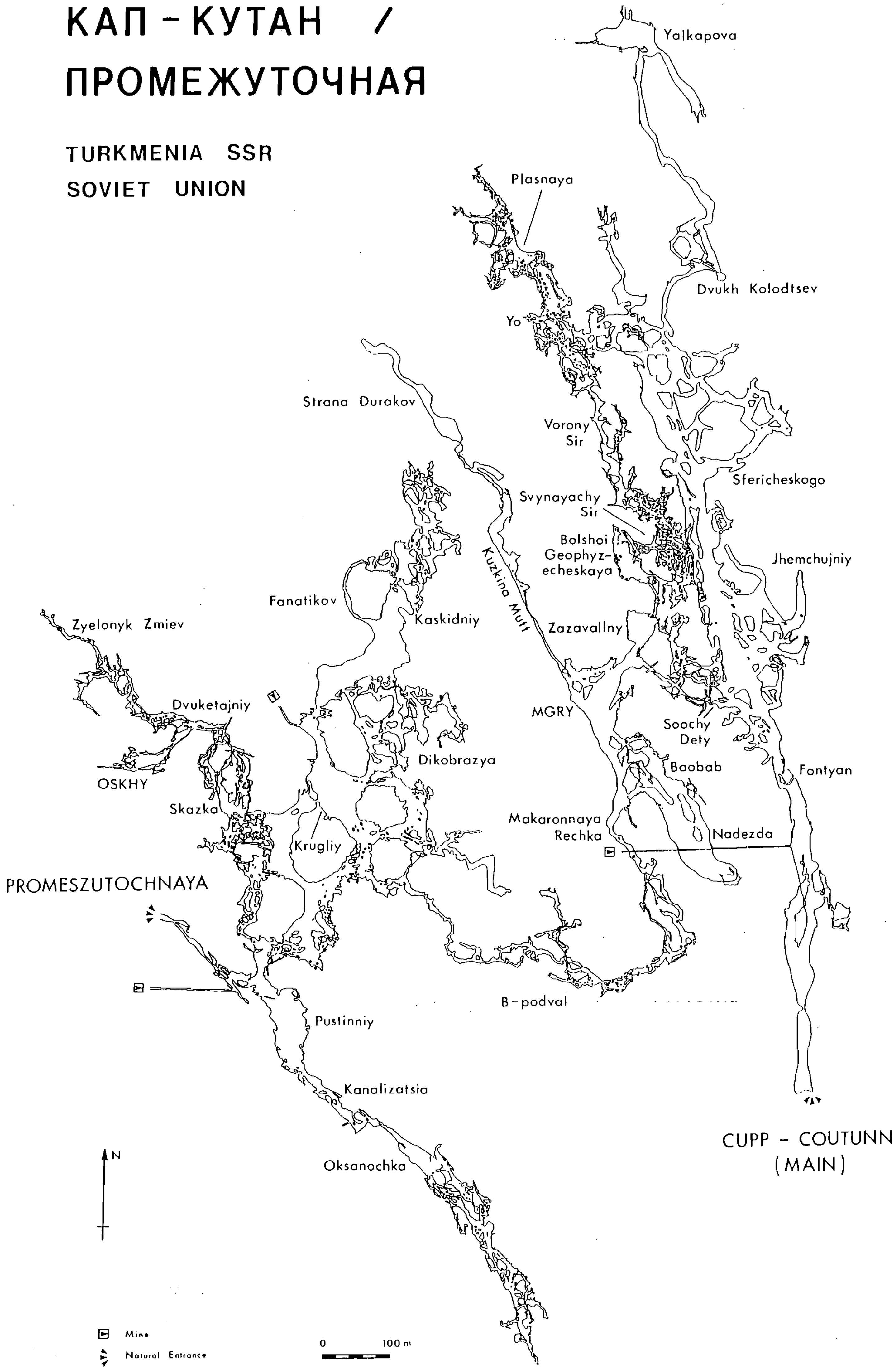

Figure 16. *Plan survey of Cupp-Coutunn-Promeszutochnaya cave system.*

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Article

An overview on the subterranean fauna from Central Asia

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Abstract
Survey of the aquatic subterranean fauna from caves, springs, interstitial habitat, wells in deserts, artificial tunnels (Khanas) of five countries of the former URSS (Kazakhstan, Kyrgyzstan, Tadjikistan, Turkmenistan, Uzbekistan) located far east the Caspian Sea. The cave fauna present some originalities: - the rich fauna of foraminiferida in the wells of the Kara-Kum desert (Turkmenistan); - the cave fish *Paracobitis starostini* from the Provull gypsum Cave (Turkmenistan); - the presence of a rich stygobitic fauna in the wells of the Kyzyl-Kum desert (Uzbekistan); - the rich stygobitic fauna from the hyporheic of streams and wells around the tectonic Issyk-Kul Lake (Kyrgyzstan); - the eastern limit of the European genus *Niphargus* from the sub-lacustrin springs on the eastern shore of the Caspian Sea (Kazakhstan); - the presence of cave fauna of marine origin. Approximately 96 stygobionts, 9 stygobionts/stygophiles and 3 troglobionts are recorded.

Key words: karst, caves, wells, interstitial, khanas, subterranean fauna, cave fish.

I Geographical setting

The subterranean fauna was studied in five countries, part of the former Soviet Union (1924-1991): Kazakhstan (Asian part), Kyrghyzstan, Tadjikistan, Turkmenistan and Uzbekistan. Central Asia is ecologically diverse, characterized by desert basins, steppes and high mountains landscape. The area can be divided in two main zones: first, the plains of Kazakhstan, Turkmenistan and Uzbekistan: secondly, the inter-mountainous depressions, piedmonts and high mountains of the Tien Shan and Pamir (Figs. 1 and 2).

Figure 1. Central Asia. Map of main karst areas, in brown. (After Klimchouk, 2003; modified).

II Karsts, caves and artificial galleries (kiarizs)

Several features characterize the karst of Central Asia:

- Arid and ultra arid climate in relation to the continental position of Central Asia and the barriers to the influence of summer mousson. The result is the poor contemporary development of limestone karst;

- A specific central Asia arid karst: - epikarst characterized by scarcity of dolines and density of fissures near the surface; - development of evaporate karst (gypsum, salt, with spectacular evaporate karsts;

- Hydrothermal or sulfuric acid generation of much caves. Caves of these types are reported from the Tien Shan, Pamir, Kopetda;

- Caves developped in some mountainous zones where local conditions create higher precipitations;

The relief range from lowlands near the Caspian, to the high plateau of Pamir and the highest mountains of the Tien Shan.

Central Asia can be divided in four large regions: the Turansky plain, - the plains and low mountains of central Kazakhstan, - the Caledonian and Hercynian mountains of the Tien Shan, - the Alpin mountains of the Kopetdag and Pamir (Klimchouk, 2004).

The Turansky Plain is a vast desert region which contents carbonates and evaporates of Mesozoïc and Cenozoïc ages. It is occupied by the large sand deserts of Kara-Kum, Kyzyl-Kum and Mujunkum.

Some small caves are present: the longest is Sarykamyshskaya (200 m long) and the deepest is the shaft Bolojuk (-120 m). In the eastern part of the Turansky Plain, carboniferous gypsum and limestone karst are reported in the Betpak-Dala desert and the Chujsky region.

Figure 2. Central Asia. Collecting sites of subterranean fauna. Map A: numbers 1 = Kendyrli Bay; 2 = Kushka. a and b = Two detailed mountain ranges: **A** Kuldzhuktau Mountains, b - Nuratau Mountain range: H = Pit for hyporheic fauna; K = Kanat, artificial subterranean gallery groundwater collector and conveyer; W = Well (after A. I Jankowskaya, 1972, modified). Aral Sea in 2010. **B** 3 = Cholpon-Aty river and the Biological Station at Cholpon-Aty; 4 = Aksu and Dzhirgalan rivers, affluents Issyk-Kul lake; 5 = Vannovka; 6 = Shimkent; 7 = Fergana valley; 8 = Urgut; 9 = Bakhmal; 10 = Khaydarkan; 11 = Varzob; 12 = Khodzhambass; 13 = Gaurduk; 14 = Kaptar-Khana cave; 15 = Cupp-Coutunn cave system; 16 = Kugitangtau Mountains; 17 = Fergansky Mts; 18 = Alaiskiy Mts; 19 = Surkhob River; 20 = Gissarkiy (Hissarkiy) Mts; 21 = Kyzyl-Ravata.

The Central Kazakhstan consists of plains and low hills broken by wide valleys and depressions. Most of the territory consists of dry steppes, with salt lakes in the northern region, and deserts to the west and south. Deposits of bauxite and phosphorites are associated with the Upper Devonian and Carboniferous limestones, often heavily karstified at depth, with high level of porosity and karst water. In the eastern region, larges caves were formed by sulfuric acid dissolution.

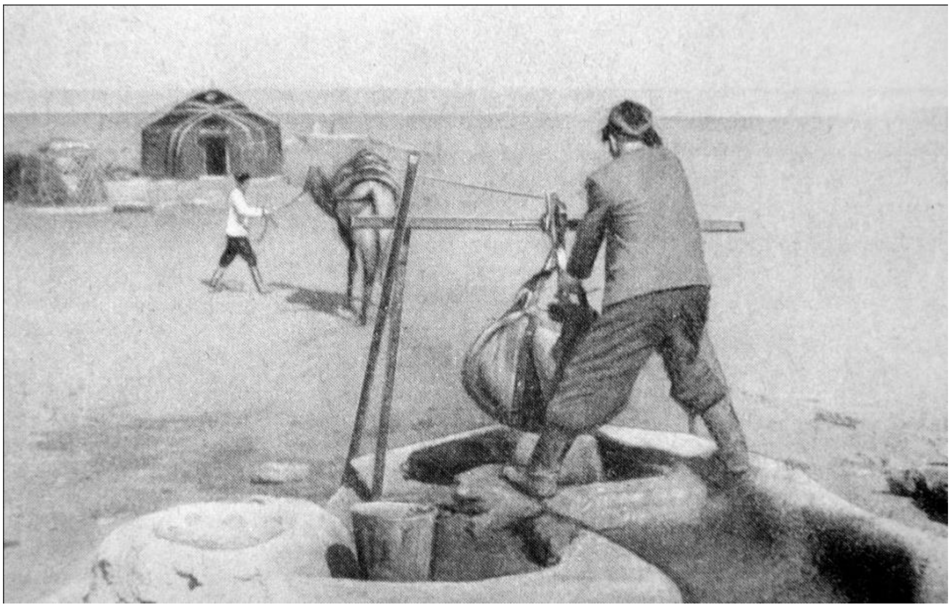


Figure 3. Drawing out water from a well with a ram skin (~100 l, volume), south of Kyzyl-Kum desert (Photo A. Jankowskaya, 1972).

The Tien Shan is a block folded region during the Caledonian and Hercynian orogenies, regenerated during the Alpine cycle. It strechtes east to west for around 3,000 km through Uzbekistan, Tadjikistan, Kyrghyzstan and north-western China. The highest peaks exceed 7,000 m. Thick and extensive Paleozoic carbonated rocks are widespread, Mesozoic and Cenozoic sediments fill depressions.

Caves

To the north of the Fergansky depression (Fig. 2B: 17), karst and caves are described from the Ugamsky and Pskemsky ranges; the largest caves are: the Zajdmana Cave 830 m length, - 506 m depth, the Uluchurskaya Cave, 1,500 m and – 280 m.

Many karst massifs lie south and southwest of the Fergansky depression. There are many small hydrothermal caves and some larger such as: Kun-Ee-Gout (3,000 m long), Pobednaja Cave (1,480 m long), and Fersman'Cave (-220 m deep). Numerous caves are reported from the salt and gypsum karst in the Kysyl Dzhar Mountains.

Over 100 shafts and the Kievskaya Cave (-990 m deep) were explored in the Kyrktau plateau, a karst of the southern Tien Shan.

The limestone escarpement of Bajuntau and Chul' bear rises to 3,000 m a.s.l., and important caves are reported there: the Bojbulok (14,270 m of development and – 1,475 m deep), the deepest cave, the Festival'naja-Ledopadnaya system (13,000 m and - 625 m). In the Kugitangtau range lies the Cupp-Coutunn cave system (Fig. 2B: 15) which exceed 80 km of passages (see Turkmenistan) (Bernabei & De Vivo, 1992; Klimchouk, 2004).

The Pamir Mountains are mainly situated in Tadjikistan. The eastern part is a high upland with arid climate, the floor of valleys at 3,600/4,000 m a.s.l., the mountains rising 6,000 m a.s.l. The western part is a series of ranges that rise to 1,500/3,500 m above the bottoms of valleys at 1,500/2,500 m. The highest peaks rise to over 7,000 m in the central and northern mountains.

Limestones of Silurian, Devonian, Carboniferous and Triassic ages have extensive outcrops. The most notable site is Rangkulskaya Cave in Triassic limestones at 4,600 m a.s.l., 2,050 m of passages mapped, with remnants of an underground glacier.

Gypsum karst is known at several high altitude and gypsum caves in the Petra Pervogo range.

Salt karst is known on the Khodja-Mumyn dome which rises up 900 m above the surrounding plain. Several caves are reported in the dome: Dnepopretovskaya (2,500 m length), Komsomolskaya (1,800 m), Chjudo (870 m) and Vershinnaja (338 m) (Klimchouk, 2004).

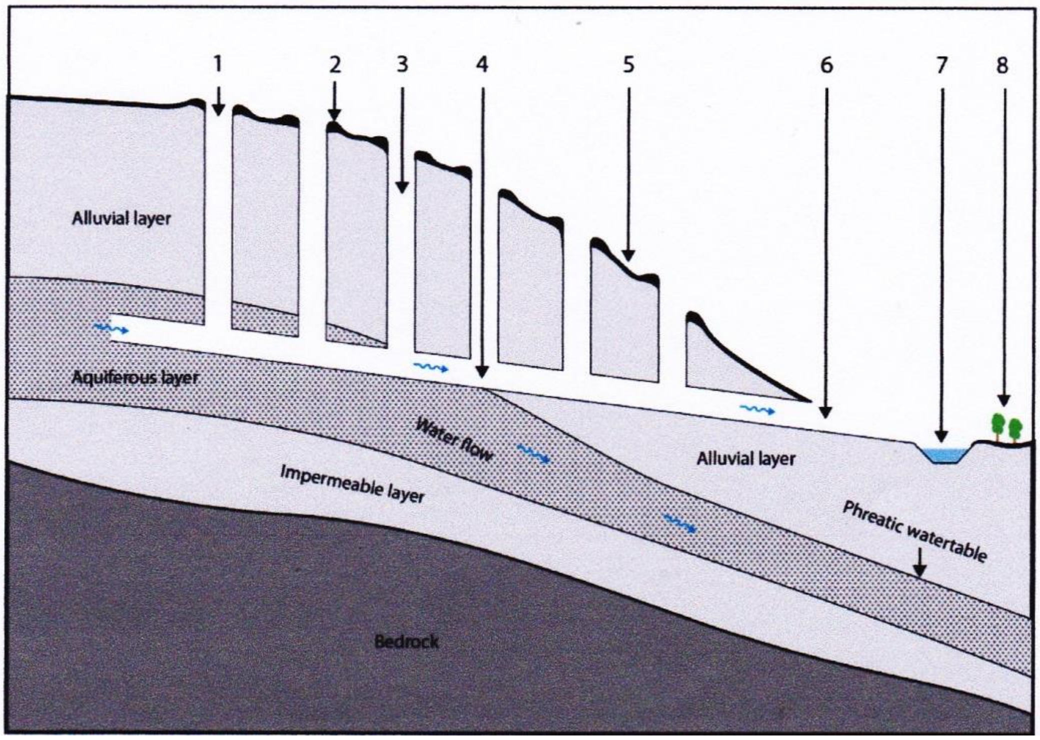


Figure. 4 Schematic diagram showing the kiariz (khana) concept. 1 = Mother well; 2 = excavation debris (soil crater); 3 = vertical shafts; 4 = kiariz gallery; 5 = land surface; 6 = outlet; 7 = storage tank; 8 = irrigation land (After Jankowskaja, 1972; modified). Kiarizs are present in Tadjikistan, Turkmenistan and Uzbekistan. They are artificial subterranean galleries dug in desert zones to reduce evaporation. They collect water from mountains or foot hills, for alimentation or irrigation. Khana wells are 1.1 to 22 m depth, the water from 0.5 to 9 m depth, the temperature from 12 to 22°C, the pH of 7.2/7.5; water Na Cl or Na-SO4 type.

Kazakhstan

Kazakhstan lies on two continents as it extends across both sides of the Ural river and range. It has a total area of 2,700 000 km^2 but only the Asian part is concerned here.

It shares borders of 6,800 km with Russia, Uzbekistan, Turkmenistan, Kyrghyzstan and China. Its Asian terrains extend from Ural to the Altai mountains, and north to south from the plains of western Siberia to the oases and deserts of Central Asia. The Kazakh steppe covers one-third of the country, with large areas of grasslands and sandy region.

The Syr Darya River, around 2,000 km long, is one of the important river of the central Asia that flows through the Khazakhstan. Several lakes are present (Balkhash, Zaysan), and a part of the rest of Aral Sea. The Charyn river and its canyon are located in northern Tien Shan. The climate is continental, arid to semi-arid, with warm summers and cold winters.

Kyrghyzstan

It is a mountainous landlocked country, bordered by Kazakhstan to the north, Uzbekistan to the west, Tadjikistan to the southwest and China to the east. Several picks rising over 7,000 m a.s.l. in the Range forming the Chinese border.

Climate. It varies according to areas and elevation. It is subtropical and extremely hot in summer in the south-western Fergana valley, but the northern foothills are temperate, and the mountainous Tien Shan varies from dry continental to subpolar climate.

The country has about 2,000 lakes, mostly located between 3,000 to 4,000 m a.s.l., the three largest are the Issyk-Kul, Son-Kul and Chatyr-Kul.

The Issyk-Kul Lake (Fig. 2B, 5A-B) lies in the north-eastern part of the territory, it is the second largest mountain lake in the word after the Titicaca: 1,606 m a.s.l., length 179 km, wide 60 km, depth -668 m. The Issyk-Kul area is a tectonical depression bordered by convergent faults (Fig. 5a) and in the north by the Kungey Ridge (4,770 m a.s.l.), in the south by the Terskey Ridge (4,502 m and 5,216 m a.s.l.). The Miocene and Pliocene mark periods of intensive orogenic uplift. The Issyk-Kul depression has been occupied by lake since early Neogene (Voskresenskaya, 1983), the present lake has existed since mid Pleistocene about 700,000 years ago (Trofinov, 1990). During the Holocene the water level of the lake dropped to 110 m below the present level as indicated by underwater terraces, submerged canyons, river channels. In the first half of the 19th century the lake level rose to 1,622 m, since it has gradually dropped towards its current 1,606 m level.

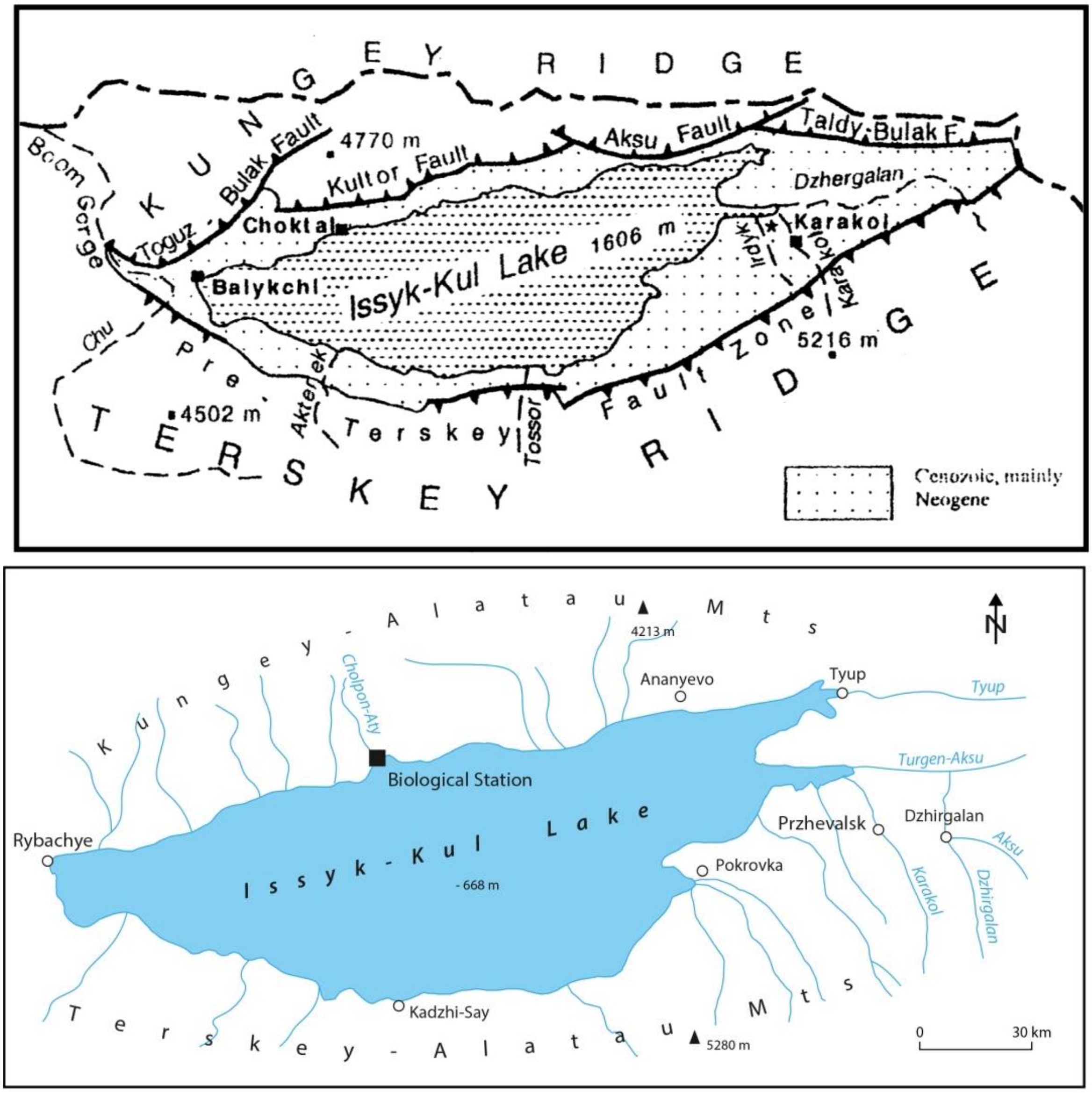


Figure 5. **A (upper)** Tectonical aspect of the Issyk-Kul Lake depression, northern Tien Shan, Kyrghyzstan (After Bowman *et al.*, 2004). **B (lower)** Sketch of the Issyk-Kul Lake, and its rivers in adjacent lands (After Jankowskaja, 1972; modified).

The lake is fed by about 100 rivers and mountain streams, all fed by ice caps on the surrounding mountains. Littoral plateforms are mainly located on the eastern and western sides of the lake.

The climate is continental. A strong gradient of precipitation exists from the east with 720 mm/year to the west with 120 mm/year.

Intensive survey of the interstitial and karst spring subterranean fauna in the Issyk-Kul area has been particularly carried out along the shore of the lake and in the rivers, managed by the Choktal Biological Station.

Tadjikistan

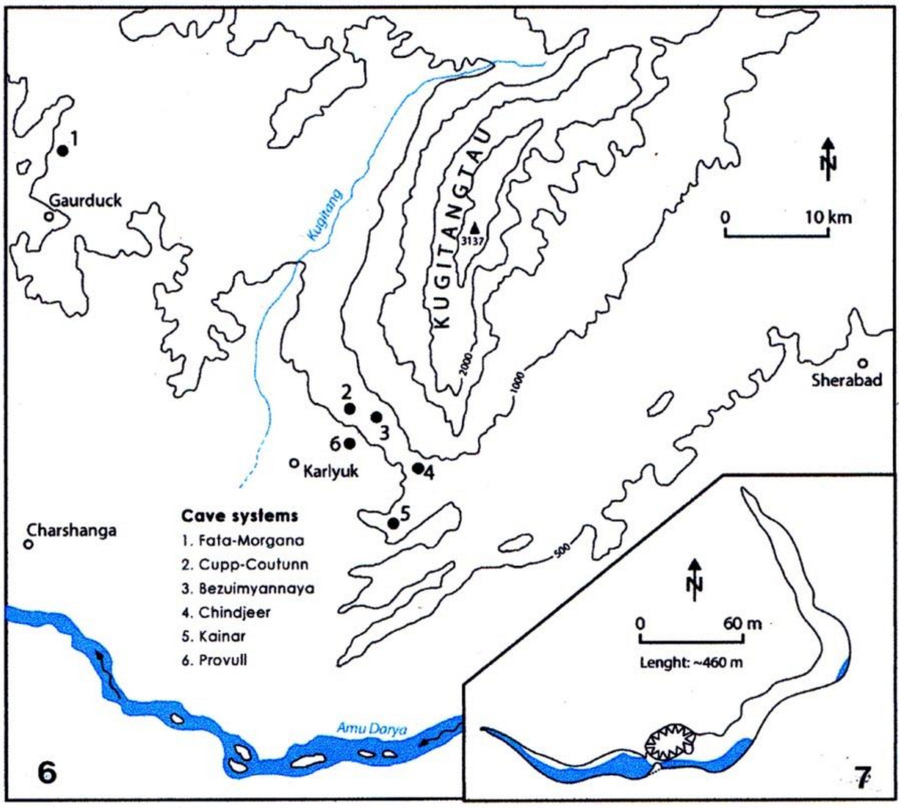
It is a landlocked country and the smallest in Central Asia. Plateau and mountains of the Pamir cover more than 90% of the country, and more than 50% of the territory is over 3000 m a.s.l. The lowest area lies in the northern part of the Fergana Valley and in the southern Kofernibon and Vakish valleys which rivers form the Amu Darja. There are more than 900 rivers, and glaciers on the Tadjikistan's mountains, they were an important source of runoff for the Aral Sea.

Turkmenistan

It has an area of 488,000 km^2. It is bordered by Kazakhstan to the northwest, Uzbekistan to northeast, Afghanistan to the southeast, Iran to the south. The west frontier borders the Caspian Sea, along 1,758 km.

Kara-Kum desert. The center of the country is covered by the arid Turansky depression and the Kara-Kum desert which represent 80% of the Turkmenistan. The Kara-Kum desert covers 350, 000 km^2 and consists of dunes and barkhanes, clayed desert zones (fatines) and salt zones. The Kara-Kum was a great bay of the Akchagilian Sea (Fig. 9) during the late Pliocene and some periods in the Pleistocene. The sand of the desert contains crusted calcareous thallous of the Algae *Melobesia* sp. which is still living in the Caspian. The last connection with the Caspian Sea and the Aral Sea was in the early Pleistocene (the Baker Age) (Starobogatov, 1994).

The mountainous areas. They consist of the Great Balkan Range in the west, rising 1,880 m a.s.l., and the Koytendag Range on the southeastern border with Uzbekistan. The highest summit is the Ayrybaba (3,137 m). The Amu Darja River flows near and along the northeastern border with Uzbekistan.



Figures 6-7. 6 Sketch of the Kugitangtau Mountain ridge with the location of several cave systems. (After Maltsev & Self, 1992). **7** Right corner. Sketch of the Kaptar-Khana Cave (Khodjambass district). (After V. Andreyev, *in* Birstein & Ljovuschkin, 1965; modified).

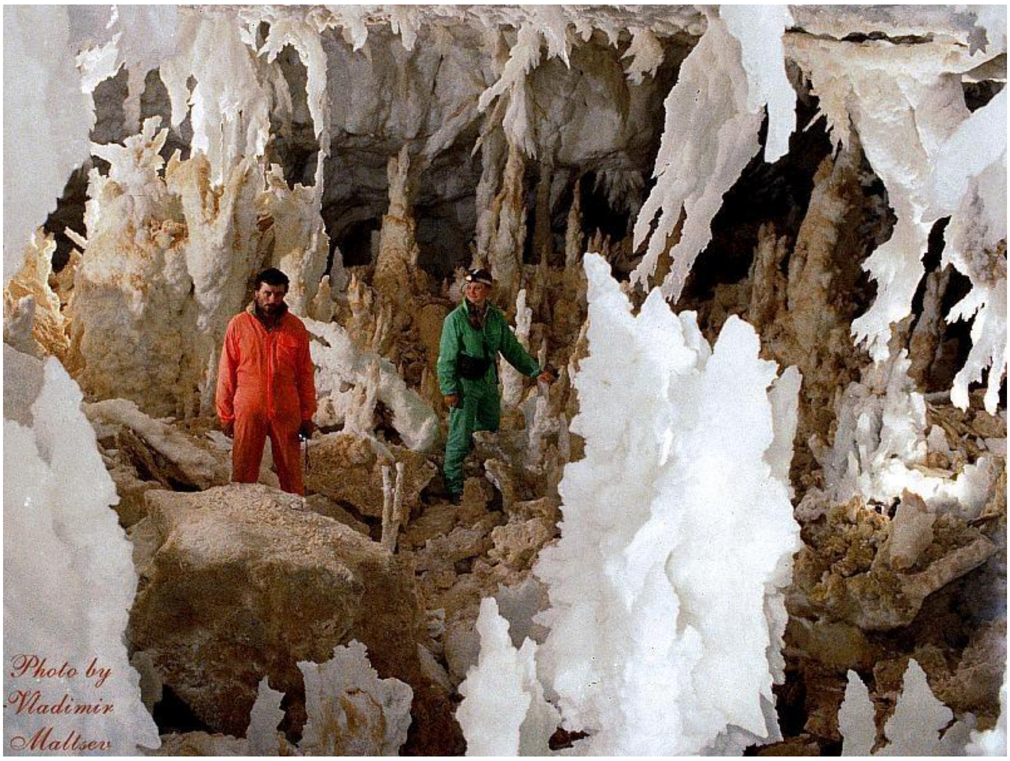


Figure 8. Cupp-Coutunn Cave (Kap Kutan) (Lebap Province). Gorgeous Cave systems with enormous speleothems of aragonite and gypsum. Some calcite crystals are almost 2 m long; aragonite crystals form something similar to snow-white forest. Total length of cave system exceeds 80 km, the longest cave is Kap Kutan II - 57 km, and cave is up to 1,017 m deep. (Text and photo by V. Maltsev).

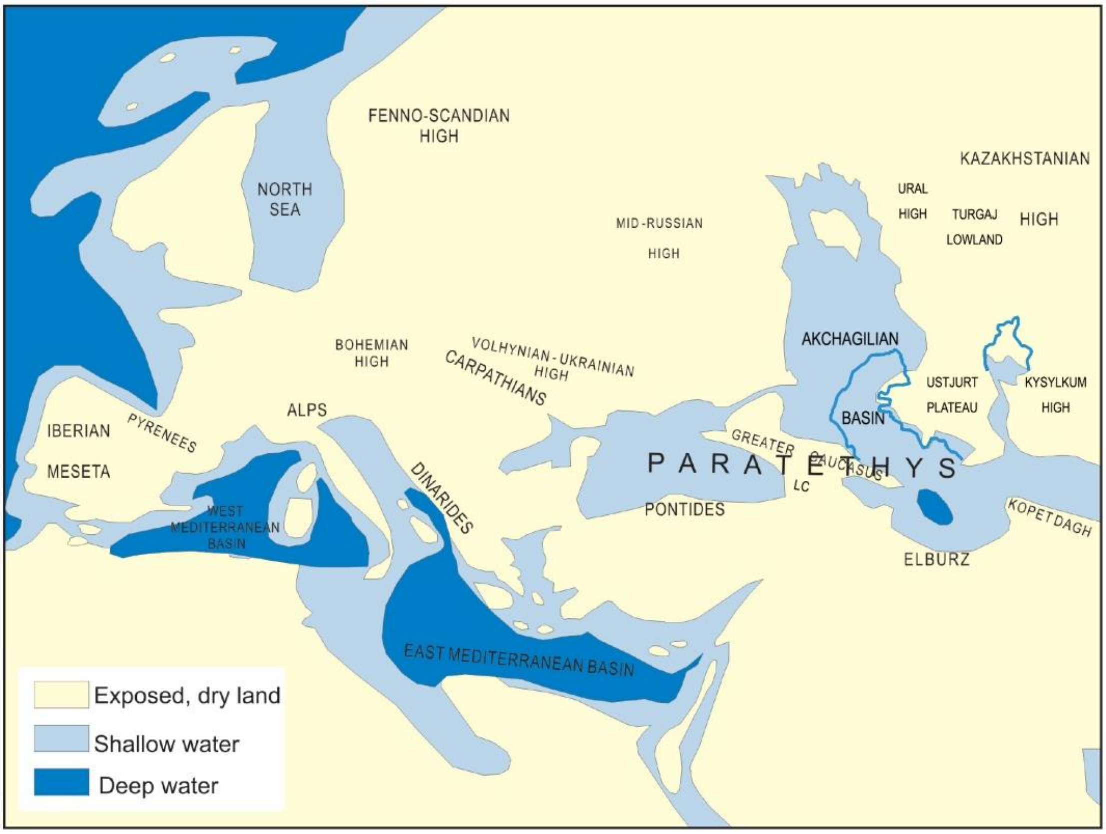


Figure 9. Paleogeographic configuration of the Parathethys domain during Late Romanian (3, 4-1,8 Ma). (After Olteanu & Jipa, 2006, simplified, and after Popov *et al.*, 2004). (See the location of the Akchagilian Basin).

The Kugitangtau mountains (50 km long) along the frontier to Turkmenistan and Uzbekistan are the karst region the most explored. The climate is semi-desert with rains for only short periods in spring and autumn. Flowing water in caves is unusual and except a few isolated pools, thus caves are dry. The temperatures in caves vary with altitude, from 17°C in the Geophyszicheskaya Cave, to 22° C in southern part of the Promeszutochnaya Cave. Locally in some part of caves there are a high level of H_2S and CO_2 and sometimes radon..

This region is a part of a paleokarst area, perhaps of Middle Cretaceous age, rejuvenated during the Alpine orogeny and invaded during the Middle Quaternary by thermal waters which deposited calcite, fluorite and metallic sulfides. Post thermal and re-working of these deposits has produced a great number of mineral species and great variety of speleothems forms (Maltsev & Self, 1992).

Caves

The most known and longest cave is the Cupp-Coutunn cave system located in Upper Jurassic limestone in the south West zone of the lower Plateau of the Kugitangtau mountains ridge, in eastern Turkmenistan (Fig. 6: 2); see topography in Self, 2004). The total length of the cave system exceeds 80 km, including 57 km for the complex Cupp-Coutunn - Promeszutochnaya Cave. It is internationally famous for its mineralogy (sauconite, fraipontite) and with very high aragonite and calcite speleothems (Fig. 8) (Maltsev & Self, 1992; Maltsev, 1997; Self, 2004).

Much others caves are developed in Jurassic limestones, gypsum and salt. - Kaptar-Khane Cave in gypsum (Fig. 7). - Hushun-Oyeek Cave (7 km of passages with high gypsum stalagmites and stalactites) was the first cave reported so early than 40 BC by *Diodorus Siculius.* - Geophyszicheskaya Cave (4.5 km), with spectacular stalactites. - Tush-Yuknuck Cave (3.2 km), Verticalnaya Cave (1.6 km).

Kaptar-Khana Cave (Fig. 7) (= Kaptarhana Cave in Sendra *et al.*, 2017) is located at the foot of the Koytendag Mountain, alt. 550-600 m, on the left bank of the Kugistang-Darya River, in Jurassic gypsum, near the village Gurshun Magdany, Kodzhambass District, extreme east of Turkmenistan, near Uzbekistan. An aven, where pigeons built their nests in walls, give access to the cave, approximately 450 m long, which consists of two galleries, with gysum boulders, guano and brackich lakes on the floor, 2-2.5 m depth. The salinity of the water is relatively high (11, 8 g/l of Cl-Na, pH = 7.8). According to Birstein and Ljovuschkin (1965) this level of salinity cannot related to presence of ancient sea on the territory, the nearest marine deposits are 300 km far the cave. Probably the salinity occurred from water flowed upon layers of salt.

The exploration of the Kaptar-khana Cave begun in summer 1963 by a group of speleologists of Moscow, then in November 1963 by the biospeologist S. Ljovuchkin who published in 1969 a short report mentioning the Psocoptera *Psyllipsocus ramburii*. Starobogatov in 1972 described the cave gastropod *Pseudocaspia ljovuchkini.* Sendra. Sket and Stoev explored the cave in 2015 and described in 2017 the first troglobiotic Campodea *Turkmenocampa mirabilis*, and collected undetermined spiders, springtails, crytophagid beetles, parasitic flies.

The cave lakes are inhabited by a fauna from marine origin: foraminifers, gastropods, copepods and isopods. Based on geologic data the two biologists don't considered this fauna as a relict fauna from the Tertiary Sea, but they played either for a more ancient origin or for a dispersion far from the marine transgressions. During the Paleogene the territory was below the Turan Sea (Eastern Paratethys), which began to regress in early Miocene (Popov *et al*., 2004). During the Pliocene the Akchagilian transgression extends far East (Fig. 9) but the Kugitangtau Mountains remain out of the sea.

Provull Cave. About 5 km SW of the Cupp-Coutunn Cave is located the Provull Cave in a gypsum karst (Fig. 6: *6*) where was discovered by V. Maltsev the stygobiont balitorid fish *Paracobitis starostini* (Fig. 14).

Karst thermal spring. In the southern part of the Kugitangtau is located the thermal karst spring Kainar (Khodja-Kaynar in Birstein & Ljovuschkin, 1965), 1000-1500 l/s. Stygobiotic Hydrobioidea, Stenasellidae and Bogidiellidae were collected from this spring. 50 km beyond exists another spring, 30 l/s, characterized by a high H_2S level.

Stenasellus asiaticus sometimes appears in the two Kaynar springs of the Kaynar Lake (Maltsev & Selz, 1992).

Climate: the main part of the country has a climate mostly arid subtropical.

Uzbekistan

Uzbekistan has an area of 447,000 km^2, completely surrounded by landlocked countries: Kazakhstan and Aral Sea to the northwest, Tadjikistan to the southeast, Kyrghyzstan to the northeast, Turkmenistan to the southwest and Afghanistan to the south. It consists of endoreic basins, a vast desert (Kyzyl-Kum), mountains and intensively cultivated and irrigated land in valleys and oases. The highest point is the Khazret Sultan (4,463 m a.s.l.) in Shurkhandarya Province, on the border with Tadjikistan.

For 1984 to 2013 the explorations of caves is carried out by Russian, Spanish, English, Italian and German speleological groups in the Baisun Tau Mountains, in the Surkhandar'inskii region (Tsurikhin *et al.* 2012, 2013, 2014).

The Baisun Tau range is located in southern Uzbekistan (around 67° E and 38° N), it strechtes 50 km from southwest to northeast, and consists of two mountainous ranges, the Kemen'Chapty and the Hodja-Gur-Gur-Ata, with absolute altitudes ranging between 3,500 and 3,900 m.

Caves

On the Hodja-Gur-Gur-Ata the caves open in high altitude, between 3,200-3,750 m a.s.l. and usually at different elevation on walls of clifs. The speleological potential of the region is very high, and many systems could be connected. The entrances lying at altitudes of 3,200-3,800 m and the groundwater discharge occurring through springs, the largest spring located at 1,400 m a.s.l., the difference between cave entrances and spring exceeds 2000 m.

The Festival'naya Cave found and explored for 1985 was the main focus of cavers and by 1990 it had became with connection the Ledopadnaya-Kozlinaya Cave, the Festival'naya-Ledopadnaya caves system. Now, the Festival'naya-Ledopadnaya caves system (16 km of galleries and - 625 m) represents the eastern part of the Central Karst System of Hodja-Gur-Gur-Ata which in 2013 includes six entrances (Dark Star, Capricorne oned, Cancro, Red Dwarf and Vino Rosso) with 9,537 m of surveyed passages to a depth of – 858 m. In the Dark Star, temperature ranges from 0°C to 5°C, ice-crystal on walls and frozen lakes are presents.

On the neighbouring Surkhan Tau range, the Ural speleological club with English and Spanish has explored the Boï Boulok Cave, - 1,415 m deep.

In Uzbekistan, the subterranean fauna (Table 1) mostly arise from interstitial, springs, wells, caves and khanas (kiarizs) explored in the southern Kyzyl-Kum (mainly from the Nuratau and Kuldzhuktau) (Fig. 2A). In 1972, A. Jankowskaya published a list of species mostly stygophile which consists of copepods, ostracods, hydracari, dipters, etc.

III Subterranean fauna

Subterranean fauna (Table 1) was described from caves, khanas, springs, interstitial, from wells in Kara-Kum desert, in spring, wells and interstitial around the Issyk-Kul Lake of Kyrghyzstan, near the Choktal Biological station, and from subterranean habitats in other zones: Kyzyl-Kum desert, mountainous range (Fig. 2).

BACTERIA

Microbiological investigation in the Cupp-Coutunn/Promezhutochnaya cave system on the Kugitangtau mountain ridge (Semikolennnykh, 1997) showed the presence of :

- neutrophilic and acidophilic *Thiobacillus* in the quantity of 8.5 x 10^6 per gr.,
- sulfate-reducing bacteria of *Desulfotomaculum* genus,
- methylotropic corynebacteria *of Arthrobacer, Rhodococcus* and *Mycobacterium* with idenficated as *Bacillus, Derxia, Pseudomonas, Pedomicrobium, Staphylococcus.*

FUNGI

In the same cave system there is a high biodiversity of Mycromycetes: *Aspergillus flavus, A. niger, A. terreus, Choetonium* sp., *Penicilium camembertii, P. chrysogenum, P. faniculesum, P. glabrum, P. purpurogenum, P. waksmanii, Scopuliaropsis* sp., *Trichoderma harzanum, Ulocladium bofritis, Verticilium* sp.

AQUATIC HYPOGEAN FAUNA

RHIZOPODA FORAMINIFERIDA

About 4,500 taxa of Foraminiferida are known, among them more than 3,500 are fossil forms. They inhabite mainly the benthos of tropical seas with normal salinity, some others the brackish water, and a few continental freshwater or slightly brackish; the latter are estimated marine relicts (Golemansky, 1994).

Brodsky (1928, 1929) for the first time signalized presence of living stygobiotic foraminiferida in wells in the Kara-Kum desert, then Nikoljuk (1945, 1948, 1958) and Mikhalevich (1976) found in subterranean waters of the Kara-Kum desert several genera of Foraminiferida. According to authors these Foraminiferida inhabite the subterranean aquifer of the Kara-Kum and can be collected in wells. Other species, *Borovina zernovi* Schmalhausen (= *Entzia*), *Miliammina* sp., *Trochamminita* sp. were found by Birstein and Ljovuschkin (1965), then *Birsteiniolla macrostoma* Jankowskaja & Mikhailevich, 1972 in the Kaptar-Khana Cave, in brackich water (11,68 mmg/l). *Borovina zernovi* is probably widespread in the subterranean water of the country because theques has been found in many sites (Fig. 12).

All other species in Table 1 were found in wells of Kara-Kum, except *Elphitiella* sp. found in interstitial of southern beach of the Issyk-Kul Lake (Jankowskaya, 1966).

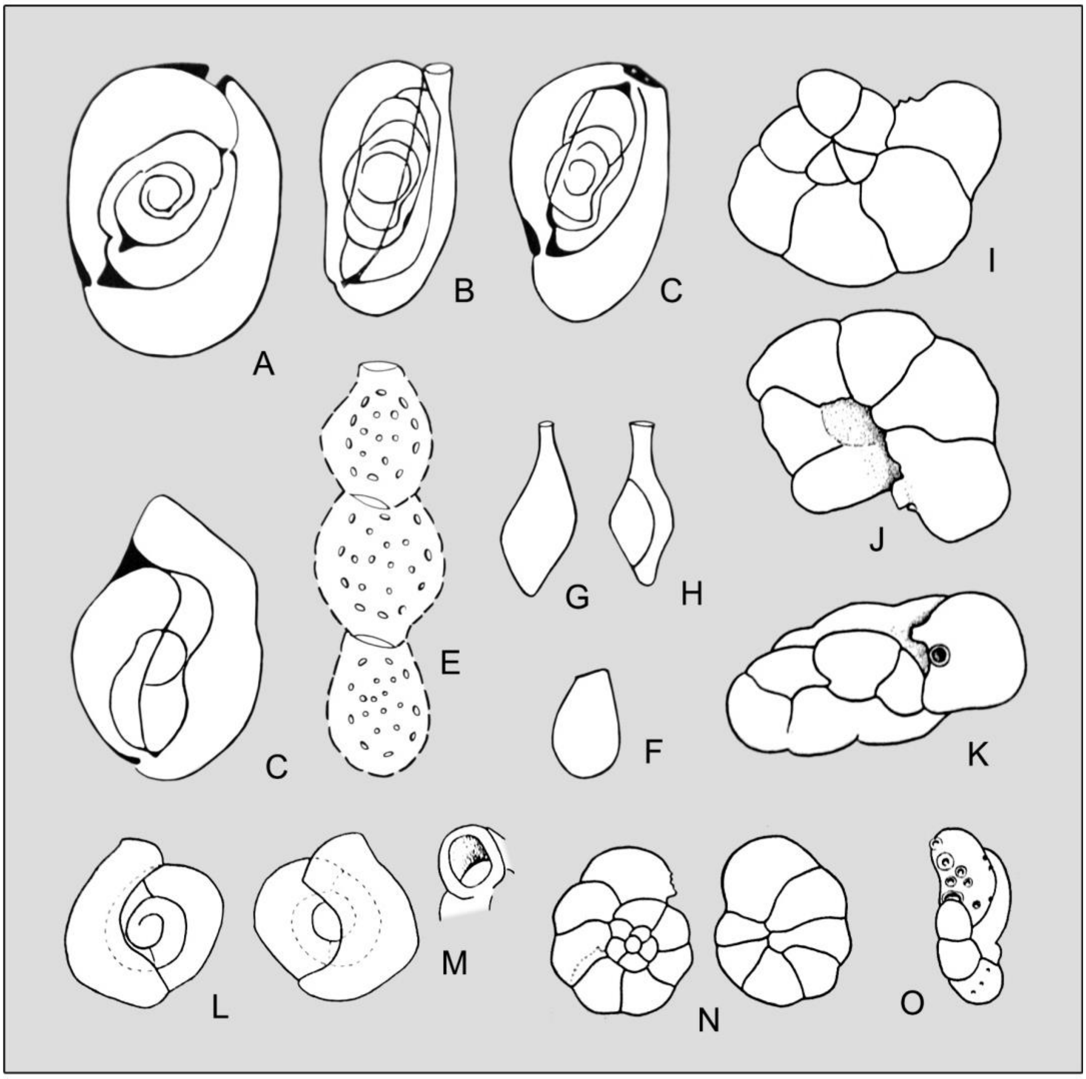


Figure 10. Foraminiferida: A = *Spiroloculina turkomanica* Brodsky, 1928; B = *Biloculina elongata turkomanica* Brodsky, 1929; C = *Biloculina turkomanica* Brodsky, 1928; D = *Triloculina turkomanica* Brodsky, 1929; E, F = *Nodosaria turkomanica* Brodsky, 1929; G, H = *Lagena turkomanica* Brodsky, 1929; I, J, K = *Trochamminita* sp.; L, M = *Miliammina* sp.; N, O = *Borovina zernovi* Schmalhausen, 1950. (Figs. A-H, after Brodsky, 1928; figs. I-O, after Birstein & Ljovuschkin, 1965).

NEMATODA
Monohysteridae
Three stygobiotic species of genus *Anguimonhystra* are known. *A. tenuissima* (Goffart) inhabites the phreatic water at Aschaffenburg in Uzbekistan. The two other species, *A. amphiceps* (Goffart, 1950) and *A. stadlleri* (Goffart, 1950) are known from subterranean water in Erlangen region (Germany).

GASTROPODA
From the Central Asia 11 subterranean taxa were recorded in Botosaneanu *Stygofauna mundi* (1986) belonging to the genera *Kainarella, Paladilhiopsis, Pseudamnicola,* and *Pseudocaspia*, 7 described only on shells.

In 2010 Atullaev and Stadnichenko have published the distribution of aquatic molluscs related to their habitats. From springs they recorded: *Bucharamnicola, Kainarella, Martensamnicola, Pseudocaspia, Turkmenamnicola* and *Valvatamnicola*, we add *Cincinna, Melanoides, Sogdamnicola* and *Tadzhikamnicola*. All species of *Kainarella* and *Melanoides* and some species of *Cincinna* and *Pseudocaspia* were collected in hot springs (Fig. 15).

In 2014 Gloër, Boeters and Pešić described *Chirgisia alaarchaensis* (Fig. 15I) from a rheocrenic spring in the National Park Ala Archa in northern Kyrgyzstan (Gloër *et al*. 2014): troglophile or trogloxene species.

On Table 1, 15 stygobionts and 10 possible stygobionts are recorded, 68% collected in springs, several known only by shells.

The ecological status of molluscs collected in springs is sometimes dubious.

OLIGOCHAETA
Cekanovkaya (1972) published a list of 14 species, stygoxene or stygophile, from subterranean water in Central Asia. From wells and hyporheic of the region of the Issyk-Kul lake: *Dero* sp., *Rhyacodrilus* sp., *Nais elinguis, Lumbriculus variegatus, Eisenia rosea*. From wells in the Kyzyl-Kum desert: *Aelosoma* sp. (Aelosomatidae), *Nais communis, Nais pardalis* (Naididae), *Cristina jankinae, Erilodrilus bavaricus*.

HIRUDINEA
Erpobdellidae
A possible subspecies of *Erpobdella octoculata* Linnaeus was found in spring in the Kyzyl Kum desert.

CLADOCERA
A subspecies of *Ceriodaphnia laticauda deserticola* Manuilova (Fig. 11A) a possible stygobiont, has been collected in a well at Dzingilkuduk, S. Kuldzhuktau Mts, Uzbekistan. Several other species, with stygophile populations, have been collected from springs and wells around the Issyk-Kul Lake and in the Kyzyl-Kum desert. The most frequent are *Chidorus sphaericus* (O. F. Müller), *Daphnia curvirostris* (Eylmann), and with numerous individuals *Ceriodaphnia laticauda deserticola, Moina weberi* Richard, *Oxyurella terminalis* (Sars), *Pleuroxus aduncus* (Jurine).

OSTRACODA
The only stygobiont ostracod is *Cavernocypris subterranea* (Wolf) (Fig. 11B), sampled in a well near the Issyk-Kul Lake, a species widespread in Europe and Asia.

Akatova (1972) records 15 species from the southern zone of the Kyzyl-Kum desert and the shore of the Issyk-Kul Lake, mostly with stygophile populations. From the interstitial of the Issyk-Kul shore: *Cyprideis pedaschenkoi* Daday; from wells in the area of Issyk-Kul, *Cavernocypris subterranea,* from southern springs in Issyk-Kul zone, *Pseudocandona albicans* (Brady)*, Eucypris afganistanensis* (Hartmann), *Heterocypris chevreuxi* (Sars); from wells in the Kysyl-Kum desert, *Pseudocandona albicans, Pseudocandona inaequivalvis* Bronstein, *Heterocypris incongruens* (Romdohr), *Ilyocypris bradyi* Sars, *Pseudocandona marchica* (Hartwig); from khana (kiarizs) of the Nuratau Mts zone, *Pseudocandona inaequivalvis* Bronstein, *Eucypris afghanistanensis* Hartmann, *Ilyocypris bradyi* Sars.

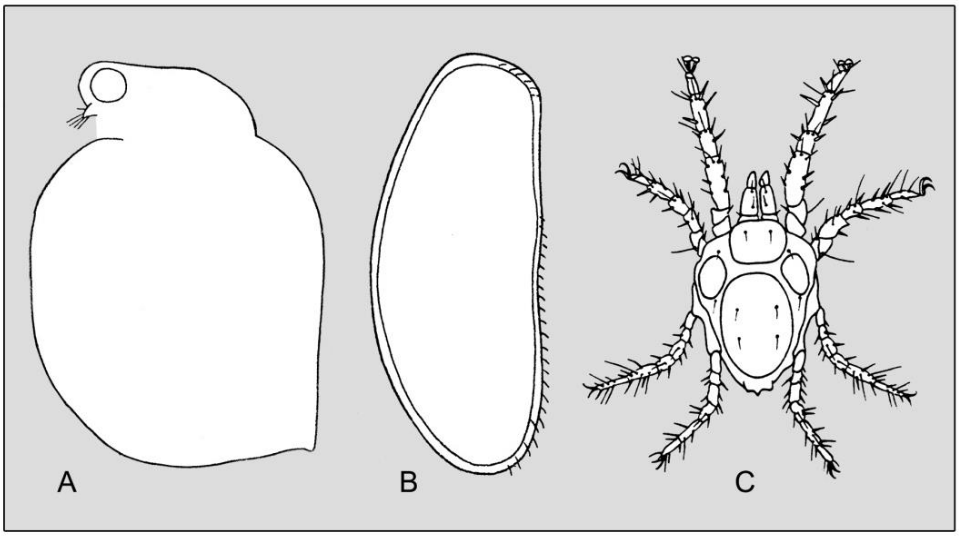


Figure 11. Cladocera: A = *Ceriodaphnia laticauda deserticola* Manuilova, 1972. Ostracoda: B = *Cavernocypris subterranea* (Wolf, 1919); (after Akatova, 1972). Acari, Limnohalacaridae: C = *Soldanellonyx chappuisi* Walter, 1917 (after Imamura, 1968).

COPEPODA

Twelve genera have stygobiotic species or stygobiotic populations in Central Asia: Cyclopidae (3 genera, 4 species), Harpacticoidae (9 genera, 17 species). 80% of the species have been sampled in interstitial hyporheic and phreatic in the Kuldzhuktau and Muratau Mts, south Khyzyl-Kum desert, and on the shore of the Issyk-Kul Lake.

Cyclopidae. Cyclopids with stygobitic populations: *Eucyclops serrulatus* (Fischer) the most frequent and abundant in subterranean aquatic habitats of Central Asia; *Diacyclops bisetosus* (Rheberg) and *D. bicuspidatus* (Claus) and the stygobiont *Bryocyclops jankowskayae*.

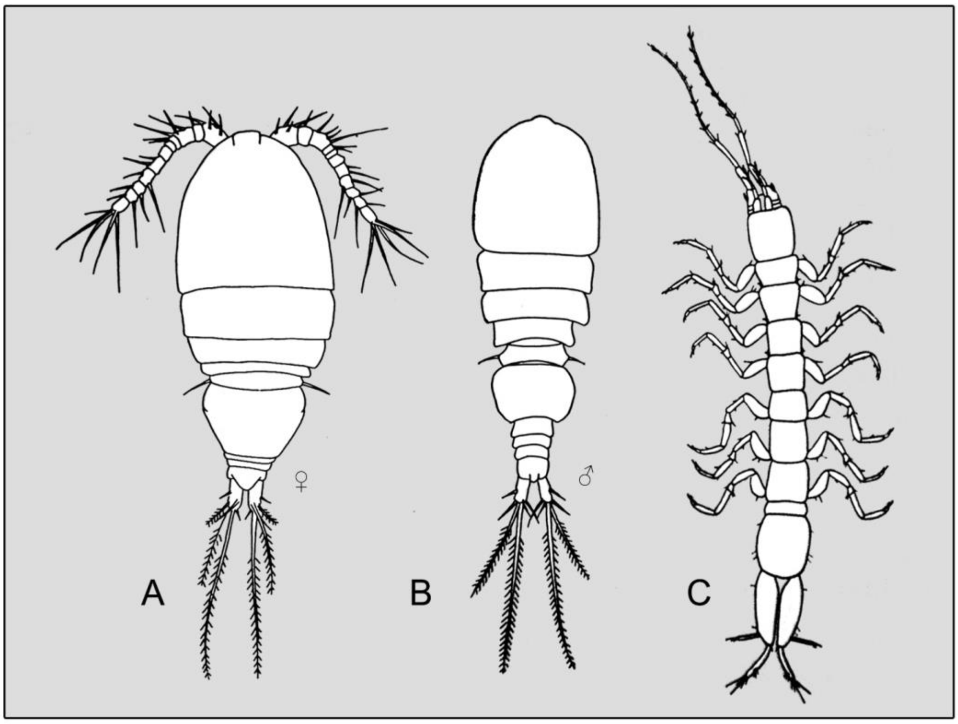


Figure 12. Copepoda: A, B = *Bryocyclops jankowskajae* Monchenko, 1972. Isopoda: C = *Microcharon halophilus* Birstein & Ljovuschkin, 1949.

Harpacticoidae. Among the harpacticids, the genera *Nitocrella* and *Reinitocrella*, with 9 stygobiotic species are the most frequent, whereas *Attheyella*, *Bryocamptus* and *Maraenobiotus* are widely present in aquatic surface habitats; a species *Bryocamptus aqueductus*, described by Borutzky (1934) from subterranean water pipe in N Caucasus, was found in springs of Turkmenistan and Bulgaria, and in mosses in Bulgaria (Rouch, 1986). The genus *Schizopera* is well present in interstitial habitat: *S. paradoxa* (Baday) recorded by Birstein and Ljovuschkin (1965) from the brackish lake inside the Kaptar-Khana Cave, Turkmenistan, then from the spring Khodza-Kajnar and wells on northern slope of the Issyk-Kul Lake (Monchenko, 1972).

Three harpacticids have stygophile populations: *Ectinosoma abreau* (Kirtschagin), a marine genus Ponto-Uralo-Caspian in brackish and freshwater; *Nitocra* sp. from Kaptar-Khana Cave, genus widespread in brackish water; *Bryocamptus minutus* (Claus).

ISOPODA

Stenasellidae

Stenasellus asiaticus Birstein & Starostin is the alone species known in Central Asia, found in the thermal spring Khodza-Kajnar and from the Cupp-Coutunn Cave system were is common. Body pink, colored by hemolymphatic pigments.

Lepidocharontidae

Three species of *Microcharon* are recorded from subterranean water of Central Asia: *M. kirghisicus* Jankowkaya from sand and gravel interstitial near the Issyk-Kul Lake; *M. halophilus* Birstein & Ljovuschkin (fig. 15) inhabites the brackish lake inside the Kaptar-Khana Cave; *Microcharon* sp. from hyporheic of a dry valley in southern Kyzyl-Kum desert. All species present a strong thigmotactisme.

AMPHIPODA

Gammaridae

Three stygobionts have been described from springs in Tadjikistan*:* *Comatogammarus ferghanensis* (Martynov & Behning), *Tadzocrangonyx schizurus* (Birstein) (Fig. 13) and *Tadzocrangonyx setiferus* (Birstein & Ljovuschkin). Other species without troglomorphic characters were recorded from springs: *Chaetogammarus shadini* (Birstein) in Tadjikistan, *Gammarus gracilis* (Martynov) from Turkestan, and *Gammarus turanus* (Martynov) from Turkestan, a relict species.

Three new species stygobiont and stygophile of *Gammarus* and *Tadzocrangonyx* has been described by Sidorov *et al.* (2018).

Bogidiellidae

All species anophthalme and unpigmented, from subterranean habitats. *Bogidiella ruffoi* Birstein & Ljovuschkin recorded from thermal karstic spring Khodza-Kajnar, Turkmenistan.

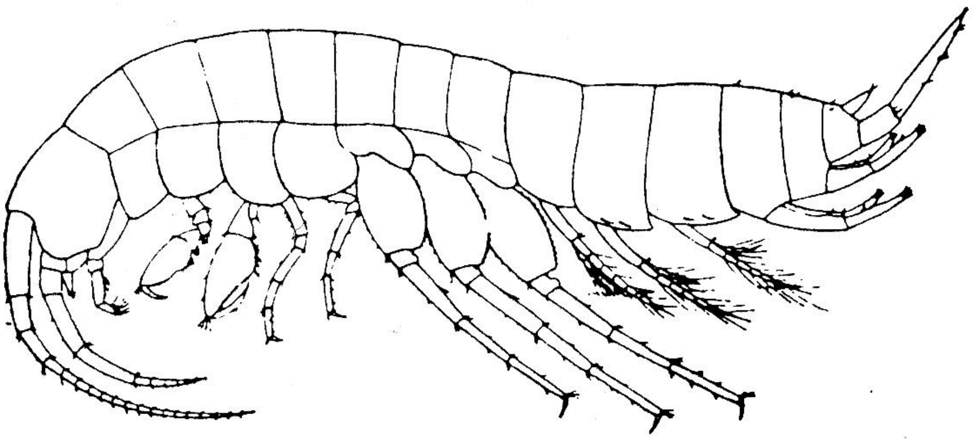


Figure 13. Amphipod *Tadzocrangonyx schizurus* (Birstein, 1948), spring, Hissar Mts.

ACARI

Four stygobiont Limnohalacaridae are known in Central Asia: *Soldanellonyx chappuisi* Walter (Fig. 11C), anophthalme as all the *Soldanellonyx*, from interstitial of two tributaries of the Issyk-Kul Lake;

Parasoldanellonyx parviscutatus (Walter) stygobiont from hyporheic in southern Kyzyl-Kum desert; two stygobionts of the genus *Lobohalacaruswere* collected in wells in Kuldzhukutau and Nuratau Mts.
Hydryphantidae

Tadjikothyas connexa Sokolow stygobiont from a spring in the canyon Kandera, N Tadjikistan.
Aturidae

Kongsbergia sp. stygobiont from a spring in southern Uzbekistan.

PISCES
Balitoridae

A stygobiotic fish was found by V. Maltsev, *Paracobitis starostini* (Fig. 14) in the Provull gypsum Cave, located in southern region of the Kugitangtau Mts. Anophthalme, body yellow light. Cave Balitoridae are also known from Iran (*Paracobitis smithi*), China (*Paracobitis longibarbatus*) and India (*Shistura papulifera*).

Figure 14. Pisces Balitoridae *Paracobitis starostini* (Parin, 1983), Provull gypsum Cave, Kugitangtau (Photo S.A.Smirnova).

DIPTERA
Larvae of almost 40 genera of Chironomidae and Culicidae have been collected from water of subterranean habitats in Central Asia (Pankratova, 1972). From wells around Issyk-Kul Lake, *Chironomus thummi* Lenè; from khana in Uzbekistan, *Lymnophyes transcaucasicus* Ishern., *Thienemanniella fusca*, *Tanytarsus exigus* John; from hyporheic of Ciolpa-Ata, *Corinoneura scutellata* Winn.,*Orthocladius frigidus* Zetterst, *Tanytarsus gregarius* Kieff., *Microcrotipus bicolor* (Zetterst.). From springs several species of *Orthocladius*, *Ablabesmya*, *Corinoneura*, *Chironomus*, *Tanytarsus*. From wells and springs in the Kyzyl-Kum desert, *Culiseta longilireolata* (Macq.), *Culex hortensis* Fic.

TERRESTRIAL HYPOGEAN FAUNA

Cave terrestrial fauna is a few known, relatively to the aquatic fauna.

Four troglobionts are recorded: - the springtail *Pseudacherontides stachi* Ljevochkin, from Uzbekistan, - the cosmopolitan *Folsomia candida* Willem, from Turkmenistan, - the tenebrionid *Leptodes lindbergi* Kazab, from Turkmenistan, - and described in 2017 the Campodeidae *Turkmenocampa mirabilis* Sendra & Stoev, also from Turkmenistan. One species presumably troglobiont was collected, the widespread Psocoptera *Psyllipsocus ramburii* Selys-Longchamps.

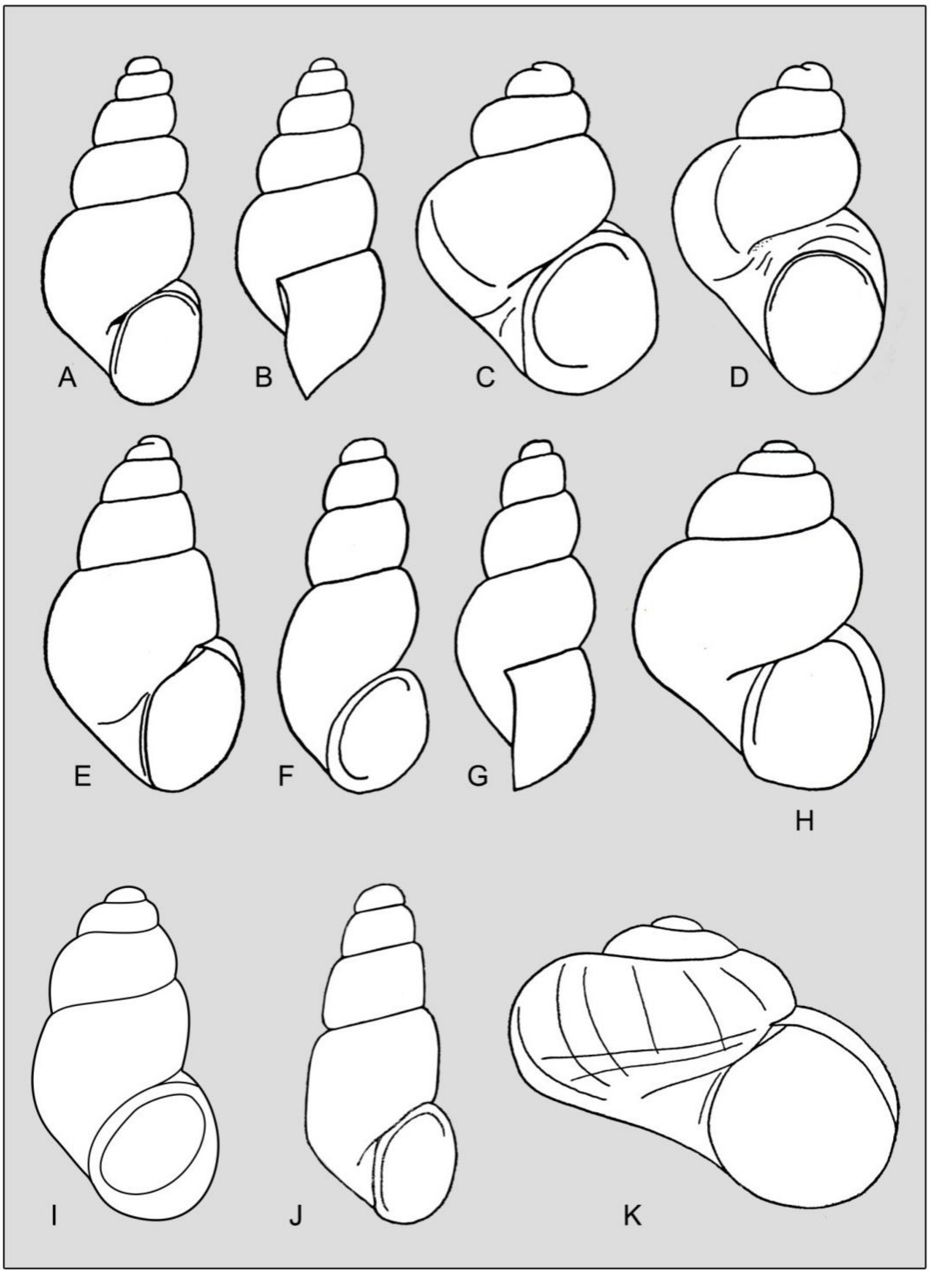


Figure 15. Gastropoda: A, B = *Pseudocaspia ljovuschkini* Starobogatov, 1972; C, D = *Pseudocaspia kainarensis* Starobogatov, 1972; E = *Pseudocaspia starostini* Starobogatov, 1972; F, G = *Kainarella minima* Starobogatov, 1972; H = *Bucharamnicola bucharica* (Shadin, 1952); I = *Chirgisia alaarchaensis* Glöer, Boeters & Pešić, 2014; J = *Paladilhiopsis* sp.2 Starobogatov, 1962; K = *Cincinna pamirensis* Starobogatov.

DIPLURA

A troglobiomorphic species *Turkmenocampa mirabilis* Sendra & Stoev was described in 2017 from the Kaptar-Khana Cave in the Kugistang Mountain, Turkmenistan (Sendra *et al*. 2017). Ten males and 17 females have been found in pitfalls, 200-250 m inside the larger gallerie, near boulders and guano of *Rhinolophus bocharicus.* Troglobiomorphic traits of the species are (Sendra *et al*. 2017): – slightly elongated body and appendages, moderate increase in the number of antennomeres, – an increase of the complexity and size of porous surface of the cupuliform organ, an olfactory receptor, which has no analogue in any other Campodeidae, – transversal crest on claws, an adaptation to walking on wet and soft surface in subterranean environment.

Several troglophile species are recorded:

- the diplopod *Elongeuma speophilum* Golovatch,

- the pseudoscorpion *Dinocheirus transcaspius* (Redikorzev),
- the springtail *Folsomia candida* (Willem), widespread on water surface of caves in Europe, and also in caves or Central Asia. Life cycle on the surface of water.

About twelve species of Blattidae and beetles are classified troglophile, but their ecological status is perhaps trogloxene.

Two subtroglophile genera of Lepidoptera and Diptera and one subtroglophile beetle of the genus *Cholevinus* are collected in the entrance of caves.

Table 1. List of stygobiotic species known from countries of Central Asia. Species supposed to be stygobiotic are given with a question mark.

KAZAKHSTAN

GASTROPODA
Hydrobiidae
• ?*Martensamnicola kazakhstanica* Izzatullaev, Sitnikovka & Starobogatov, 1985; spring near Vannovka, Shymkent region, S. Kazakhstan.
COPEPODA
Cyclopidae
• *Monchenkocyclops mirabdullayevi* Karanovic, Yoo & Lee, 2012; well, S. Kazakhstan.
Canthocamptidae
• *Bryocamptus zschokkei caucasicus* Borutzky, 1960; hyporheic water, Alma-Atinka river, near Alma-Ata.
Ectinosomatidae
Halectinosoma limnophila Sterba, 1967; interstitial Varzob river near Duschanbe (Džambul).
AMPHIPODA
Niphargidae
• *Niphargus pseudocaspius* Karaman, 1982; sub-lacustric spring in Kendyrli Bay, depth 32-36 m; E. Caspian Sea.
Crangonyctidae
• *Stygobromus kazakhstanicus* Kuklina, 1992; spring near Chernorechenskaja (Agalataskaya) Cave, NE Bishkek.

KYRGYZSTAN

GASTROPODA
Cochliopidae
• ?*Pseudocaspia issykkulensis* (Clessin, 1894); hyporheic water and wells, shore Issyk-Kul Lake; also from the lake.
Hydrobiidae
•*Chirgisia alaarchaensis* Glöer, Boeters & Pešić, 2014.
COPEPODA
Ameiridae
• *Nitocrella jankowskajae* Borutzky, 1972; hyporheic, several stations, shoreline N. Issyk-Kul Lake; numerous individuals.
• *Nitocrella kirgizica* Borutzky, 1972; hyporheic water, shoreline Cholpon-Ata River, N. Issyk-Kul Lake.
• *Reidnitocrella borutzkyi* Karanovic & Hancock, 2009; interstitial, shoreline Issyk-Kul Lake.
• *Reidnitocrella djirgalanica* (Borutzky, 1978); interstitial, Dzhirgalan River (affluent of the Issyk-Kul Lake).
• *Reidnitocrella* (ex *Stygonitocrella*)*tianschanica* (Borutzky, 1972); well, hyporheic water, shoreline N. Issyk-Kul Lake.
Canthocamptidae
• *Attheyella orientalis mesasiatica* Borutzky, 1969; well, shoreline N. Issyk-Kul Lake.
Diosaccidae
• *Schizopera pseudojugurtha* Borutzky, 1964; hyporheic water, several stations, shoreline N. Issyk-Kul Lake.
• ?*Schizopera paradoxa* (Daday, 1904); wells, N. shore Issyk-Kul Lake.
OSTRACODA
Cyprididae
• *Cavernocypris subterranea* (Wolf, 1919) (Fig. 11 B); well, Cholpon-Ata Biological Station, shoreline N. Issyk-Kul Lake.
SYNCARIDA
Bathynellidae
• *Eobathynella mesasiatica* (Birstein & Ljovuschkin, 1964); cave near Khaidarkan, Osh region.
Parabathynellidae

• *Issykkulibathynella* (*ex Parabathinella*) *tianschanica* (Jankowskaja, 1964); well, shoreline N. Issyk-Kul Lake, Cholpon-Ata Biological Station; numerous individuals.
• *Tianschanobathynella jankowskaja*e Serban, 1993; region of the Issyk-Kul Lake.
• *Tianschanobathynella paraissykkulensis* Serban, 1993; groundwater of Tian Shan and region of the Issyk-Kul Lake.
• *Tianschanobathynella issykkulensis* (Jankowskaja, 1964) Issyk-Kul Lake, Tian Shan North.
ISOPODA
Lepidocharontidae
• *Microcharon kirghisicus* Jankowkaya, 1964; well, shoreline Issyk-Kul Lake.
AMPHIPODA
Gammaridae
• *Tadzocrangonyx setiferus* (Birstein & Ljovuschkin, 1972); spring close to the Atbasha River.
• *Tadzocrangonyx alaicus* Sidorov, Hou & Sket, 2018; from Batken region.
ACARI
Limnohalacaridae
• *Soldanellonyx chappuisi* Walter, 1917; hyporheic, borders Aksu and Dzhergalan rivers (affluents of the Issyk-Kul Lake). (fig. 11 C).

TADJIKISTAN

GASTEROPODA
Cochliopidae
• ?*Pseudocaspia* (ex *Pseudamnicola*) *narzikulovi* Izzatuallaev, 1972; hyporheic Vaksh River, „Tigrovaya balka" near Jetty.
• ?*Pseudocaspia* (ex *Pseudamnicola*) *tadjikistanica* Izzatuallaev, 1972; hyporheic Vaksh River, „Tigrovaya balka" near Jetty.
Hydrobiidae
• *Bucharamnicola* (ex *Pseudamnicola*) *bucharica* (Shadin, 1952); spring, Hissar (Gissar) Mts, N of DUshanbe. (Pl. I, H).
• ?*Martensamnicola hissarica* (Shadin, 1950); spring in Gazhni ravine in Hissar ridge, 92 km N. of Dushanbe; spring on right bank of Kondara River.
• *Sogdamnicola shadini* Izzatullaev, 1984; spring in Tadjikista (also spring at Urgut, SE of Samarkand in E. Uzbekistan, and springs in Central Asia).
• *Tadzhikamnicola* (ex *Pseudamnicola*) *likharevi* (Izzatullaev, 1973); spring in Tadjikistan (also from alluvion of the Surkhov River, vicinities of the farm Muminabd, E. Urgut, Kulyaniskij district in Uzbekistan). Listed on the Red Book.
• *Tadzhikamnicola* (ex *Pseudamnicola*) *pavlovskii* (Izzatullaev, 1973); spring in Tadjikistan (also from alluvion of the Surkhov River, vicinities of the farm Muminabd, E. Urgut, Kulyaniskij district in Uzbekistan. Listed on the Red Book.
Thiaridae
• *Melanoides pamiricus* Lindholm, 1930; Dzhanshangoz hot spring, at 3,360 m. alt., Shakhdara River, W. Pamir. Listed on the Red Book.
• *Melanoides shadaraensis* Starobogatov & Izzatullaev, 1980; Dzhanshangoz hot spring, Shakhdara River, W. Pamir. . Listed on the Red Book
Valvatidae
• *Cincinnapamirensis* (Starobogatov, 1972); Gorno-Badakhshanskaya, Shaimak, 7 km of Kyzyl-Ravata, warm spring on right bank of Aksu river, SE Tadjikistan.
COPEPODA
Ameiridae
• *Nitocrella asiatica* (Sterba, 1967); hyporheic, Varzob River at Dushanbe.
• *Nitocrella sterbai* Borutzky, 1969; hyporheic, Varzob River at Dushanbe.
Ectinosomatidae
• *Arenosetella limnophila* Sterba, 1967; hyporheic, Varzob River at Dushanbe.
AMPHIPODA
Gammaridae
• *Comatogammarus ferghanensis* (Martynov & Behning, 1948); spring.
• *Tadzocrangonyx schizurus* (Birstein, 1948); spring, Hissar Mts. (Fig. 13).
• *Tadzocrangonyx setiferus* (Birstein & Ljovuschkin, 1972); spring close to the Atbasha River.
HYDRACHNIDIA
Hydryphantidae
• *Tadjikothyas connexa* Sokolow, 1948; spring in Kondara pass, N. Tadjikistan.

TURKMENISTAN

FUNGI
Micromycetes
- *Aspergillus flavus, A. niger, A. terreus, Choetonium* sp., *Penicilium camembertii, P. chrysogenum, P. faniculesum, P. glabrum, P. purpurogenum, P. waksmanii, Scopuliaropsis* sp., *Trichoderma harzanum, Ulocladium bofritis, Verticilium* sp.

RHIZOPODA: FORAMINIFERIDA
**Borovina zernovi* Schmalhausen, 1950 (= *Entzia*), Kaptar-Khana Cave, Kugitang Darja River, Kodjambass district.

Cibicididae
• *Cibicides strelkovi* Mikhalevich, 1976; well, Kara-Kum desert.

Discorbidae
• *Discorbis subterranea* Mikhalevich, 1976; well, Kara-Kum desert.

Elphidiidae
• *Elphidiella* sp.Jankowskaja, 1972; limnostygal, N. shoreline Issyk-Kul Lake.

Globigerinidae
• *Globigerina turkomanica* Brodzky, 1929; well, Kara-Kum desert.

Lagenidae
• *Lagena subterranea* Brodzky, 1929; well, Kara-Kum desert.
• *Lagena turkomanica* Brodzky, 1929; well, Kara-Kum desert (Fig. 10G-H).

Lituolidae
• *Haplophragmoides brodskyi* Mikhalevich, 1976; well, Kara-Kum desert.

Miliolidae
• *Biloculina elongata turkomanica* Brodzky, 1929; well, Kara-Kum desert (Fig. 10B).
• *Biloculina turkomanica* Brodzky, 1928; well, Kara-Kum desert (Fig. 10C).
• *Jajdammina zernovi* Schmalhausen, 1950; Kaptar-Khana cave, Kugitang Darja River, Kodjambass district (Fig. 10N-O).
• *Miliammina elongata arenacea* Chapman, 1800; well, interstitial beaches, Kara-Kum desert.
• *Miliammina* sp.; Kaptar-Khana Cave, Kugitang Darja River, Kodjambass district (Fig. 10L-M).
• *Nodosaria turkomanica* Brodzky, 1929; well, Kara-Kum desert (Fig. 10E-F).
• *Spiroloculina turkomanica* Brodzky, 1928; well, Kara-Kum desert (Fig. 10A).
• *Triloculina turkomanica* Brodzky, 1929; well, Kara-Kum desert (Fig. 10D).

Turrilinidae
• *Bollivina brodskyi* Mikhalevich, 1976; well, Kara-Kum desert.
• *Turrilina turkomanica* Mikhalevich, 1976; well, Kara-Kum desert.

Trochamminidae
• *Trochamminita* sp.; Kaptar-Khana Cave, Kugitang Darja River, Kodzhambass district (Fig. 10I-K).

GASTROPODA
Cochliopidae
• *Kainarella minima* Starobogatov, 1972; thermal spring Khodza-Kajnar (20-22 ^{o}C), Chardzhu region.
• *Kainarella* sp. Starobogatov, 1972; thermal spring, Khodza-Kajnar, Chardzhu region.
• *Pseudamnicola lindholmi* Shadin, 1952 Shar-Arab spring near Kuška.
• *Pseudocaspia kainarensis* Starobogatov, 1972; thermal spring Khodza-Kajnar, Chardzhu region (Fig. 15C-D).
• *Pseudocaspia ljovuschkini* Starobogatov, 1972; Kaptar-Khana cave, Kugitang Darja River, Kodzhambass district (Fig. 15A-B).
• *Pseudocaspia starostini* Starobogatov, 1972; thermal spring Khodza-Kajnar, Chardzhu region (Fg. 15E).

Hydrobiidae
• *Turkmenamnicola* (ex *Pseudamnicola*) *lindholmi* (Shadin, 1952); Shar-Arab spring (near Kushka), S. Turkmenistan.
• ?*Turkmenamnicola* (ex *Pseudamnicola*) *smaradovae* (Abrikosov & Tzvetkov, 1945); springs of the Sekiz-yab River, near Germab village, south of the Geok-Tepe, NW of the Ashhabad.

Thiaridae
• *Melanoides kainarensis* Starobogatov & Izzatullaev, 1980; thermal karstic spring Khodza-Kajnar, Chardzhu region. Listed in the Red Book.

COPEPODA
Ameiridae
Nitocra sp.; Kaptar-Khana Cave, Kugitang Darja River, Kodzhambass district.

Canthocamptidae
• ?*Bryocamptus aqueductus* Borutzky, 1934; spring.

Cylindropsyllidae

• *Paraleptastacus spinicaudatriseta* Noodt, 1954; interstitial, beaches of the Caspian Sea.
Diosaccidae
• ?*Schizopera paradoxa* (Daday, 1904); Kaptar-Khana Cave, Kodjambass district; thermal spring Khodza-Kajnar (20-22°C)
Ectinosomatidae
Halectinosoma abrau (Krichagin, 1877).
ISOPODA
Lepidocharontidae
• *Microcharon halophilus* Birstein & Ljovuschkin, 1965; brackish water lake inside the Kaptar-Khana Cave, Kodjambass district. (Fig. 12C).
Stenasellidae
• *Stenasellus asiaticus* Birstein & Starostin, 1949; phreatic of the Cupp-Coutunn caves system, thermal spring Khodza-Kajnar and Kajnar lake, Chardzhu region.
AMPHIPODA
Bogidiellidae
• *Bogidiella ruffoi* Birstein & Ljovuschkin, 1968; thermal spring Khodza-Kajnar, Chardzhu region.
Gammaridae
• *Sarothrogammarus asiaticus* Martinov, 1935; spring.
Two other species are described (Sidorov *et al*., 2018); from Lebap Province, in the extreme East of Turkmenistan:
• *Gammarus troglomorphus*, troglobiont; from springs Çulinka, 58° 0' 48" E, alt: 980 m.
• *Gammarus parvioculatus*, troglophile, with slightly smaller eyes but not troglomorphic.
PISCES
Balitoridae
• *Troglocobitis starostini* (Parin, 1983); subterranean water of the Provull gypsum Cave, Kugitangtau, 70 km SE of Gaurduk; SE. Turkmenistan. (Fig. 14).

UZBEKISTAN

NEMATODA
Monhysteridae
• *Anguimonhystra tenuissima* (Goffart, 1950) Andrassy, 1981; phreatic at Aschaffenburg.
GASTROPODA
Hydrobiidae
• *Bucharamnicola bucharica* (Shadin, 1952); spring, Aiak-Guzhumdy territory, S. Kuldzhuktau. (Fig. 15H).
• ?*Martensamnicola hissarica* (Shadin, 1950); spring at Bakhmal, Jizzakh Province.
• *Paladilhiopsis* sp.1 Starobogatov, 1962; subterranean waters, SW. Kyzyl-Kum desert.
• *Paladilhiopsis* sp. 2 Starobogatov, 1962; hyporheic, Bukhchasaja River at Akbela hillock; 18 km SE. Nuratau Mts, Samarkand district.
• *Sogdamnicola* (ex *Pseudamnicola*) *pallida* (Martens, 1874); little pond in the garden in Uzgun, Zeravshan valley; spring and spring-fed water courses in Central Asia.
• *Sogdamnicola shadini* Izzatullaev, 1984; springs, Urgut, SE of Samarkand, Uzbekistan.
• *Tadzhikamnicola* (ex *Pseudamnicola*) *likharevi* (Izzatullaev, 1973); spring, hyporheic of the river Surkhob, vicinities of the farm Muminabad (E. of Urgut), Kulyabskij district, E. Uzbekistan.
* *Tadzhikamnicola* (ex *Pseudamnicola*) *pavloskii* (Izzatullaev, 1973); interstittial Surkhob River, near the farm Muminabad (E. Urgut), Kulyabskij district, E. Uzbekistan.
• ?*Valvatamnicola* (ex *Pseudamnicola*) *archangelskii* (Shadin, 1952); spring, road from Vozadil village to Shahimardan (near Khaydarkan), Altai mountain system, N. Pamir.
• ?*Valvatamnicola schahimardanica* Izzatullaev, 1984; spring between Shahimardan and Vyadil, Fergan Area.
HIRUDINEA
Erpobdellidae
• *Erpobdella octoculata* (Linnaeus, 1758) ? ssp. Birstein & Ljovuschkin, 1967; limnocrene spring in S. Kyzyl-Kum desert.
CLADOCERA
Daphniidae
• ?*Ceriodaphnia laticauda deserticola* Manuilova, 1972 (Fig. 11 A); well at Dzhingilkuduk, S. Kuldzhuktau Mts.
COPEPODA
Cyclopidae
• *Bryocyclops jankowskajae* Monchenko, 1972; wells at Sultan-Bibi and Tashkuduk, S. Kuldzhuktau Mts (Fig. 12, A, B).
• *Monchenkocyclops* (ex *Acanthocyclops*) *biarticulatus* (Monchenko, 1972); hyporheic at Akbela hillock; SE. Nuratau Mts, Samarkand district.
Ameiridae

• *Nitocrella kyzylkumica* Borutzky, 1972; hyporheic, river near Nuratau, S. Kyzyl-Kum desert.
• *Nitocrella monchenkoi* Burutzky, 1972; wells and springs at Sultan-Bibi and Tashkuduk, S. Kuldzhuktau Mts.
Ectinosomatidae
• *Halectinosoma uniarticulatum* Borutzky, 1972; well at Uchkuduk, S. Kuldzhuktau Mts.
Canthocamptidae
• *Maraenobiotus insignipes kyzylkumicus* Borutzky, 1972; well near Sarykiariz, S. Nuratau Mts; a very large population.
SYNCARIDA
Parabathynellidae
• *Eobathynella minima* Jankowskaja, 1972; hyporheic in a dry river bed, S. Kyzyl-Kum desert.
AMPHIPODA
Gammaridae
Sarothrogammarus asiaticus Martinov, 1935; spring.
ISOPODA
Lepidocharontidae
• *Microcharon* sp. Jankowskaja, 1972; hyporheic in a dry river bed, Kyzyl-Kum desert.
ACARI
Limnohalacaridae
• *Lobohalacarus bucharensis* Jankowskaja, 1967; wells at Sultan-Bibi, Shaidarez, Uchkuduk and Uruskuduk; S. Kuldzhuktau and S. Nuratau Mts.
• *Lobohalacarus* sp.; wells at Uchkuduk and Uruskuduk; S. Kuldzhuktau and Nuratau Mts.
• *Parasoldanellonyx parviscutatus* (Walter, 1917); subterranean waters, S. Kyzyl-Kum desert.
Aturidae
• *Kongsbergia* sp.; spring, S. Kuldzhuktau Mts.

Table 2. List of troglobionts, troglophiles and subtroglophiles

KYRGYZSTAN

DIPLOPODA
Antroleucosomatidae
Elongeuma speophilum Golvatch, 1982; Кeннын-Кын Cave, troglophile.

TURKMENISTAN

PSEUDOSCORPIONES
Dinocheirus transcaspius (Redikorzev, 1922); from Бахарденской (= Дурунсой) Cave, troglophile.
COLLEMBOLA
Folsomia candida Willem, 1902; cosmopolitan, troglobiont.
Numerous undetermined species.
DIPLURA
Campodeidae
***Turkmenocampa mirabilis* Sendra et Stoev, 2017; Kaptar-Khana Cave, Kugitangtau mountains, troglobiont.
DICTYOPTERA-BLATTARIA
Blattidae
Blatta orientalis Latreille, 1810; from Бахарденской (= Дурунсой) Cave.
Shelfordella lateralis (Walker, 1868); from Бахарденской (= Дурунсой) Cave.
PSOCOPTERA
Psyllipsocus ramburii Selys-Longchamps, 1872; Kaptar-Khana Cave, Kugitangtau Mountains.
COLEOPTERA
Carabidae
Cymindis andreae Ménéstriés, 1832; from Бахарденской (= Дурунсой) Cave.
Platytarus famini (Dejean, 1826); from Бахарденской (= Дурунсой) Cave.
Dytiscidae
Bidessus thermalis var. *tetragrammus* Hochhuth; from Бахарденской (= Дурунсой) Cave.
Ptinidae
Niptus holoceucus (Faldermann, 1836); cosmopolitan, troglophile.
Salpingidae
Aglenus brunneus (Gyllenhall, 1813); from Бахарденской (= Дурунсой) Cave.
Staphylinidae

Phyllodrepa caucasica (Kolenati, 1846); from Бахарденской (= Дурунсой) Cave, troglophile.
Tenebrionidae
**Leptodes lindbergi* Kazab, 1959; from Отмече вКардюкской Cave.
Blaps desplaneta Ménéstriés, 1832; from Бахарденской (= Дурунсой) Cave, troglophile.
Cyrphogenia gibba Fischer de Waldheim, 1821; from Бахарденской (= Дурунсой) Cave, troglophile.
Netuschilia hauseri (Reitter, 1897); from Бахарденской (= Дурунсой) Cave, troglophile.
Ocnera imbricata Fischer de Waldheim, 1820; from Бахарденской (= Дурунсой) Cave, troglophile.
LEPIDOPTERA
Tineidae
Tinea sp.
DIPTERA
Trichoceridae
Trichocera sp.
CHIROPTERA
Rhinolophidae
Rhinolophus bocharicus.
Also, Isopoda Oniscoidea, Pseudoscorpiones, Araneae, undetermined.

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COLLEMBOLA
**Pseudacherontides stachi* Ljevochkin, 1972; Amir-Temip Cave, troglobiont.
COLEOPTERA
Cholevidae
Cholevinus pallidus Ménéstriés, 1832); from Указан нз Cave, subtroglophile.
Eucatops tenuicornis Iablokoff-Khnzorian, 1967; from Калчак-Унгур Cave, troglophile.

IV Conservation

Several protected cave species of gasteropods are listed in the Red Book: *Melanoides pamiricus, Melanoides shakdarensis, Tadzhikamnicola likharevi* and *Tadzhikamnicola pavlovskii*, from Tadjikistan*; Melanoides kainarensis* from Turkmenistan.

Note. Encyclopaedia Biospeologica special issue. This paper corresponds to an up to date survey of the subterranean species in Asian countries of the former URSS, a special issue of Encyclopaedia, following “Siberia” published in *Ecologica Montenegrina* in 2016 (Juberthie *et al*. 2016) and the first special issue “Subterranean fauna of Mexico” with Palacios Vargas from Mexico and James Reddell from USA, published in 2014 in *Mundos subterraneus*.

References

Akatova, N. A. (1950) On the ostracod fauna of Central Asia. *Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk, SSSR*, 9 (1), 90-115.
Akatova, N. A. (1972) Subterranean water ostracods from southern Kisil-Kum and the shore of Issyk-Kul, *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR, Leningrad*, 51, pp. 120-130. (In Russian).
Akhmetyev, M., Dodoniv, A., Somikova, M., Spasskaya, I., Kremenetsky, K. & Klimanov, V. (2005) Kazakhstan and Central Asia (Plains and Foothills). *In*: Velichko, A. & Nechaev, V. (eds.). *Cenozoic climatic and environmental changes in Russia. Special paper* 382. Boulder Colorado. Geological Society of America.
Andrassy, I. (1981) Revision of the order Monhysterida (Nematoda) inhabiting Soil and Inland waters. *Opuscula. Zoologica* (*Budapest*), 17/18, 13-47.
Bena, P., Hanak, V. & Cerveny, J. (2011) Bats (Mammalia: Chiroptera) of the Eastern Mediterranean and Middle East. Part 9. Bats from Transcaucasia and Turkestan in collection of the Natural Museum, Prague. *Acta Societatis Zoologicae Bohemicae*, 75, 159-222.
Bernabei, T. & De Vivo, A. (1992) *Grotte e storie dell’Asia Centrale*. Centro Editorial Veneto, Padova.

Birstein, J. A. (1948) Amphipoda of Tadzhikistan. In memory of Acad. S. A. Zernov. *Publ. House Academia Nauk. SSSR*, 263-273. (In Russian).

Birstein, J. A. (1970) Caractéristique zoogéographique de la faune souterraine de l'Union Soviétique. *In*: *Livre du centenaire „Emile Racovitza"* 1868-1968. Ed. Academie R. S. Romana, pp. 121-221.

Birstein, J. A. & Ljovuschkin, S. I. (1964) Occurence of Bathynellacea (Crustacea Syncarida) in Central Asia. *Zoologicheskii Zhurnal*., 43 (1), 17-27. (In Russian).

Birstein, J. A. & Ljovuschkin, S. I. (1965a) Faune des eaux souterraines saumatres de l'Asie centrale. *International Journal of Speleology*, 1 (3), 307-320.

Birstein, J. A. & Ljovuschkin, S. I. (1965b) Subterranean Paraselloidea (Crustacea, Isopoda) in SSSR. *Zoologicheskii Zhurnal*, 44 (7), 997-1013. (In Russian).

Birstein, J. A. & Ljovuschkin, S. I. (1967) Some results and research problems concerning the subterranean fauna from SSSR. *Zoologicheskii Zhurnal*., 46 (10), 1509-1535. (In Russian).

Birstein, J.A. & Ljovuschkin, S. I. (1968) A representative for the SSSR the new family Bogidiellidae (Crustacea, Amphipoda) in subterranean waters of Central Asia. *Zoologicheskii Zhurnal*, 47, 676–683. (In Russian with English abstract).

Birstein, J. A. & Ljovuschkin, S. I. (1972) *Crangonyx setiferus* sp. n. (Crustacea, Amphipoda) from springs of Tian Shan, *In:* Jankowskaja, A. I. (ed), *Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, Leningrad, 51, pp. 139-146. (In Russian).

Bole, J. & Velkovrh, F. (1969) Molluska from continental subterranean aquatic habitats. *In*: Botosaneanu, L. (ed.). *Sygofauna mundi*. E. J. Brill, Leiden, pp. 177-208.

Borutsky, E. V. (1967) On the genus *Nitocrella chappuissi* (Copepoda, Harpacticoida). Biospeologica Sovietica 32. *Bull. Moskovskogo Obschestva Ispytatelei Prirody* (nov. ser.), 72, 32-39. (In Russian).

Borutzky, E. V. (1972) Copepoda Harpacticoida from subterranean water of the shore of Issyk-Kul and Southern Kisil-Kum. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii SSSR nauk*, *Leningrad*, 51, pp. 98-119. (In Russian).

Borutsky, E. V. (1978) Copepoda-Harpacticoida from subterranean waters of Tien Shan. *Sbornik Trudov Zoologiches Muzeum MGU*, 16, 65-91.

Botosaneanu, L. (ed.) (1986) *Stygofauna mundi*. E. J. Brill, Leiden, 1-740.

Botosaneanu, L. (ed.) (1998) *Studies in Crenobiology.The biology of springs and springbrooks*. Backhuys Publ., Leiden, 1-261.

Bowman, D., Korjenkov, A. & Porat, N. (2004) Late-Pleistocene seismites from Lake Issyk-Kul, the Tien Shan range, Kyrghyzstan. *Sed. Geology*, 163, 211-228.

Brodsky, A. L. (1928) Foraminifera (Polythalamia) in Grundwater der Wuste Kara-Kum. *Acta Universita Asiae Mediae*, Ser. 8, Zoologica, 5, 1-17. (In Russian).

Brodsky, A. L. (1929) The fauna of the basins of the desert Kara-Kum. *Acta Universita Asiae Mediae*, Ser. 12, Geographica, 5, 1-43. (In Russian).

Cekanovskaja, O. V. (1972) On the fauna of subterranean oligochaetes from Middle Asia. *In:* Jankowskaja, A. I (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, *Leningrad*, 51, pp. 64-70. (In Russian).

Daday, E. (1904). Microscopische Sasswassertiere aus Turkestan. *Zoologisch Jahrbuch, Systematic*, 19 (5), 469-583.

Dumont, H. J. & Negrea, S. (1996) A conspectus of the Cladocera of the subterranean waters of the world. *Hydrobiologia*, 325, 1-30.

Glantz, M. M. (2010) The history of hominin occupation of Central Asia in Review, 101-112. *In*: Norton, C. J. & Braun, D. R. (eds.), *Asian Paleoanthropology: from Africa to China and beyond.* Vertebrate Paleobiology and Paleoanthropology. Springer Science & Bussiness. DOI 10.1007/979-90-481-9094-2-8.

Glöer, P., Boeters, H. D. & Pešić, V. (2014) Freshwater molluscs of Kyrgyzstan with description of one new genus and species (Molluska: Gasteropoda). *Folia Malacologica*, 22 (2), 73-81.

Golemansky, V. (1986) Rhizopoda: Foraminiferida. *In:* Botosaneanu, L. (ed.) *Stygofauna mundi*, E. J. Brill, Leiden, pp. 17-19.

Golemansky, V. & Bonnet, L. (1994) Protozoa, 23-33. *In:* Juberthie, *C.* & Decu, V. (eds.), *Encyclopaedia Biospeologica I*. Soc. Biospéol. Moulis-Bucarest, Fabbro, Saint Girons, 1-834.

Gourbault, N. (1971) Recherches sur les triclades paludicoles hypogés. *Thèse de Doctorat. Mémoires du Muséum national d'Histoire naturelle, Paris*, 83, 1-249.

Gvozdetski, N. A., Morozov, A. I., Smirnov, S. A. & Golovatch, S. I. (1994) C. E. I., Bielorussie, Ukraine. *In:* Juberthie, C. & Decu, V. (eds.), *Encyclopaedia Biospeologica I*. Soc. Biospéol. Moulis-Bucarest, Fabbro, Saint Girons, pp. 641-648.

Holsinger, J. R. (1994) Pattern and process in the biogeography of subterranean amphipods. *Hydrobiologia*, 287, 131-145.

Izzatullaev, Z. I. & Stadnichenko, A. P. (2010) Distribution des mollusques aquatiques de l'Asie Centrale en fonction des habitats et des types d'eau. *Université Pédagogique Nationale V. Hnatiuk, série Biologie, Ternopol*, 2 (43). (In Russian).

Izzatullaev, Z. I., Sitnikova, T. Y. & Starobogatov, I. (1986) Taxonomic position of the Middle Asian Pseudamnicola". *Proceedings of the Zoological Institut of Leningrad*, 148, 55-60. (In Russian).

Jankowskaja, A. I. (1964) Relict Crustaceans of costal bottom waters of the Lake Issyk-Kul (North Tien-Shan). *Zoologicheskii Zhurnal*, 43 (7), 975-986. (In Russian).

Jankowskaja, A. I. (1965) Sur la présence de la faune phréatique dans le nord du Tien-Shan. *Frunze*, 126-131. (In Russian).

Jankowskaja, A. I. (1967) Sur la faune souterraine aquatique de l'Asie Centrale. Hydracariens du groupe des Porohalacaridae (Acari) dans les puits de Kyzyl-Kum. *Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, 43, 109-117. (In Russian).

Jankowskaja, A. I. (1972) New species of *Parabathynella* (Crustacea, Syncarida) and *Microcharon* (Isopoda) from interstitial waters of the desert Kisil-kum,. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR, Leningrad*, 51, pp. 131-138. (In Russian).

Jankowskaja, A. I. (1972) Phreatic and spring fauna of northern Tien Shan and soutern Kisilkum. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, 51, Leningrad, pp. 5-56. (In Russian).

Juberthie-Jupeau, L. & C. Bareth (1980) Ultrastructure des sensilles de l'organe cupuliforme de l'antenne des Campodés (Insecta, Diplura). *International Journal of Insect. Morphology & Embryol*ogy,18, 1-10.

Juberthie, C., Sidorov, D., Decu, V., Mikhaljova, E. & Semenchenko, K. (2016) Subterranean fauna from Siberia and Russian Far East. Encyclopaedia Biospeologica (Siberia-Far East special Issue). *Ecologica Montenegrina*, 7, 507–529.

Kantor, Y. I., Schileyko, A. A., Vinarski, M. V. & A. A. Sysoev (2009) *Catalogue of the continental mollusks of Russia and adjacent territories*, Version 1.0 (published online on February 15).

Karaman, G. (2012) New species of the subterranean genus *Niphargus* Schiödte, 1849 (Amphipoda, Gammaridea, Niphargidae) from Russia, *N. krasnodarus* sp. n. (Contribution to knowledge of Amphipoda). *Biologica Serbica*, 34 (1-2), 75-88.

Karanovic, T. & Hancock, P. (2009) On the diagnostic characters of the genus *Stygonitocrella* (Copepoda, Harpacticoida), with descriptions of seven new species from Australian subterranean waters. *Zootaxa*, 2324, 1-85.

Karanovic, T., Yoo, H. & Lee, W. (2012) A new cyclopoid copepod from Korean subterranean waters reveals an interesting connection with the Central Asian fauna (Crustacea: Copepoda: Cyclopoida). *Journal Species Research*, 1 (2), 156-174.

Kaszab, Z. (1959) Neue *Leptodes*-Arten aus Asien, nebst einer Revision der Leptodirini (Coleoptera, Tenebrionidae). *Acta Zoologica Academiae Scientiarum Hungaricae*, 4 (3-4), 349-368.

Klimchouk, A. (2004a) Russia and Ukraine, 626-629. *In:* Gunn, J. (ed.), *Encyclopedia of Caves and Karst Science*. F. Dearborn, New York and London, 1-902.

Klimchouk, A. (2004b) Asia Central, 94-96. *In:* Gunn, J. (ed.), *Encyclopedia of Caves and Karst Science*. F. Dearborn, New York and London, 1-902.

Kulkina, L.V. (1992) *Stygobromus kazakhstanica* sp. n. (Amphipoda, Crangonyctidae) from underground waters of Tien Shan. *Zoologicheskii Zhurnal*, 71, 40–45. (In Russian with English abstract).

Ljovuschkin, S. I. (1969) On the subteranean fauna of Soviet Central Asia. *Proceeding 4th international Speleology Congress, Ljubljana*, IV, 145-149. (In Russian).

Ljovuschkin, S. I. (1972) A new species of Hypogastruridae (Collembolla) from the cave in the vicinity of Samarkand,. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk*, Leningrad, 51, pp. 151-154. (In Russian).

Magniez, G. (2005) Comments about Stenasellids (Crustacea, Isopoda, Asselota) of underground waters in Asia. *Subterranean Biology*, 3, 69-74.

Maltsev, V. A. (1997) Cupp-Coutunn Cave, Turkmenistan. *In*: Hill, C. A. & Forti, P. (eds) *Cave Minerals of the world*. 2nd edition. *National Speleological Society*, Huntsville, Alabama.

Maltsev, V. A. &. Self, C. A (1992) Cupp-Coutunn cave system, Turkmenia, Central Asia. *Proceeding University. Bristol Speleology Society*, 19 (2), 117-149.

Manuilova, E. F. (1972) Subterranean water cladocerans from Middle Asia. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk, Leningrad*, 51, pp. 71-77. (In Russian).

Martynov, A.V. (1935) Amphipoda Gammaridea of the running waters of Turkestan. *Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SS*SR, 2, 411-508. (In Russian with English abstract).

Martynov, A.V. (1936) Zametka o bokoplavah (Gammaridae). *Proceedings Kirghiz expedition. Academia. Science SSSR, Moscow, Leningrad*, 3, 211-214. (In Russian).

Martynova, E. F. (1972) Springtails (Collembola) inhabiting the outlets of subterranean water in the Kirghiz and Uzbek SSR. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk, Leningrad*, 51, pp. 147-150. (In Russian).

MikhaIlevich, V. I. (1976) New data on the Foraminifera of the Groundwaters of Middle Asia. *International Journal of Speleology*, 8 (1/2), 167-175.

Mirabdullayev, I. M. & A. R. Kuzmetov (1997) Second record of *Acanthocyclops biarticulatus* Monchenko, 1972 and first description of its male (Crustacea: Copepoda). *Bulletin Zoology Museum, University of Amsterdam*, 16, 1-14.

Monchenko, W. I. (1972) Subterranean water *Cyclops* (Copepoda, Cyclopoidae) from Kysyl-Kum. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, Leningrad, 51, pp. 78-97. (In Russian).

Nikoljuk, V. F. (1948) The relict Foraminifera of the Kara-Kum desert. *Bulletin Academia of Science Uzbeck. S.S.R.*, 1, 79-88. (In Russian).

Olteanu, R. & Jinga, D. (2006) Dacian basin environmental evolution during Upper Neogene within the Paratethys domain. *Geo-eco-marina, Bucuresti*, 91-106.

Pankratova, V. J. A. (1972) On the fauna of subterranean water chironomids from Middle Asia, 155-164. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk, Leningrad*, 51, 1-176. (In Russian).

Parin, N. V. (1983) *Noemacheilus* (*Troglocobitis*) *starostini* sp. n. (Osteichthyes, Gobitidae), un nouveau poisson aveugle des eaux souterraines de Kugitang-Tau (Turkménie). *Zoologicheskii Zhurnal*, 62 (1), 83-89 (In Russian).

Popov, S. V., RogL, A. Y., Rozanov, F. F., Steininger, I., Shcherba I. G. & Novac, M. (2004) Lithological-Paleogeographical maps of Paratethys. Late Eocene to Pliocene. *Courier Forschunginstitut Senckenberg*, 13d, 250, Frankfurt and Main, 1-46, maps 1-10.

Rubtzov, I. A. (1972) Two new species of *Mesomermis* Daday (Mermithidae) from interstitial waters. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, Leningrad, 51, 1-176. (In Russian).

Self , C. A. (2004) Cupp-Coutunn Cave, Turkmenistan. *In*: Gunn, J. (ed.), *Encyclopedia of Caves and Karst Science*. F. Dearborn, New York and London, pp. 273-275.

Semikolennykh, A. A. (1997) Microorganisms in the caves of the former SSSR: geography, ecology and geochemical activity. *Proceedings12th international, Congress of Speleology, Switzerland*, 3.

Sendra, A, Sket, B. & Stoev, P. (2017) A stricking new genus and species of troglobitic Campodeidae (Diplura) from Central Asia. *Subterranean Biology*, 23, 47-68.

Serban, E. (1993) *Tianschanbathynella jankowskajae*n. n. g., n. sp. et *Tianschanbathynella paraissykkulensis* n. sp. (Bathynellidae, Bathynellacea, Podophallocarida). *Travaux de l'Institut, de Spéologie Emil Racovitza*, 32, 19-41.

Serban, E. (1994) *Issykkulibathynella* n. g., n. sp. et son espèce-type *I. tianschanica* (Jankowskaja) (Parabathynellidae, Bathynellacea, Podophalocarida). *Travaux de l'Institut, de Spéologie Emil Racovitza*, 33, 31-48.

Shadin, V. I. (1952) Molluks of fresh and brackish waters of the SSSR. *Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, 46, 1-376 (In Russian).

Sidorov, D., Hou, Z & Sket, B. (2018) Three new amphipod species (Crustacea: Gammaridae) from springs and subterranean waters of Central Asia. *Zootaxa*, 4444, (4), 437-461.

Smirnov, S. A. (1983) A blind cave loach from southwestern Asia. *Nemacheilus starostini* Parin. *Tropical Fisch Hobbist*, 8.

Sokolow, I. I. (1948). Hydrachnellae from Tadjikistan. In memory of Acad. S. A. Zernov. *Publication House AN SSSR*, 242-262. (In Russian).

Starobogatov, Y. I. (1962) On the knowledge of the subterranean molluscs from Kazakhstan. *Bulletin Moscow Institut Sciences naturelles, ser. Biology*, 67 (6), 42-54. (In Russian).

Starobogatov, Y. I. (1972) New species of gasteropods from springs and subterranean waters of Middle Asia. *In:* Jankowskaja, A. I. (ed.), *Underground water fauna from Central Asia. Trudi Zoologischeskogo Instituta Rosiiskai akademii nauk SSSR*, Leningrad, 51, pp. 165-172 (In Russian).

Starobogatov, Y. I. (1994) Fauna and zoogeography of mollusks of Turkmenistan. *In*: *Biogeography and Ecology of Turkmenistan*. Monographiae Biologicae, 72, 535-543.

Sterba, O. (1968) Neue Harpacticoidea (Crustacea, Copepoda) aus dem asiatischen Teil der Palearktis. *Zoologischer Anzeiger,* 180, 60-68.

Sterba, O. (1973) Die neue Harpacticidenarten der Gatung *Nitocrella* (Crustacea, Copepoda) aus Afghanistan. *Zoologischer Anzeiger*, 190 (5-6), 333-342.

Stock, J. H. (1986) Amphipoda: Gammarid grouping (Gammaridae s. str. sensu Bousfield). *In*: L. Botosaneanu (ed). *Stygofauna mundi*, E. J. Brill, Leiden, 1-740.

Trofimov, A. K. (1990) Quaternary deposits of the Issyk-Kul depression related to its tectonics. *Proceeding of Academia Sciences Kirgkhiz SSR*, 1, 87-95. (In Russian).

Tsurikhin, E. A., Loginov, V. L. & Sauro, F. (2012) Baisun-tau 2011. La reprise des expéditions en Asie Centrale. *Spelunca*, 125, 36-40.

Tsurikhin, E. A., Loginov, V. L, Sauro, F. & Breitenbach, S. (2013) Exploration of high altitude caves in the Baisun-tau mountain. *Proceedings 13th International Congress Speleology, Brno, Czech Republic*, 147-152.

Tsurikhin, E. A., Breitenbach, S., Loginov V. & Antonina, A. (2014) The Dark Star of Baisun-tau: a history of cave exploration in Southern Uzbekistan, 1990-2013. *Cave and Karst Science*, 41 (1), 36-41.

Turbanov, I. S., Palatov, D. M. & Golovatch, S. I. (2016a) The state of the art of biospeleology in Russia and other countries of the former Soviet Union: A review of the cave (endogean) invertebrate fauna. I. Introduction – Crustacea. *Zoologicheskii Zhurnal*, 95 (10), 1136-1159. (In Russian).

Turbanov, I. S., Palatov, D. M. & Golovatch, S. I. (2016b) The state of the art of biospeleology in Russia and other countries of the former Soviet Union: A review of the cave (endogean) invertebrate fauna. 2. Arachnida – Acknowledgements. *Zoologicheskii Zhurnal*, 95 (11), 1283-1304. (In Russian).

Vainola, R., Witt, J. D. S., Grabowski, M., Bradbury, J. H., Jazdzewski, K. & Sket, B. (2008) Global diversity of amphipods (Amphipoda: Crustacea) in freshwater. *Hydrobiologia*, 595, 241-255.

Weber, A., Proudlove, G. S., Parzefall, J., Wilkens, H. & Nalbant, T. T. (1998) Pisces, 1177-1213. *In*: Juberthie, C. & Decu, V. (eds.), *Encyclopaedia Biospeologica*, 2. Soc. Biospéol. Moulis-Bucarest, Fabbro, Saint Girons, 839-1373.

Zalesskaya, N. T. & Golovatch, S. I. (1989). The condition of biospeleology in the USSR. *Problems of Complex Karst Study of Mountainous Countries.* Metsnierba, Tbilisi, 240-242. (In Russian).