pianetaterra
Le Scienze della Terra per la Società
Commissione Italiana

COMUNE
DI GORIZIA

PROVINCIA
DI GORIZIA

PROCEEDINGS OF THE

10th International Symposium on Pseudokarst

29 April - 2 May 2008
Gorizia (Italy)

Stampato con il contributo della

FEDERAZIONE SPELEOLOGICA REGIONALE DEL FRIULI VENEZIA GIULIA

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Organizzazione / Organization

INTERNATIONAL UNION OF SPELEOLOGY
Commission for Pseudokarst

CENTRO RICERCHE CARSICHE
"CARLO SEPPENHOFER" - GORIZIA

FEDERAZIONE SPELEOLOGICA REGIONALE
DEL FRIULI VENEZIA GIULIA

In collaborazione con / With the collaboration

COMUNE DI GORIZIA

PROVINCIA DI GORIZIA

FONDAZIONE CASSA DI RISPARMIO DI GORIZIA

Con il patrocinio di / Promoted by

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PROVINCIA DI GORIZIA

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FEDERAZIONE SPELEOLOGICA ISONTINA

METSO PAPER GORIZIA S.p.A.

KERATECH

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Fabio Forti (Trieste – Italy)

Paolo Forti (Bologna – Italy)

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Maurizio Comar (San Canzian d'Isonzo GO – Italy)

Comitato organizzatore / Organizing committee

Maurizio Tavagnutti (Chairman)

Cristina Pussig (Secretary)

Maurizio Comar (Excursions)

Erika Devetak (Secretary – Translater service)

Sabrina Peric (Secretary – Translater service)

Indirizzo organizzazione – The organizer's address

10th INTERNATIONAL SYMPOSIUM ON PSEUDOKARST
Centro Ricerche Carsiche "Carlo Seppenhofer"
Via Ascoli, 7 - 34170 Gorizia (Italy)
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MEINE SEHR GEERTE DAMEN UND HERREN WERTE GÄSTE!

Im Namen des Pseudokarstischen Kommissions von der Internationalen Union für Speläologie möchte ich alle Teilnehmer am 10. Internationalen Symposium über den Pseudokarst herzlich wilkommen. Ich freue mich sehr darüber, dass Sie unsere Jubiläumsveranstaltung mit Ihrer Tailnahme beehrt haben. Besonders möchte ich mich bedanke bei den einheimischen Organisatoren des Symposium – also bei der Karst Forschung Zentrum „Carlo Seppenhofer”. Weiterhin bedanke ich mich bei allen Personen, wer die Ausführung dieser Veranstaltung geholfen haben.

Unser vorigen Symposium war in Polen, wo wir viele vorzügliche Referate gehört haben und wir einige pseudokarstische Höhlen der Beskiden besucht haben. An der Kommissionstagung dieses Symposiums haben wir die Tätigkeiten, Ergebnisse der vorherigen Jahre besprochen. Wir haben gestritten, dass der „Nachrichtenbrief” in welcher Sprache erscheine. Zu guter Letzt sind wir bei der deutsch-englischen Sprachen geblieben. Wir haben über die folgeden Veranstaltungen vereinbart. Wir haben eine Vorstandswahl gehalten.

Die Forscher im pseudokarstischen Berich haben in aller Welt erfolgreich gearbeitet. Sie haben viele neue Höhlen gefundet und erforscht. Mit Frenden haben wir erfahren, dass die pseudokarstische Forscher des Nord und Südamerikas, ferner Russlands sich der Kommissionstätigkeit eingeschaltet haben. Leider haben wir von der Pseudokarstforschung des Afrikas, der Asien und der Australien wenige Informationen. Im Informationsblatt, in den „Nachrichtenbrief” der unseren Kommission kommen die Artikel noch immer schleppfälling an. Für die Erscheinung dieses Blattes haben wir vom Sekretariat des UIS eine Unterstützung gebeten. Sie haben auf unserem Ersuchen gar nicht geantwortet. Seit vorherigen Symposiums waren zwei unsere internationale Veranstaltungen, sowie die Internationale Konferenz über die Granithöhlen in Spanien mit 30 Teilnehmer aus 13 Länder und eine Arbeitstagung über die Wurzelstrukturen der Pseudokarsthöhlen in Tschchien mit 25 Teilnehmer aus 4 Länder. Die Beziehungen zwischen uns und der Kommission für Vulkanhöhlen, sowie der Kommission für Geschichte der Höhlenforschung sind auch ferner eng und befreundet. Unsere Tätigkeit zusammenfassend, unsere Ergebnisse sind in der Mehrheit neben die vorhandene Mängel. Ich hoffe, dass dieses Symposium uns genug Stärke gibt, in Zukunft weitere Ergebnisse zu erreichen.

Ich wünsche Ihren herzlich, dass Sie am wissenschaftlichen Session Ihre Kenntnisse erweiten und bei der Exkursionen viele wunderbaren Erlebnisse sammeln. Ich vertraue darauf, dass die Kommissionssitzung vorwärtsziegende und hauptsächliche durchführbare Beschlüsse fassen wird. Ferner wünsche ich Ihren noch, dass die freundschaftlichen Verhältnissen sich weiter festigen und Sie nach Schlissen des Symposium angenehmen Eindrücken aus Italien heimkehren.

Nach dem Vorausschicken dieser Gedanken eröffne ich das 10. Internationalen Symposium über den Pseudokarst.

István Eszterhás
Präsident
der Internationalen Kommission für Pseudokarst

GENTILI SIGNORE E SIGNORI!

A nome della Commissione di Pseudocarsismo dell'Unione Internazionale di Speleologia, vorrei dare un caloroso benvenuto a tutti i partecipanti del 10° Simposio Internazionale sullo Pseudocarsismo. In particolare, desidero ringraziare il Centro Ricerche Carsiche "Carlo Seppenhofer" che ha organizzato questo incontro. E inoltre, vorrei ringraziare anche tutti coloro che hanno contribuito alla riuscita di questo evento.

Nel corso del nostro ultimo simposio, svoltosi nel 2006 in Polonia, abbiamo ottenuto dei buoni risultati, ci sono state delle eccellenti presentazioni nel corso delle quali si sono potute ascoltare delle interessanti relazioni e conoscere alcune delle grotte pseudocarsiche situate nella zona di Beskydy. Durante la riunione della nostra Commissione, svolta al termine di quel simposio, abbiamo discusso anche sui risultati degli anni precedenti e delle attività da svolgere nei prossimi anni. Abbiamo sostenuto che la rivista "Nachrichtenbrief" continui ad essere stampata in lingua tedesca ed inglese. È stato eletto il nuovo direttivo ed è stato nominato anche il presidente della Commissione. Infine abbiamo concordato che il 10° Simposio venga svolto qui a Gorizia.

In questi due anni i ricercatori di pseudocarsismo hanno lavorato con successo stabilendo relazioni in tutto il mondo. Essi hanno scoperto ed esplorato molte nuove grotte. Abbiamo stretto rapporti di amicizia con ricercatori provenienti dal Nord e Sud America, dalla Russia. Purtroppo non conosciamo molto dello pseudocarsismo dell'Africa, dell'Asia e Australia in questi continenti le informazioni sono limitate. A questo scopo il foglio informativo "Nachrichtenbrief" della Commissione potrà svolgere un importante ruolo di diffusione e informazione. Per la stampa di questo foglio, abbiamo già chiesto il sostegno della segreteria dell'U.I.S.

Dopo il precedente simposio svoltosi in Polonia ci sono stati due nostri eventi internazionali: la Conferenza Internazionale, in Spagna, dedicata alle grotte in granito con 30 partecipanti provenienti da 13 paesi e una sessione di lavoro sulle strutture di pseudocarsismo in Cecoslovacchia con 25 partecipanti provenienti da 4 paesi.

Si sono intensificati i rapporti di amicizia tra noi e la Commissione per le grotte di origine vulcanica e la Commissione per la Storia della speleologia. Spero che questo convegno ci dia la forza sufficiente, in futuro, per raggiungere un maggior numero di risultati.

Mi auguro sinceramente che questa sessione scientifica contribuisca a progredire nella conoscenza di questo fenomeno e possa raccogliere il frutto delle tante esperienze acquisite durante le meravigliose escursioni fatte. Inoltre, vi auguro un piacevole ritorno a casa e che, dopo la chiusura del simposio, le relazioni amichevoli iniziate qui in Italia continuino e si consolidino.

István Eszterhás
Presidente della Commissione
Internazionale per lo Pseudocarsismo

10° INTERNATIONAL SYMPOSIUM ON PSEUDOKARST

PRESENTAZIONE

La stampa degli atti di un simposio rappresenta l'atto finale di un lungo lavoro di organizzazione. Finalmente è finita! mi viene da esclamare.

Quando due anni fa mi ero ripromesso di portare qui a Gorizia l'eccellenza degli studiosi di carsismo non avevo ancora in mente quanto lavoro bisognava affrontare per realizzare questo sogno. Ora posso dire che ne è valsa la pena ma, quanta fatica!

Il 10° International Symposium on Pseudokarst che si è svolto qui a Gorizia è stato un evento davvero unico e la partecipazione di studiosi provenienti da Paesi anche al di fuori dei confini della vecchia Europa, hanno posto Gorizia al centro di un interesse davvero particolare da parte del mondo universitario, non solo locale.

La splendida cornice della grande Sala del Conte in castello a Gorizia ha dato vita ad uno dei raduni più prestigiosi degli ultimi anni riguardanti lo studio del carsismo. In un ambiente davvero eccezionale si è svolto il 10° International Symposium on Pseudokarst organizzato dal Centro Ricerche Carsiche "C. Seppenhofer", su mandato dell'Union International de Speleologie, con la coorganizzazione del Comune di Gorizia, della Federazione Speleologica Regionale del Friuli Venezia Giulia e con il patrocinio della Provincia di Gorizia e della Società Speleologica Italiana.

Il castello di Gorizia è stato dunque il polo d'attrazione per un raduno di studiosi provenienti da varie parti del mondo tra cui oltre a numerosi paesi europei erano presenti anche Brasile, Iran, Russia, per la prima volta nella storia di questo simposio che, viene svolto ogni due anni in un Paese diverso, facevano il loro ingresso i rappresentanti di stati al di fuori dei confini europei.

Grande soddisfazione non solo da parte degli organizzatori per i risultati ottenuti da questa assise ma anche da parte dell'assessore alla cultura di Gorizia sig. Antonio Devetag.

Il quale, nel suo discorso di benvenuto, ha voluto consegnare un omaggio rispettivamente al sig. Giampietro Marchesi presidente della Società Speleologica Italiana, all'ungherese Istvan Eszterhas presidente della Commission for Pseudokarst dell'U.I.S. , all'olandese Jan Pol Van der Pas vicepresidente dell'U.I.S. e al dr. Gabassi direttore del polo universitario di Gorizia.

Proprio quest'ultimo ha espresso soddisfazione per questa iniziativa che dimostra una volta in più l'estrema dinamicità delle associazioni goriziane nel campo delle scienze della terra. Alla fine del suo intervento egli ha voluto rimarcare per il futuro la piena disponibilità dell'università verso questo tipo di iniziative.

L'assessore Devetag ha colto questa occasione anche per consegnare, da parte del comune di Gorizia, al Centro Ricerche Carsiche "C. Seppenhofer" una targa a ricordare che nel 2008 ricorre il trentesimo anno di fondazione dell'associazione goriziana senza peraltro dimenticare che proprio quest'anno si ricordano i cento anni dalla morte di Carlo Seppenhofer, pioniere della speleologia a Gorizia.

Nella tre giorni goriziana sono stati svolti temi di notevole interesse che, a vario livello, come si è detto hanno coinvolto studiosi provenienti anche da Paesi molto lontani.

Tra le altre, particolarmente interessante, per il suo contenuto, è risultata la relazione *svolta, dei cechi Mlejnek, Ouhrabka e Růžička dell'Institute of Entomology e Biology Centre dell'Accademia di Scienze della Repubblica Ceca. Per la prima volta è stato fatto uno studio meticoloso e multidisciplinare su una zona carsica, tra le più vaste in Europa, situata proprio al centro del territorio della Repubblica Ceca.*

Grande curiosità, come era prevedibile, ha destato l'esposizione dell'iraniano Ahmad Afrasiabian su un territorio di cui noi europei abbiamo ancora poche notizie e che potrebbe riservare notevoli sorprese non solo dal punto di vista dello studio del carsismo visto che, le rocce in quei territori sono piene di idrocarburi.

I contatti con l'esponente iraniano sono poi proseguiti nella pausa tra un lavoro e l'altro tanto da raggiungere importanti accordi per lo sviluppo di cooperazione per un progetto per la ricerca dell'acqua nella zona di Zagros Rnage in Iran da realizzare il prossimo anno.

Non è mancato un certo interesse per la bella e interessante relazione fatta dalla brasiliana Soraya Ayub sul più profondo abisso del mondo interamente scavato nella quarzite, una roccia molto dura che sino ad ora si pensava non potesse dare sviluppo a fenomeni di questo tipo.

Insomma è stato un susseguirsi di relazioni ed interventi di grosso spessore e anche, se questa materia potrebbe sembrare un argomento di nicchia, l'interesse è stato tale da far ricredere gli stessi organizzatori.

Nella giornata conclusiva gli studiosi hanno potuto visitare la Grotta di Villanova nel tarcentino, una cavità parzialmente turistica di grande interesse, aiutati poi da una splendida giornata hanno concluso i lavori con una cena, presso l'Hotel Internazionale di Gorizia, allietata da un'applauditissima esibizione dei Danzerini di Lucinico.

Maurizio Tavagnutti
Presidente del Centro Ricerche Carsiche
"C. Seppenhofer"

INTERVENTO DEL PRESIDENTE DELLA FEDERAZIONE SPELEOLOGICA REGIONALE DEL FRIULI VENEZIA GIULIA ALL'INAUGURAZIONE

A nome della Federazione Speleologica Regionale del Friuli Venezia Giulia e quindi dei 26 gruppi che essa rappresenta, voglio dare il benvenuto a tutti voi qui presenti.

Lo studio dei fenomeni di pseudocarsismo è considerato il fratello minore di quella speleologia che viene normalmente praticata in cavità naturali, ma il suo ruolo è altrettanto importante per una corretta e completa conoscenza di quel mondo sotterraneo e sconosciuto, che solo gli speleologi sono in grado di esplorare e divulgare.

La speleologia della nostra regione, vista la ricchezza e l'importanza dei fenomeni carsici – basti pensare alle aree del Carso e del Monte Canin – si è interessata relativamente tardi ai fenomeni pseudocarsici, ma in questi ultimi anni sta recuperando molto in fatto di conoscenza, esplorazioni e documentazione.

Un grosso merito di ciò va sicuramente al Centro Ricerche Carsiche "C. Seppenhofer", che da anni opera nell'area del Fiume Judrio, delle Valli del Natisone e dell'Altopiano della Bernadia. La nostra Federazione, vista l'importanza della manifestazione, ha ritenuto di entrare come co-organizzatrice nell'allestimento del Symposium, a supporto del CRC Seppenhofer, che è uno dei gruppi aderenti. E lo ha fatto con grande compiacimento.

Nelle prossime giornate avrete occasione di visitare la Grotta Nuova di Villanova, la più importante cavità "di contatto" e l'area del Campo di Bonis, interessata da fenomeni di pseudocarsismo. Ma vorrei invitarvi a visitare ed ammirare in futuro anche altre aree e cavità di interesse speleologico che numerosissime si trovano in Friuli Venezia Giulia: dal Carso alle Alpi Carniche, dalle Alpi Giulie alle Prealpi Carniche e Giulie.

Auguro quindi ai partecipanti, soprattutto a quelli che vengono da lontano, di poter ammirare e godere delle bellezze naturali carsiche o pseuocarsiche che ci circondano.

Vi ringrazio e auguro buon lavoro ai partecipanti.

Gorizia, 30 aprile 2008

Gianni Benedetti
Presidente Federazione Speleologica Regionale
del Friuli Venezia Giulia

PROGRAMME

Tuesday 29 April

15.00-20.00: Arrival and registration of participants
(Hotel Internazionale - Viale Trieste, 173 - Gorizia - Italy)

Wednesday 30 April

9.00: "Sala del Conte" Castle of Gorizia - Official opening of the Symposium

10.00: Opening work session:

- Eszterhàs I. (Hungary), *Mediaeval Cave-monasteries in Hungary*
- Urban J., Kasza A. (Institute of Nature Conservation PAS, Krakow - Poland), *Genetical types of caves in the sandstones of the Swietokrzyskie (Holy Cross) Mts, Central Poland*
- Tulucan T. (Western University Vasile Goldis Arad, Arad - Romania), *Exo pseudokarst in ice*

11.00: Coffee break

11.15: Papers:

- Gadanyi P. (Hungary), *Lava Tumulus Caves*
- Pavuza R. (Dept. of Karst & Caves Museum of Natural Hist., Vienna - Austria), *Caves in non-solid rocks of Austria*
- Barovic G. (Philosophical faculty, Niksic - Montenegro), *Speleo-touristic map of Montenegro*

12.30: Lunch

14.30: "Sala del Conte" Castle of Gorizia - Opening work session:

- Cucchi F. (Dipartimento di Scienze Geologiche, Ambientali e Marine, University of Trieste - Italy), *Pseudo Kamenitzas*
- Eszterhàs I., Szentes G. (Hungary), *Geological sketch and the caves of the Màtra Mountains in Hungary*
- Frumkin A. (Geography Department The Hebrew University, Jerusalem - Israel), *Basalt caves in Harrat Ash-Shaam, Middle East*
- Comar M. (Italy), *Fenomeni di formazione di cavità da erosione eolica nel deserto di Wapirum in Giordania*
- Vinod Kumar J. (Pt Ravishankar Shukla University, Raipur - India), *Environmental Monitoring of Karst Aquifers and Assessment of physio-chemical Proper ties of Karst Water*

16.00: Coffee break

16.15: Papers:

- Calandri G, Gobis D. (Italy), *I flysch del Ponente Ligure (Italia occidentale): Pseudocarsismo e carsismo*
- Peša V. (Vlastivědné muzeum a galerie, Česká Lípa - Czech Republic), *Elbsandsteingebirge (Böhmen/Sachsen) - urgeschichtliche Kulthöhlen und die Besiedlungsstruktur der Felslandschaft*
- Gaál L., Bella P. (Slovakia), *Spràva slovenskych jaskyn*

17.00: Closing session

17.30: Museum Castle of Gorizia - Visit to the exhibition

18.00: Museum of the Great War - Visit to the exhibition

Evening: Assembly of the Pseudokarst Commission of UIS (Hotel Internazionale - Viale Trieste, 173 - Gorizia - Italy)

Thursday 1st May

9.30: Hotel Internazionale - Opening work session:

- Mlejnek R., Ouhrabka V. & Růžička V. (Institute of Entomology, Biology Centre, Czech Academy of Sciences, České Budějovice - Czech Republic), *Poseidon: pseudokarst system in sandstones in the Czech Republic: geomorfological structure and biogeographical importance*
- Furlani S., Cucchi F. (Dipartimento di Scienze Geologiche, Ambientali e Marine, University of Trieste - Italy), *Short-term micro-morphology changes on sandstones*

10.30: Coffee break

10.45: Papers:

- Lyakhnitsky Yu., Vodovets M. (Russian Geological Research Institute-VSEGEI, Saint-Petersburg - Russia), *Pseudokarst in sandstone of the Leningrad Region*
- Cigna A. (Italy), *The family of karst phenomena: some physical-chemical parameters of the rocks involved in*
- [a]De Waele J., [b]Sanna L., [c]Rossi A., ([a]University of Bologna, [b]University of Sassari, [c]University of Modena and Reggio Emilia - Italy), *Pseudokarstic cavities in pyroclastic rocks: some examples from North Sardinia*

12.30: Lunch

14.30: Hotel Internazionale - Opening work session:

- Calandri G, Gobis D. (Italy), *Pseudocarsismo dell'area Sahariana*
- Ahmad A. (Managing Director of Pars Karst Company and founder of Iran Karst Research Center, Tehran - Iran), *Karst features in Zagros Rnage, in Iran*
- Ayub S. (Technical and Scientific Projects Akakor Geografical Exploring, Lierna-LC - Italy), *Aspects of Geology and Geomorphology of the deepest cave in the world quartzite (Amazon, Brazil)*

- [a]Cucchi F., [a]Furlani S., [a]Zini L., [b]Tretiach M. ([a]Dipartimento di Scienze Geologiche, Ambientali e Marine, University of Trieste, [b]Dipartimento di Biologia, University of Trieste - Italy), *Weathering by endolitic lichens on limestone surfaces: a geostatistical approach*

16.30: Coffee break

16.45: Papers:
- Calandri G., Gobis D. (Italy), *Pseudocarsismo nelle sieniti del Malawi meridionale*
- Maleckar F. (Slovenia), *Poljanska buža nel flysch dell'Istria nord occidentale*
- Simmert H. (Germany), *Even the pseudokarst-commission decides to carry out the 11. Symposium in Dresden (Germany), I give a short overview of this area - Poster: Pseudokarst in Saxony*

17.00: Closing session

17.30: *Presentation of* Atti del Convegno ALCADI

20.30: Meeting of Commission for Pseudokarst

Evening: Video-presentations, films, etc.

Friday 2 May

9.00: Hotel Internazionale - Visit to the Grotta Nuova di Villanova (Villanova delle Grotte - Udine) by bus
12.00: Lunch (Taipana - Udine)
14.30: Visit to the "Campo di Bonis"
17.00: Departure to Gorizia
20.00: Dinner and closing of the Symposium

ELENCO DEI PARTECIPANTI

10° INTERNATIONAL SIMPOSYUM ON PSEUDOKARST

Afrasiabian Ahmad – Theran (Iran)
Ayub Soraya – Lierna LC (Italy) – (Brazil)
Balciar Igor – Rimavska Sabota (Slovakia)
Barazzetti Andrea – Gorizia (Italy)
Barovic Goran – (Montenegro)
Benedetti Gianni – Trieste (Italy)
Benevenia Margherita – Trieste (Italy)
Bottegal Mila – Trieste (Italy)
Bottoli Costantino – Roveredo in Piano PN (Italy)
Bressan Franco – Gorizia (Italy)
Calandri Gilberto – Imperia (Italy)
Cancian Graziano – Gorizia (Italy)
Cigna Arrigo – Cocconato AT (Italy)
Comar Maurizio – San Canzian d'Isonzo GO (Italy)
Coronica Renato – Gorizia (Italy)
Cucchi Franco – Trieste (Italy)
Deidda Delia – Bologna (Italy)
De Waele Jo – Bologna (Italy)
De Waele Thomas – Bologna (Italy)
Devetak Ester – Gorizia (Italy)
Eszterhas Ištvan – Isztimer (Hungary)
Fajdiga Mattia – Gorizia (Italy)
Fornasier Giorgio – Pordenone (Italy)
Fornasier Gianpaolo – Pordenone (Italy)
Frumkin Amos – Gerusalemme (Israel)
Furlani Stefano – Trieste (Italy)
Gaál Ludovít – Rimavska Sabota (Slovakia)
Gadanyi Peter – Szombathely (Hungary)
Ghidelli Sandro – Busto Arsizio MI (Italy)
Gobis Diana – Imperia (Italy)
Grassi Roberto – Villaggio del Pescatore TS (Italy)

Graziuso Gabriella – Gorizia (Italy)
Hollender Werner – Wien (Austria)
Yermakov Nikolaj – Hradok (Slovakia)
Jiři Kopecky – (Czech Republic)
Marchesi Giampietro – Monticelli Brusati BS (Italy)
Marizza Simone – Gradisca d'Isonzo GO (Italy)
Meneghini Marco – Mezzolombardo TN (Italy)
Miani Antonella – Ronchi dei Legionari GO (Italy)
Mlejnek Roman – Blansko (Czech Republic)
Naparus Magdalena – (Romania)
Oldřich Jenka – (Czech Republic)
Ouhrabka Vratislav – Bozkov (Czech Republic)
Pape Barbara – Zlan (Austria)
Pavuza Rudolf – Wien (Austria)
Peša Vladimir – Česka Lipa (Czech Republic)
Pirrò Livio – Gorizia (Italy)
Primosi Isabella – Gorizia (Italy)
Pussig Cristina – Gorizia (Italy)
Rupini Luciano – Trieste (Italy)
Rutar Antonella – Gorizia (Italy)
Růžička Vlastimil – České Budějovice (Czech Republic)
Simmert Hartmut – Dresda (Germany)
Susmel Gianni – Gorizia (Italy)
Susmel Michele – Gorizia (Italy)
Szentes George – Bad Vilbel (Germany)
Tavagnutti Maurizio – Gorizia (Italy)
Torre Antonino – Tolmezzo UD (Italy)
Tulucan Tiberio – (Romania)
Urban Jan – Krakow (Poland)
Urban Weiten – Krakow (Poland)
Van der Pas Jan-Paul – Schimmert (Netherlands)
Vdovets Marina – St. Petersburg (Russia)
Venuti Maria – Gorizia (Italy)
Vinod Kumar Jena – Raipur (India)
Wutzig Bernd – Dresda (Germany)
Zanin Gianluca – Gorizia (Italy)
Zimolo Ferdinando – Gradisca d'Isonzo GO (Italy)

Minutes of the assembly of the Pseudokarst Commission UIS, 30th April and 1st May 2008, during the 10th International Symposium on Pseudokarst in Gorizia (Italy)

Attendance: Jan Paul van der Pas (Netherlands), Georg Szentes (Germany), István Eszterhás (Hungary), Rudolf Pavuza (Austria), Maurizio Tavagnutti (Italy), Jan Urban (Poland), Hartmut Simmert (Germany), Bernd Wutzig (Germany), Marina Vdovets (Russia), Ahmad Afrasibian (Iran), Soraya Ayub (Brazil), Valentina Tropiano (Italy), Ludovít Gaál (Slovakia).

In the assembly were discussed the following items:

1. Subjects of the last meeting of the Commission in Poland
2. More important events between the two symposiums
3. Present symposium
4. Future events and programmes
5. Election

Ad 1.

The proceedings of the symposium in Poland were published in the "Nature Conservation" vol. 63 (6) 2007 and in the "Zacisk", Bulletin of Speleoclub Bielsko-Biala, special number. Many thanks to Jan Urban.

Thanks to Istvan Eszterhás the Newsletter is issued twice a year, but the reports come only sporadically.

Ad 2.

a.) The 12th Symposium for Volcanospeleology was held in Topoztlán (Mexico) in 8-13th July 2007. Information was given by Jan Paul van der Pas.

b.) The International Conference on Granite Caves was held in La Coruña (Spain) in 17-22th September. Thanks to Marcos Vaqueiro and Juan Ramón Vidal Romani.

c.) The International Working Meeting of Root Structures in Pseudokarst Caves was held in Teplice nad Metují (Czech Republic) in 21-23th September 2007. Thanks to Jiří Kopecký.

Ad 3.

Present 10th Symposium on Pseudokarst in Gorizia is running successfully till now – thanks to Maurizio Tavagnutti. In the symposium 63 participants from 11 countries took part (Austria, Brazil, Czech Republic, Germany, Hungary, Iran, Italy, Netherlands, Poland, Russia and Slovakia) and 20 papers were presented in Castle of Gorizia and the Hotel Internazionale. During the field trip the Grotta di Villanova cave and Campo di Bonis were visited.

Ad 4.

The following events are expected:

a) 13th International Symposium for Volcanospeleology in Jeju (Korea), 1-10th September 2008.

b) 15th Congress of UIS in Kerrville (Texas, USA), 19-26th July 2009. It has not yet come to our knowledge, whether the Organizing Committee of the Congress in Texas will keep a Pseudokarst Section. The assembly suggests to secretary to send a request to Organizing Committee of the Congress.

c) The 11th Symposium on Pseudokarst will be held in Germany in 2010. H. Simmert informs us about the place of Symposium in Königstein near Dresden.

d) The assembly suggests three potential sites of the next symposium in 2012: Palaeozoic sandstones around Saint Petersburg (Russia, manager M. Vdovets), Granite caves in Sweden (manager N. A. Mörner) or Finland (manager A. Kejonen). Assembly suggests to the secretary to send an information letter to Mr. Mörner and Mr. Kejonen.

e) Problem of the "Newsletter" and other possibilities of the promotion of activity of the Commission were discussed. The internet homepage of the Pseudokarst Commission was proposed and will be realized.

Ad 5.

Commission members up to now were: Jiří Kopecký (honorary president), István Eszterhás (president), Rudolf Pavuza (vice-president), Ludovít Gaál (secretary), Maurizio Tavagnutti, Jan Urban and Marcos Vaqueiro.

The assembly recalls all functionaries. I. Eszterhás announced, he was not available as a candidate for the presidential function. The assembly elected the following new functionaries: Jiří Kopecký (honorary president), István Eszterhás (honorary president), Jan Urban (president), Rudolf Pavuza (vice-president), Ludovít Gaál (secretary), Maurizio Tavagnutti (member), Marcos Vaqueiro (member) and the new members: Hartmut Simmert, Ahmad Afrasibian, Marina Vdovets and Soraya Ayub.

New president acknowledged for the confidence and thanked I. Eszterhás for his work as a president of the Pseudokarst Commission.

Recorded by Ludovít Gaál

Alcuni membri della Commission on Pseudokarst U.I.S. (Gorizia, 1 maggio 2008). Simmert Hartmut (Germany), Afrasiabian Ahmed (Iran), Urban Jan (Poland), Van der Pas Jan-Paul (Netherlands), Vdovets Marina (Russia), Gaál Ludovit (Slovakia), Eszterhás István (Hungary), Szentes George (Germany), Tavagnutti Maurizio (Italy), Ruzicka Vlastimil (Czech Republic), Mlejnek Roman (Czech Republic).

Sala del Conte, Castello di Gorizia
Apertura del 10° International Symposium on Pseudokarst.
Da sinistra la signora Valentina Tropiano, interprete, Sara Vito, assessore provinciale di Gorizia, Maurizio Tavagnutti, presidente del "Seppenhofer", Giampietro Marchesi, presidente della Società Speleologica Italiana.

Sala del Conte, Castello di Gorizia
Seduta di lavoro durante l'esposizione delle relazioni.

Sala del Conte, Castello di Gorizia
Relazione del Dr. Franco Cucchi, Università degli Studi di Trieste.

Sala del Conte, Castello di Gorizia
Riunione della Commission on Pseudokarst.

Hotel Internazionale
Relazione della Dr. Marina Vdovets.

Grotta Nuova di Villanova Escursione didattica e visita del ramo turistico.

Taipana
Il gruppo dei partecipanti al simposio in visita al rifugio speleologico "C. Seppenhofer" di Taipana.

Grotta Pre-oreak
Escursione didattica e visita della grotta.

CAVES BY AEOLIAN CAUSE IN WADI RUM DESERT, SOUTH JORDAN

CAVITÀ DI ORIGINE EOLICA NEL DESERTO DI WADI RUM, SUD DELLA GIORDANIA

MAURIZIO COMAR[1]

Abstract - During a work trip in south Jordan, pointed out some particular morphologies in sandstones of Wadi Rum desert. Such morphologies are due to parakarstic forms, like caves (till 15-20 meters of developing), parietal morphologies and many others, that remember the real karst morphologies.

The sandstones get a age from cambric to ordovician. The paleo environment of deposition is mainly continental, with brief marine episodes. The phenomenona developing are mainly in Umm 'Ishrin Sandstone formation (massive brownish sandstones), of cambric age.

The sandstone is mainly quartz arenite, with quartz overgrowth or calcite cement enclosing sub-rounded well sorted quartz grains.

Every time we can see thin intercalation of beds of silty sandstone or siltstone, with calcite cement and more limestone, with true karstic phenomena.

The developing of such morphologies is due at "corrasion" phenomena (from latin "corradere", that means "clean with a rasp"), that is erosion effect about wind and sand together, that do abrasive action.

This work is a note only, because would be useful make deeper the studies of that phenomena.

Riassunto - Durante un viaggio di lavoro in Giordania del sud, si sono osservate alcune particolari morfologie nei sedimenti arenacei del deserto di Wadi Rum. Tali morfologie sono inerenti a forme paracarsiche come cavità (anche di certe dimensioni, 15-20 metri di sviluppo), morfologie parietali e morfologie varie, che ricordano quelle carsiche vere e proprie. Tali sedimenti arenacei hanno un' età che va dal cambrico all'ordoviciano. Il paleoambiente di deposizione è prevalentemente continentale, con varie e deboli trasgressioni marine. I fenomeni si sviluppano prevalentemente nella formazione di "Umm Ishrin Sandstone" (arenarie massicciee brunastre), del cambrico.

Tale litotipo è prevalentemente siliceo con cementi debolmente calcarei, spesso sostituiti da cemento siliceo. Ci sono la presenza di strati più calcarei con morfologie carsiche vere e proprie. La formazione di tali morfologie è da imputarsi in gran parte a fenomeno di "corrasione" (dal latino corradere), cioè effetto di erosione combinata di vento e sabbia trasportata da esso, che fanno azione abrasiva.

Questo lavoro è solo una nota, in quanto sarebbe utile approfondire ulteriormente lo studio del fenomeno.

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Premessa.

Questa vuole solo essere una nota su un fenomeno ipogeo osservato durante un viaggio attraverso il deserto di Wadi Rum, nel sud della Giordania. Perciò si dà solo una descrizione sommaria del fenomeno e un inquadramento morfologico e geologico della zona. Ad ogni modo sarebbe un fenomeno da approfondire in futuro con esplorazioni e osservazioni più approfondite.

Morfologia e climatologia generale della Giordania.

La Giordania, che occupa una superficie di 91.860 Km2, confina a nord con la Siria, a nord-est con l'Iraq, a est e a sud con l'Arabia Saudita e a ovest con Israele; inoltre è bagnata, a sud-ovest, dalla propaggine nord del Mar Rosso, per una trentina di chilometri.

Il clima (anche se la Giordania è caratterizzata da un clima mite durante tutto l'anno, pur con sbalzi di temperatura che portano a punte elevate di calore durante l'estate; nelle zone desertiche, sul mare e sul Mar Morto, e di freddo durante l'inverno) varia considerevolmente da una parte all'altra del paese e si può suddividere la Giordania in tre zone climatiche ben distinte: la fertile Valle del Giordano (clima sub tropicale) che corre lungo la parte occidentale del paese; l'altopiano della Transgiordania (clima mediterraneo), dove si trova la maggior parte delle città; il deserto della Transgiordania (clima caldo secco), che si allunga a est verso la Siria, l'Iraq e l'Arabia Saudita.

La caratteristica fisica principale della Giordania, è la valle del fiume Giordano, che fa parte della fossa tettonica della "Rift Valley" africana. Il fiume è lungo 251 Km ed è alimentato dal Mar di Galilea (lago di Tiberiade), dal fiume Yarmouk e da torrenti minori. Il Mar Morto, posto a 394 m sotto il livello del mare, è la depressione più profonda della terra. A sud del Mar Morto c'è il Wadi Araba, regione desolata. La Valle del Giordano in estate può essere incredibilmente calda (in genere intorno ai 40°C), mentre ad Amman e a Petra in inverno ogni tanto nevica; le precipitazioni sono sui 200 mm l'anno.

La zona dell'altopiano in genere è calda e secca, con temperature che fluttuano da un minimo di 20°C a un massimo di oltre 30°C. E' interrotto dalle gole attraversate dai torrenti del Wadi Zarqua, del Wadi al-Mujib e del Wadi al-Hesa, affluenti del Giordano. L'altopiano finisce a Ras an Naqh, dove il terreno digrada verso il Mar Rosso.

Nel deserto si soffrono notevoli sbalzi di temperatura: caldo secco (anche oltre 40° C), le piogge sono molto scarse (meno di 50 mm l'anno), frammezzato da venti freddi provenienti dall'Asia centrale. Occupa l'80 % della superficie totale della Giordania. La zona più suggestiva è il deserto di Wadi Rum, caro ai ricordi di Lawrence d'Arabia.

Il mese più rigido è gennaio, il più caldo agosto. La temperatura media invernale è 7°C, la massima estiva di 45°C. L'inverno dura da dicembre all'inizio di marzo e le precipitazioni sono piuttosto scarse durante tutto l'anno, concentrate nelle regioni nord-occidentali e sui rilievi. Le piogge nel deserto sono rare e quando si verificano sono di forte intensità e di breve durata. Il tempo, soprattutto nelle regioni desertiche, è estremamente mutevole a causa dei venti.

La Giordania è un paese piuttosto piccolo, con una curiosa linea di confine a est che sembra quasi un manico di una padella.

Le foreste di pini del nord cedono progressivamente il passo alle colline coltivate della Valle del Giordano, dove predominano il cedro, l'ulivo e l'eucalipto. Verso sud, in direzione del Mar Morto, la vegetazione non sopravvive e il paesaggio è dominato da pianori di fango e sale. Nelle regioni desertiche del paese si incontra la tipica fauna del deserto: dromedari, volpi del deserto, topi della sabbia, lepri e topi delle piramidi, mentre nelle colline a nord-est del Mar Morto ci sono cinghiali, tassi e capre. La Giordania è conosciuta per la fauna marina, e il Golfo di Aqaba ha un'enorme varietà di pesci tropicali e di coralli. La più grande riserva naturale del paese è la Shaumari Wildlife Reserve, a est, dove gazzelle e orici, una volta diffusi in tutto il paese, sono stati reintrodotti.

Cenni di morfologia e geologia della zona di Wadi Rum.

Il sud della Giordania è caratterizzato da affioramenti di rocce sedimentarie di età paleozoica inferiore. Abbiamo anche affioramenti di graniti e dicchi basaltici.

Nella zona esaminata affiora il gruppo di "Ram Sandstone", che si divide, dai termini più antichi, in:

1) Salib Arkose Formation (arenarie arkosiche stratificate).
2) Umm Ishrin Sandstone Formation (arenarie massiccie brunastre).
3) Disi Sandstone Formation (arenarie massiccie chiare).
4) Umm Sahm Sandstones Formation (arenarie brunastre stratificate).

L'età va dal cambrico all'ordoviciano.

Tettonicamente si hanno quattro direzioni principali: NNE-SSW (0°-15°); NE-SW; E-W; NW-SE. Molto importanti sono le direttrici NNE-SSW e NW-SE in subordine. Infatti la morfologia è controllata dalla tettonica, dando un aspetto suggestivo a tutta la zona. La stratificazione è suborizzontale, leggermente immergente verso est.

L'erosione, dovuta alla sabbia trasportata dal vento, ha scolpito la roccia in tutta una serie di forme di "corrasione", che sono diventate una grande attrattiva turistica (fig. 1), creando paesaggi suggestivi.

Infatti l'associazione della tettonica, della litologia e dell'azione corrasiva del vento ha

Fig. 1 - *Veduta panoramica di Wadi Rum.*

comportato la formazione di alveoli, pinnacoli, ponti naturali, torrioni rocciosi, valli di origine tettonica e di corrasione, strutture a fungo (fig. 2). Ma la cosa più importante è la formazione di cavità, anche di una certa dimensione, entro le arenarie. Nel prossimo passo si descriverà sommariamente il fenomeno.

Fig. 2 - *Erosione a fungo.*

Il fenomeno della corrasione.

La capacità del vento di trasportare, fino ad una certa distanza, particelle solide, è proporzionale alla sua velocità, che può variare vicino ad una superficie per fenomeni di attrito e turbolenza; tale velocità può essere irregolare, con frequenti pulsazioni. La direzione della corrente può essere deviata da ostacoli.

Il trasporto solido avviene in sospensione o per saltazione, importanza minore ha il trasporto per rotolamento e per reptazione (movimento dovuto per urti da altre particelle). Inoltre queste modalità di trasporto dipendono dal peso specifico, dalle dimensioni e dalla forma delle particelle. Materiali minuti come polveri, ceneri vulcaniche e sabbie fini, vengono trasportati in sospensione anche a notevoli distanze. Materiali a granulometria superiore come sabbie medio-fini e medie, si spostano per saltazione, non lontano dal terreno.

Tali fenomeni vengono esasperati, nei deserti, durante le “tempeste di sabbia”, dove qualunque ostacolo viene colpito da una fitta quantità di granuli, lanciati con una certa violenza.

Si definisce corrasione (dal latino corràdere, che significa pulire con la raspa) l’azione del vento, per mezzo di particelle solide (granuli di sabbia che, lanciati dal vento, colpiscono la roccia agendo da agente abrasivo), che si esercita su rocce coerenti, consumandole esternamente, in modo da modellarle in forme particolari.

Fig. 3 - *Cavità eolica profonda circa 20 metri, usata dai nomadi per procacciarsi acqua.*

Fig. 4 - *Particolare interno della cavità.*

Ci possono essere varie forme dinamiche di corrasione: si ha trasporto per saltazione che avviene presso terra, dove le rocce emergenti subiscono processi di corrasione fino a qualche metro d'altezza, infatti le rocce prendono forme a fungo; si hanno tracce di lisciamento delle rocce; si possono avere anche alveoli, nicchie, marmitte, cavità in pareti verticali che possono arrivare anche a 60 metri di profondità (secondo Gortani Michele), crestine e strati sporgenti, che dipendono da parti più o meno dure della roccia, formando forme e microforme di corrasione selettiva.

Forme di corrasione, a scala maggiore, possono determinare alcuni aspetti particolari del paesaggio, come colonne e cupole di corrasione, rocce allungate in un senso, valli di corrasione anche di notevoli dimensioni.

A questo fenomeno vero e proprio, possono concorrere anche fenomeni di disgregamento e disfacimento.

Descrizione del fenomeno.

La somma di tutta una serie di fenomenologie come l'alternarsi del caldo e freddo, l'azione tettonica e l'azione di corrasione della sabbia trasportata dal vento, portano al formarsi di forme di modellazione meccanica molto particolari, tipiche dei climi desertici.

Ma cavità di discrete dimensioni (sviluppo anche di 10-15 metri), in sedimenti arenacei, non ne avevo mai osservati. Forme di corrasione le ho osservate anche nei deserti americani e nordafricani, ma mai formazioni paracarsiche (si può definire fenomeno paracarsico) di queste dimensioni (figg. 3 e 4 e tavola 1, cavità impostata su frattura verticale orientata all'incirca E-W, profonda una ventina di metri, con il fondo e le pareti intonacate per renderle impermeabili, ed usata dai nomadi per raccogliere acqua). La gran parte di questi fenomeni sono stati individuati lungo lo "Wadi Umm Ishrin".

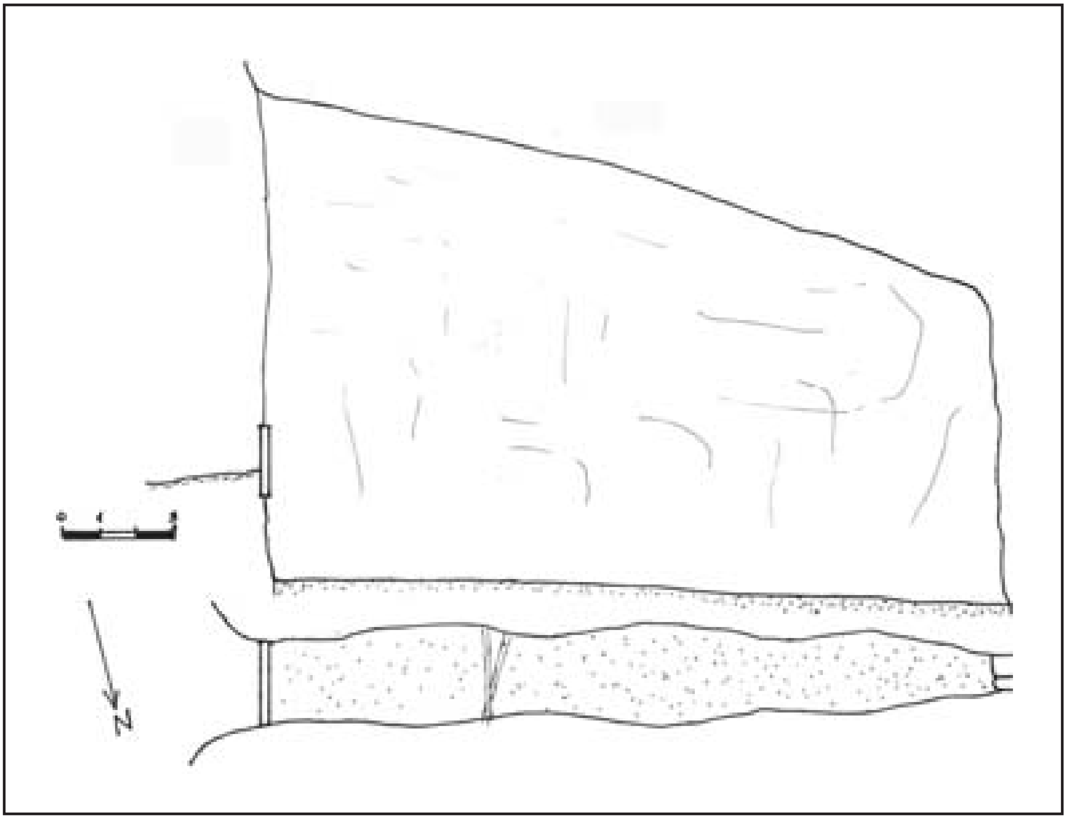

Tavola 1 - *Rilievo topografico della grotta di Wadi Rum.*

Addirittura le pareti delle cavità sembrano corrose dall'acqua, come i fenomeni carsici nostrani, e certe forme ricordano addirittura il concrezionamento (fig. 5, in verità sono corrasioni verticali strutturate anche su variazioni litologiche delle arenarie). Si è osservata anche una paravaschetta naturale in uno strato staccato dalle pareti (fig. 6).

In certi strati, con presenza anche di una certa percentuale calcarea, si possono avere anche fenomeni di dissoluzione (fig. 7). Sulle

Fig. 5 - *Erosioni somiglianti a concrezioni.*

pareti si notano spesso dei "scallops eolici".

Il fenomeno si sviluppa quasi esclusivamente nei corpi arenacei delle "Umm Ishrin Sandstones", i fenomeni più importanti si sviluppano entro fenomeni tettonici di una certa rilevanza, altrimenti si hanno fenomeni più ridotti. Tale formazione consiste di arenarie quarzose con granulometria da media a grossolana (medim to coarse-grained), con colori che vanno dal bruno-rossastro a giallo-rosa e grigio. Si hanno anche strati sottili, intercalati con arenarie massive, finemente laminati, micacei e/o ferruginosi, formati da arenarie a granulometria fine, con livelli bioturbati.

Fig. 6 - *Erosione a vaschetta.*

Fig. 7 - *Fori di dissoluzione in arenarie calcareo-selcifere.*

In sezione sottile, tali litotipi, si presentano spesso come quarzo-arenite, con quarzo accresciuto (overgrowth) su cemento calcitico che racchiude grani di quarzo, ben assortiti e subarrotondati.

L'ambiente di deposizione è dato da antichi sistemi fluviali tipo "fluvial braided streams", in ambiente climatico umido, con intercalazione di brevi ingressioni marine. Tali episodi sono individuati da arenarie fini e siltiti con livelli bioturbati, a motivo centimetrico.

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GEOLOGICAL SKETCH AND THE CAVES OF THE MÁTRA MOUNTAINS IN HUNGARY

ISTVÁN ESZTERHÁS[1], GEORGE SZENTES[2]

Abstract - The 670 km2 large Mátra Mountains are situated in the central area of the Northern Hungarian Mountain Range between the Tarna and Zagyva Rivers. The main ridge is the highest summit in Hungary, the 1014 m high Mount Kékes. The Mátra comprises of a stratovolcanic group with several eruption centres. The eruptions happened mainly in the Miocene and has resulted in various formations of lava rocks and pyroclastics. On the northern slopes pebbly and sandy sediments were deposited. Caves can be found in nearly all of the rock formations. The area is one of the most important region in Hungary from point of view of non-karstic caves. Seventy-four natural non-karstic caves and 13 artificial cavities, called caves, occur. Amongst the them can be found each genetic types. Here opens the 428 m long Csörgõ Hole, the longest non-karstic cave in Hungary. The authors describe the geology, the geomorphology and the cave development of the Mátra Mountains. They give a distinct presentation about the above mentioned Csörgõ Hole. Furthermore typical examples of the caves have been selected and presented according to the different rock formations and development types.

Key words: stratovocanic sequence, tuff depositing, syngenetic, crystal cave, gas bubble cavity, postgenetic, mass movement, corrasion, rock fragmentation, chemical weathering

Introduction

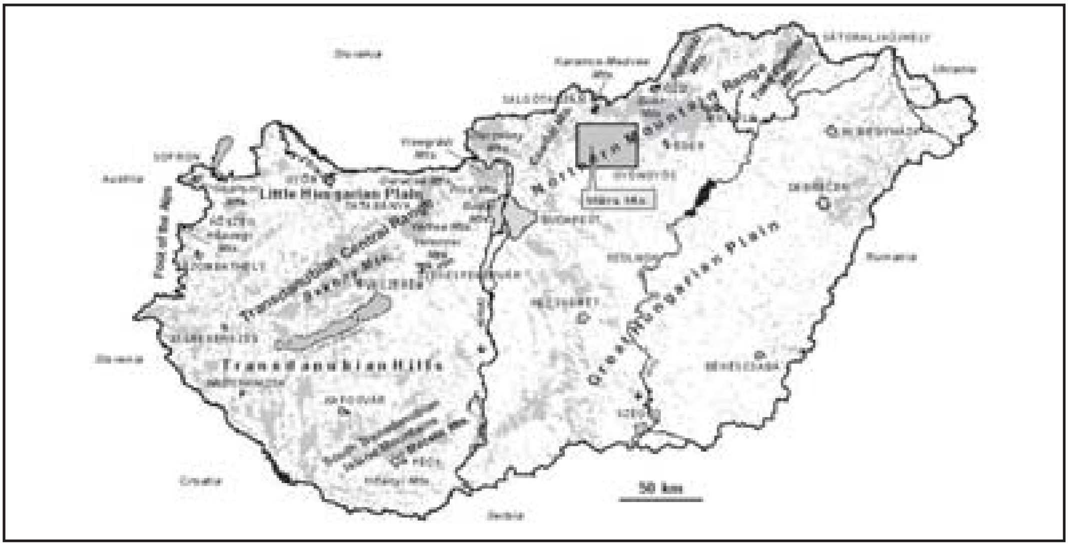

Fig. 1 - *Location of the Mátra Mountains*

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The Mátra Mountains are situated in central area of the Northern Hungarian Mountain Range between the Tarna - and Zagyva Rivers. The range stretches north to west for 50 km and south to east for 15 - 20 km wide (Fig. 1). The area is 670 km2 large including the foothills. The volcanic formation itself covers a 380 km2 surface area. The heavily dissected mountains have an average height of 700 - 800 m above the sea level. The main ridge is the highest summit in Hungary, the 1014 m high Mount Kékes. The density of the forestation is of particular interest. The mountains are the habitat of rare plant- and animal species. Some unique geological formations and minerals are located here. The Mátra Nature Conservation Area Authority is reponsible for the protection and conservation of the natural environment. Additionally many cultural and historical edifices relating to the former ore mining also are also to be found. Last but not least, as this study intends to demonstrate, the Mátra Mountains also have important speleological significance.

Geological settings

Geologically the Mátra Mountains are a part of the inner volcanic range of the Carpathian Mountains. There is limited evidence for the manner in which the lower basement was formed. It can be traced solely either the basis of some enclosed rock fragments from the lava and tuff or from the ore prospecting boreholes in the Eastern Mátra Mountains. Precambrian and Palaeozoic micaceous schist, quartziferous schist and granite inclusions were found in the andesite of the Western Mátra Mountains. This indicates the presence of a crystalline basement below the volcanic rocks and the younger sediments at an unexplored depth.

The accumulation of the Triassic Geosynclinal Sequence in the east of the mountains, near the village of Recsk has been explored as a result of ore prospecting drillings. During the course of the Triassic sedimentation basic diabase lava flows were produced in several phases. The diabase was revealed not only from the drillings, but from outcrops in the easternmost rim of the hills. Drilling penetrated several hundred metres of thick Triassic limestone, dolomite, clay slate and sandstone. In the contact zones of the sediments and the volcanic formations, metamorphic and various types of skarn minerals were found.

The Triassic sediments are overlain by a thin layer of Eocene Nummulitic Limestone (Szentes 1969), which was observed in deep boreholes. During the Eocene intense volcanic activity was typical. The oldest volcanic formation, the biotic-amphibolic andesite, andesite agglomerate and tuff outcrop in the vicinity of the village of Recsk. The hydrothermal ore occurrence is related to this Eocene volcanism.

The Oligocene sediments are known to occur in the northern foothills of the mountains. The thin Lower Oligocene is composed of shale and siliceous sandstone. The Middle and the Upper Oligocene is represented by clayey marls of great thickness. The cross bedded Upper Oligocene sandstone frequently outcrops in the deep valleys of the northern Mátra Mountains.

The main volcanic activity took place in the Miocene era. The most important geological formations in the mountains are developed during this epoch. A transgression began in the Eggenburgian Stage of the Lower Miocene. Its base is composed of a sandstone and conglomerate series, of which of outcrops are appear spectacularly in the valleys of the northern ranges, especially in the valley of Köszörû Creek (Szentes 1969). Volcanic activity recommenced in the Ottnangian Stage. The key horizon is a wide spreaded rhyolite tuff depositing the so called Lower Rhyolite Tuff. In the neighbouring basins the rhyolite tuff is overlain by Brown Coal Bearing Sequence. During the Carpathian Stage the most extensive

Picture 1.: The main ridge of the Mátra Mountains with the Mount Kékes constituted of the Covering Andesit Sequence.

sediment formation of the mountains was deposited, the sandy clayey marl, the so called Schlier Sequence. In some places the Schlier Sequence also occurs below the younger volcanic rocks.

At the same time an andesite lava and pyroclastic series were formed, known as the Lower Andesite Formation. In the border of the Carpathian and Badenian a rhyodacite tuff eruption took place, referred to as the Middle Rhyolite Tuff. It covers a 600 km2 and its thickness varies between 20

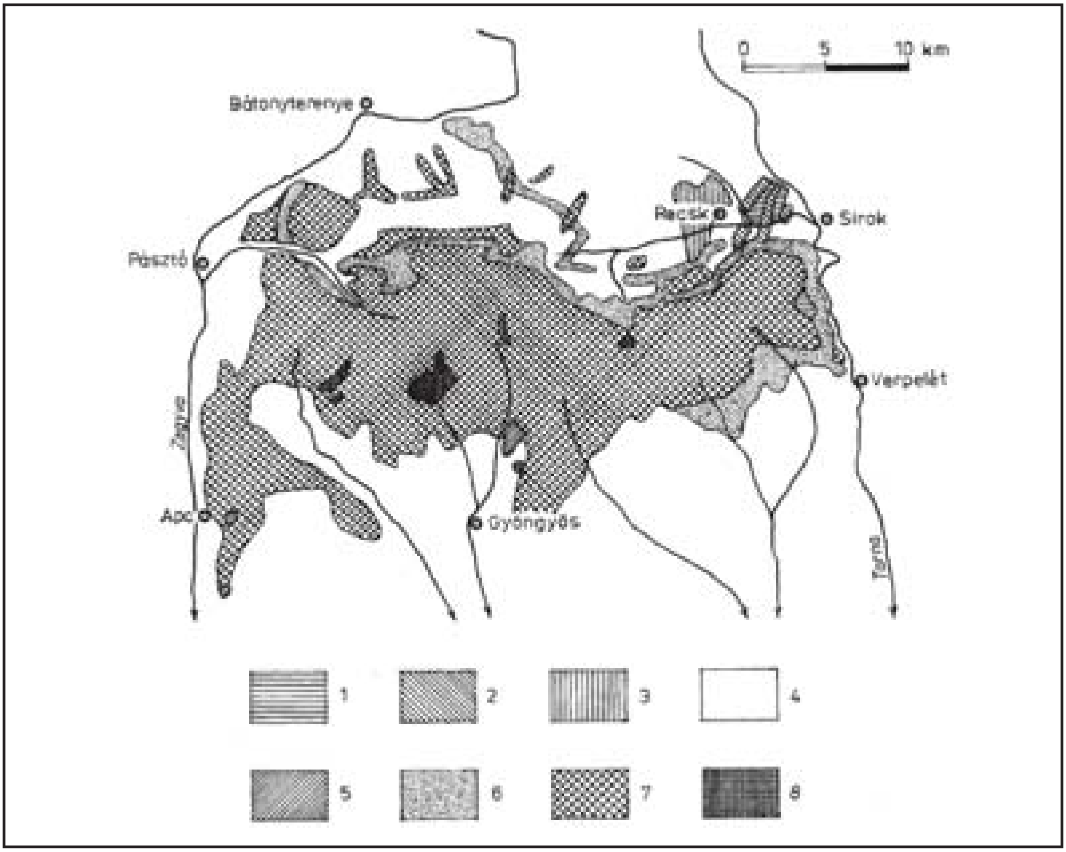


Fig. 2 - *Simplified Geolocical Map of the Mátra Mountains - Legend: 1. clay schist, 2. diabase, 3. biotic amphibole andesite, 4. sandstone, loess, talus deposits, 5. rhyolite, 6. rhyolite tuff, 7. pyroxene andesite and its agglomerate, tuff 8. quarzite.*

and 200 m depending on the relief of the contemporaneous land surface (Varga and his collaborators1975).

The majority of the volcanic superstructure of the Mátra Mountains is made up of Middle Miocene (Badenian) explosive and effusive products. This Middle Stratovocanic Sequence is is more than 1000 m thick. The sequence is composed of piroxen andesite lava rocks, tuffs, volcanic breccias and agglomerates. The lava products were subject to deuteric effects during and after the volcanism. Following this volcanic activity a hydrothermal ore mineralization was evolved in the central area of the mountains. The parts of the mountains laying above 600-700 m altitude are composed of the youngest member of the andesitic volcanism, fresh or just slightly altered pyroxene andesite, the Covering Andesite Sequence (Picture 1). In the central area of the southern rim of the mountains an occurrence of rhyolite domes of the late Badenian Stage can be observed. In the northern foreland of the eastern main ridge, light grey, coarse grained andesite, the so called carbonate andesite is to be found. The rock includes a multitude of cavities or fissures filled with carbonates (Varga and his collaborators1975).

The volcanic formation is overlain by sedimentary deposits, which contain large amount of redeposited volcanic material. One of the most characteristic sediments of the Upper Badenian is the Diatomite Sequence. Limestone, tuffaceous limestone and sandstone as the covering formation has developed gradually from the Diatomite Sequence.

The Sarmatian formations are known to occur in the south-eastern forelands. They are composed of sands and clayey sands.

The interbedded tuffite layers can be identified as the Upper Rhyolite Tuff. The fumarolic activity of the post-volcanic period took place either at the same time as this activity or subsequent to it.. The formations produced by geysers and hot springs are consisting of chalcedony-opal beds, which may represent the geysers and hot spring terraces. In the northern part post volcanic activity can still be observed, proved by the occurrence of carbon dioxide producing mofettes (Mátraderecske) or by by the emergence of springs containing carbon dioxide and hydrogen sulphide, locally known as "csevice" (Parád, Szajla).

The Pannonian formation surrounds and partly covers the volcanic area from the south and west. It is composed of alternating clays and sands with lignite seams. In the Quaternary debris cones consisting of pebbles, redeposited andesitic rubble and in the valley floors, alterating pebble, sand and silt depositions developed (Fig. 2).

Geomorphology

The Mátra's relief forms can be divided into two major groups. The first includes the primary volcanic features, which have preserved their original or suboriginal shapes up to the present time.

These includes parasitic cones and elongate ridges reminiscent of a fissure volcanic origin as well as stratovolcanic cones more resistive to the erosion. The second type of lan-

Picture 2.: The Mount Óvár was a former stratovolcanic explosion centre,in the background the Mount Ágasvár.

dform has been shaped by erosion, including canyons, the pinnacles and the weathered rock dykes etc.

The ridge of the Western Mátra can be considered as the primary feature. There, along a tectonic zone, several small crater relics can be observed (Varga 1967). Mount Óvár in the Western Mátra Mountains was a stratovolcanic centre with huge masses of coarse agglomerate accumulations on its slopes (Picture 2). Additionally, in the west, deep erosion valleys are forming a strongly dissected landform.

Mount Kékes in the Central Mátra, the highest peak in Hungary, is also considered to be a stratovolcanic centre. Its slopes below the protecting lava cover are heavily eroded.

The longest and genetically most obvious series of fissure volcanoes is represented by the main ridge of the Eastern Mátra Mountains, where 10 eruption cones or cone relics can be identified over a distance of 12 km.

It is debatable whether the curved scarps in the vicinity of Mount Galya, Mount Kékes and Mount Nagy Szár are the remains of crater rims or caldera walls. In the forehills of the main ridge characteristic subvolcanic bodies can be observed.

The development of the valleys in these mountains has taken place in three stages. In the first case the valleys which developed between the original volcanic forms were further deepened by erosion. This has resulted in symmetrical valleys. In the second case the erosion has formed linear valleys along the tectonic plains. In the third case valleys have been formed by powerful streams in the recent past.

Along the rims are typical breaking plateau fragments. The stone blocks lie at right angles to the surface of the former lava flow. The blocks are gradually denuding and breaking into small pieces on the steep slopes. Secondary, relatively recent processes (frost riving and erosion) are responsible for the "rock columns" on the northern side of the mountains.

The other group of lava bodies, younger than the previous one, is characterised by dikes. Some of which are markedly exposed on the surface.

Recently the erosion has taken lesser part in the formation of the landscape, as the major part of the formations are covered. The removal of this cover has occurred mainly in the creeks and gullies.

On the plain on the southern foreland, connected debris cones have been developed over the Pannonian sediments as a result of downcutting water courses.

The northern foothills were formerly covered by volcanitc rocks, but these tuff- lava- and agglomerate layers have been denuded. Clayey and sandy Miocene and Oligocene sediments form the strongly dissected landscape. The land became a low elevated hill country due to downcuttings water courses. The land rises gradually toward the main masses of the Mátra Mountains. In some places the remains of exhumed subvolcanos emerge on the surface (Székely 1964).

Cave Development in the Mátra Mountains

In the Mátra Mountains 87 cavities can be found in the non-karstic rock formations (Fig3.).

These include 74 natural caves and 13 artificial cavities, referred to as caves either in literature or by the local people. The total length of the natural caves is 830 m and the length of the cavities total 250 m (Eszterhás - Szentes 2006).

Amongst the, 8 % have originated as syngenetic caves. In the abandoned and flooded Gyöngyösoroszi mine, four crystal caves were found at a depth of several hundred metres. The caves were formed at the edge of an ore dyke and the tracyandesite from the influence of the ascending hot solutions. Gas bubble cavities are formed in amphibole and pyroxene

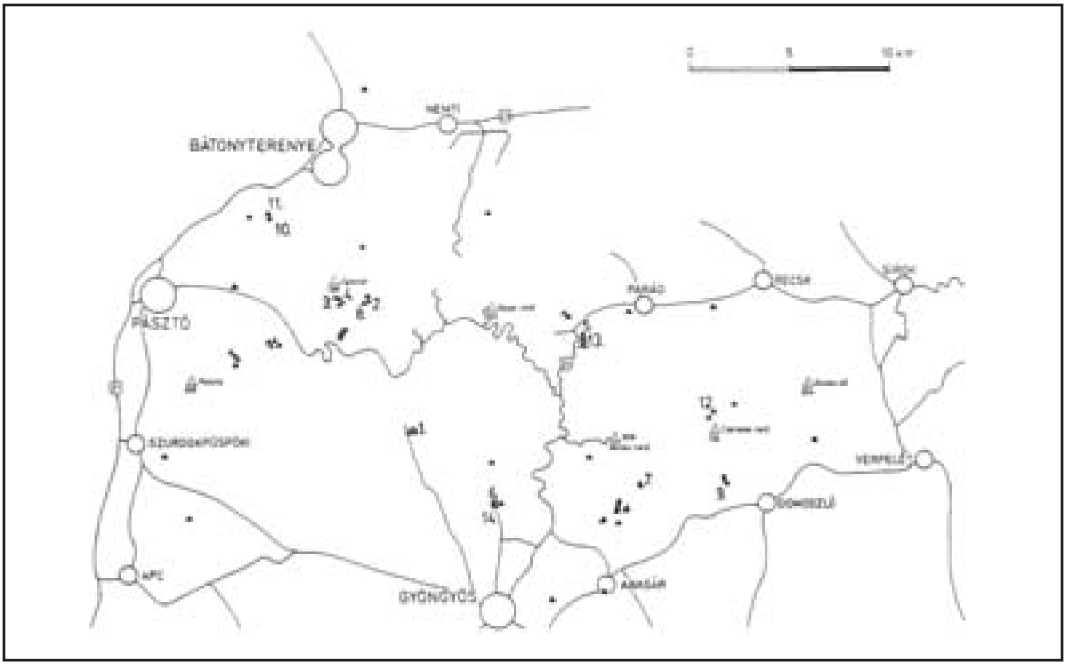


Fig. 3.: Caves in the Mátra Mountains - With number marked caves are the selected examples for the study: 1. The inclined cave in the 250 m level of the ore mine, 2. Gyula Cave, 3. Kék-útmenti Cave, 4. Csörgõ Hole, 5. Herceg-gödri Cave, 6.Csák-kõi Big Cave, 7. Kis-kõi Fissure Cave, 8. Csörgõ-pataki Pseudocave, 9. Görgeteges Rock Shelter, 10. Macska Rock Shelter, 11. Macska Cave, 12. Cserepes Rock Shelter, 13. Mismucska Cave, 14. Malomköves Hall.

andesite near near the villages of Mátrakeresztes and Mátraszentimre villages. The partial denudation of the surrounding rock opened the three passable circular cavities (Eszterhás 1993, Ozoray 1962, Szentes 1971, Prakfalvi 2006).

Most of the non-karstic caves have postgenetic origin (77%). These caves were formed after the development of their surrounding rock. Their formation can be divided into four major categories and they represent 11 different types of the cave development.

Mass movement has created 30 caves in different parts of the Mátra Mountains. These are occurring in andesite, andesite agglomerate, andesite tuff, rhyolite, quartzite and also in sandstone. Most of these (21 caves) are 2 -10 m long, narrow and high tectonic fissure caves (Bertalan 1958, Eszterhás 1993). Three atectonic caves are known, which were formed by the equalization of the arising tensions as the rock mass moved down the slope.The atectonic group is of particular importance, because it includes the longest non-karstic cave of Hungary, the 428 m long Csörgõ Hole (Bertalan 1958, Eszterhás1990, 2003, Eszterhás, Manga1996, Szabó 1871, Székely 1953). Furthermore two 3 - 4 m long leaning pseudocaves, two 2-9 m long talus caves, one 6 m long collapsed cave and one 113 m long consequence cave have formed as a result of caves originating through the mass movement of the strata (Eszterhás 1990, Eszterhás, Gönczöl, Szarka 1991).

Corrasion has formed 8 cavities. These cavities have developed in andesite agglomerate, rhyolite tuff, conglomerate and sandstone as a result of erosion from gravel transported in streams. Six cavities, 6 - 14 m wide, and 2-3 m deep rock shelters developed as a result of lateral erosion, and evorsion shaped two rock shelters below waterfalls (Eszterhás, Gönczöl, Szarka 1991).

Rock fragmentation has formed 23 caves in agglomerate, rhyolite tuff, conglomerate and sandstone in different parts of the Mátra Mountains. Twenty-two 2-5 m long niches developed as a result of the influence of the temperature and moisture variation. One 14 m long fissure cave has formed as a result of extension, which was caused by the termination of the lateral pressure in the rock masses.

Chemical weathering occurs only in the form of the alkaline solution. In the Köszörû Valley the alkaline solutions of former geysers has formed six caves in the siliceous conglomerate. The 2-14 m long tube shaped passages are gradually narrowing and become impassable (Eszterhás, Gönczöl, Szarka 1991).

Artificial cavities make up 15% of the caves in the Mátra Mountains. These cavities are called caves in literature or by the local people and some of them have formed already consequence cave. They have been carved or excavated in andesite, rhyolite and pyroclastics. They include abandoned mines, cellars and former hermitages (Bertalan 1958, Eszterhás 1990, 1996).

Csörgõ Hole, the longest non-karstic cave in Hungary

The Csörgõ Hole opens in the Western Mátra Mountains at the southern foot of Mount Ágasvár (Picture 3.). Its only entrance has an iron gate. For many years the cave was forgotten about, and became the stuff of legends. The first scientific expedition to the cave was led by the geologist József Szabó on 17th May 1869. At that time the known length of the cave was 130 m (Szabó, 1871). At the turn of the XIX. and XX. century the Hungarian Carpathian Association carried out explorations, but the their report was lost. In the 1950's two studies were published on the cave (Leél-Õssy, 1952, Székely 1953), but unfortunately the relevant manuscripts disappeared. Since 1982 the members of the Climbing and Caving Club of the town of Salgótarján have been systematically exploring the cave.

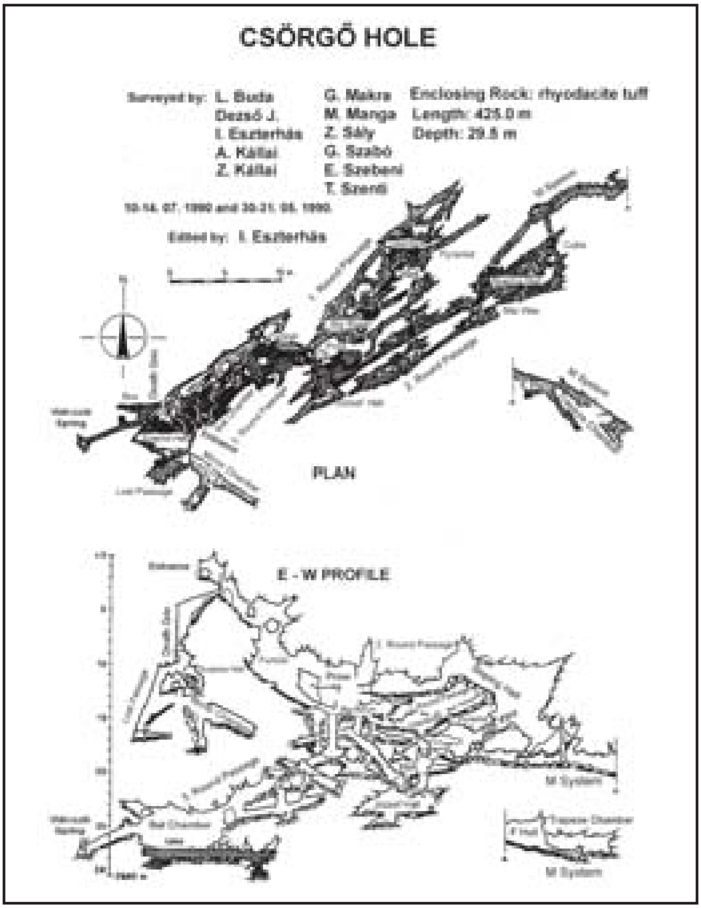
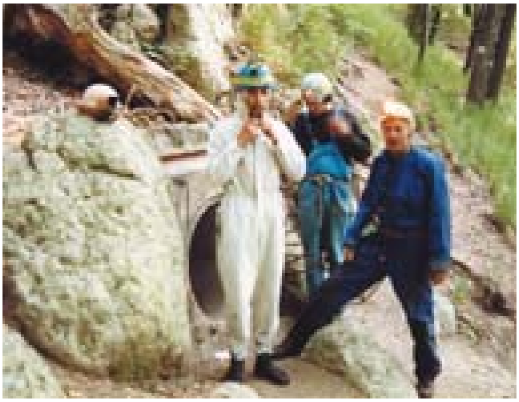


Fig. 4.: Survey of the Csörgõ Hole

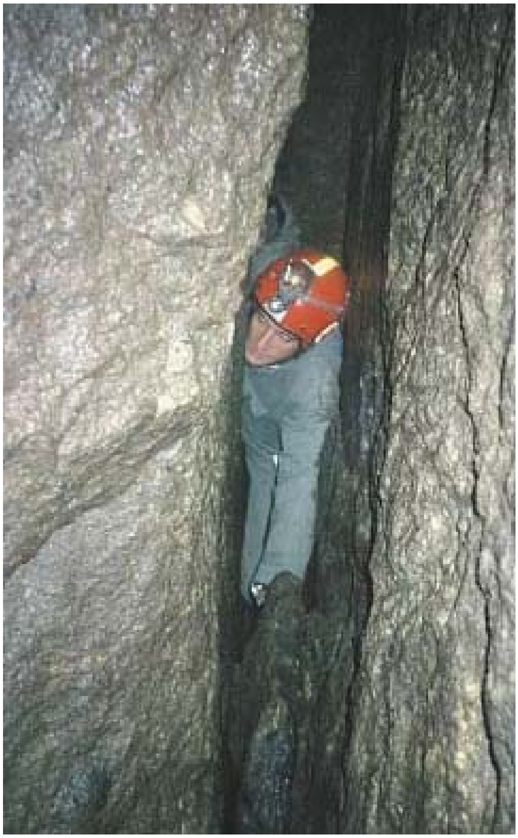


Picture 3.: Entrance to the Csörgõ Hole

Picture 4.: The 1. Round Passage in the Csörgõ Hole.

As a result of this the cave has recently been extended to 428 m long and 29.6 m deep (Fig. 4.). Since 1990 the Vulcanospeleological Collective of Isztimér has carried out scientific investigations in the cave (Eszterhás 1990, 2003).

The Csörgõ Hole is an atectonic labyrinth. The development of the cave can be traced back to the continuous sliding of the rhyodacite tuff (Middle Rhyolite Tuff) and the consequent aggradation. The first explorer of the cave, the geologist József Szabó had defined exactly how the landslide had originated in the cave development: "The position of the surroundings and the direction of the passages indicates that the layers, obeying to the pull of gravity, are sliding slowly and continuously toward the bottom of the valley. As a result of this mass movement the layers are broken apart and boulders moving at different rates are piling up on one another....". (Szabó, 1871). The boulders are sliding south-eastwards on a 20o slope, therefore between the accumulated boulders passages have formed following a NE - SW strike. Because of the continuous sliding of the boulders, the size and form of the cavities are still frequently changing.



Picture 5.: A very narrow passage in the Csörgõ Hole

The complicated labyrinth of the cave consists of several chambers, long and short passages and shafts (Fig. 4.). A tour in the cave is not easy due to the complexity of the passages (Picture 4.), the narrow corridors and shafts (Picture 5.) as well as the danger of collapse. Speleothems are not to be found in the cave. The walls and the ceiling are formed of light grey, grained and partly weathered tuff boulders. The boulders in the Big

Room are especially spectacular boulders as are those in the Prow and in the M System which contains the 8 m big Super Cube. The floors are covered with rock gravel and with some fine grained debris. In the deepest level of the cave the perennial Vidróczki Spring emerges and in the Bat Chamber an intermittent lake can sometimes be found. In Surprise Hall water can be heard gurgling through the fissures, but nobody has yet succeeded in reaching this underground stream. The members of the Vulcanospeleological Collective have proved by dye tracing the connection between the Vidroczki Spring and the Vándor Spring which emerges on the surface. The distance between the two springs is 130 m and the vertical difference is 8 m. The dye tested water emerged after 7 hours (Eszterhás 1990).

The cave temperature is cooler than the surface temperature. The air temperature in summer is about +4 Co in the deep level. This phenomenon can be explained by the extensive evaporation area of the porous tuff, which results in greater heat extraction.

In the cave 18 species have been identified. The large numbers of moths (Triphosa dubitata, Scoliopteryx libatrix, Inachis io) is unusual. In the Lost Passage large colonies of Lesser Horseshoe bats (Rhinolophus hipposiderros) roost throughout the winter (Eszterhás 1990, 2003).

Description of some characteristic caves according to the types of cave development and the surrounding rock.

The 87 caves of the Mátra Mountains are representing 14 types of cave developments in three main groups. In this chapter we describe examples from each types of the cave development (2 syngenetic originated caves, 11 postgenetic originated caves and 1 artificial cavity).

The inclined cave at the 250 m level in the ore mine was a 12 m long, 2-3 wide and 4-5 m high sloping crystal cave. The cave was formed at the edge of an ore dyke and the tracyandesite which originated from the influence of the ascending hot solutions. Its walls were covered with large brilliant individual amethyst crystals and disseminated pyrite. Unfortunately, immediately after its discovery, the cave

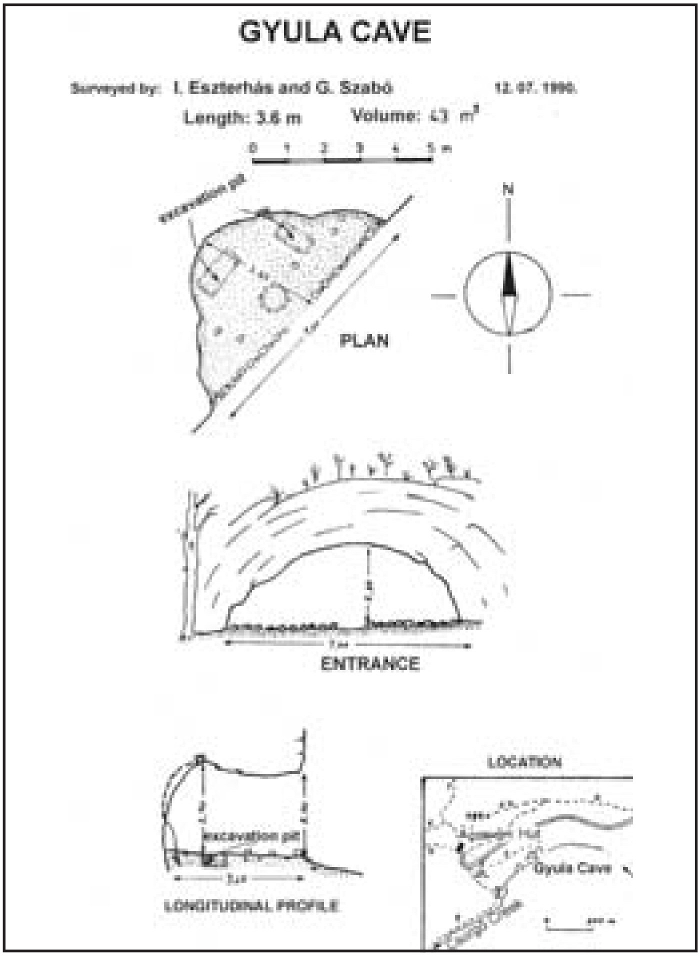


Fig.5.: Survey of the Gyula Cave.

was looted and filled in. After the mining operations ceased (1989) the whole system was abandoned and flooded (Eszterhás1996, Eszterhás, Gönczöl, Szarka 1991).

The Gyula Cave opens on the base level on the righthand side of the Csörgõ Valley (Fig. 5). Its entrance is 7 m wide and 2.3 m high. The cave consists of a single 3,5 m long and 2.3-2.7 m roundish niche, which was originally a completely ball-shaped gas bubble cavity in compact andesite. Part of the cave was denuded by the erosion of the Csörgõ Creek and filled in by stream debris. The Gyula Cave is of archaeological importance. Excavations revealed potsherds dated from the late Bronze Age to the present days (Eszterhás 1990, 1996).

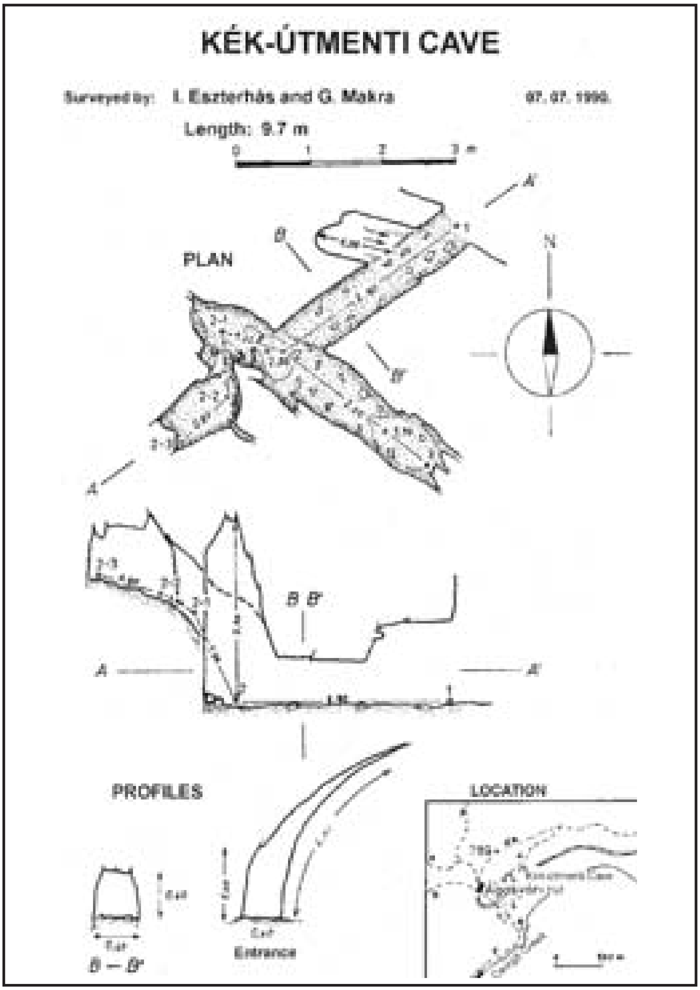


Fig. 6.: Survey of the Kék-útmenti Cave.

The Kék-útmenti Cave is a tectonic fissure cave (Fig 6.), which was formed in pyroxene andesite on the southern slope of Mount Ágasvár. Its entrance is 0.6 m wide and 2 m high. The first 3 m of the cave is a low crawl, which leads into a 2.5 m high fissure passage. The total length of the cave, including some small niches, is 9.7 m (Eszterhás 1990, 1996).

The 428 m long Csörgõ Hole, the longest non-karstic cave in Hungary, is atectonic cave in rhyodacite tuff. The Chapter 5 gives a detailed description of the cave.

The Herceg-gödri Cave is a collapsed cave in the Miocene Eggenburgian sandstone by the side of the Hereceg-gödri Creek. A narrow entrance opens into the cave, which has a single chamber measuring 6 x 2 m and is 1.6 m high. The morphology of the cave (for example the funnel shaped floor, which is composed of loose sand.) shows, that its development is the result of a breakdown in a deeper cavity. The lime content of the sandstone is 30%. A cavity developed because a third of the volume of the sandstone dissolved in the acidic water, which induced a breakdown in the loose sandstone.

Csák-kõi Big Cave can be found in a former millstone quarry near the village of Gyöngyössolymos. It consists of a large cavity in rhyolite, caused by breakdown and thus is a consequence cave. There are two distinct parts to this cave. The southern part is the orginal

Picture 6.: The 3. Entrance to the Csák-kõi Big Cave from inside.

Picture 7.: The Görgeteges Rock Shelter in the Tarjánka Gorge.

quarried chamber and consequently this is an artificial cavity (Fig 7.). On the other hand the northern part, a long labyrinth has resulted from natural breakdown and has developed as a natural cave. There are six entrances to the artificial cavity and the natural cave (Picture 6.). The length of both parts is 113 m with a vertical differential of 14.5 m and a 48 m horizontal extension. (Eszterhás 1996, Eszterhás, Gönczöl, Szarka 1991).

Kis-kõi Fissure Cave is a leaning pseudocave. The cave opens in a cliff composed of andesite and andesite agglomerate north of the village of Abasár. There is a large cavity, formed in boulders along the horizontal bedding. The lower part of the boulders have slid and moved from their original position, while the upper part is balanced on bedrock. As a result of this a passage, 4.5 m long, 2.2. m high and 0.6 m wide, open at both ends, has developed.

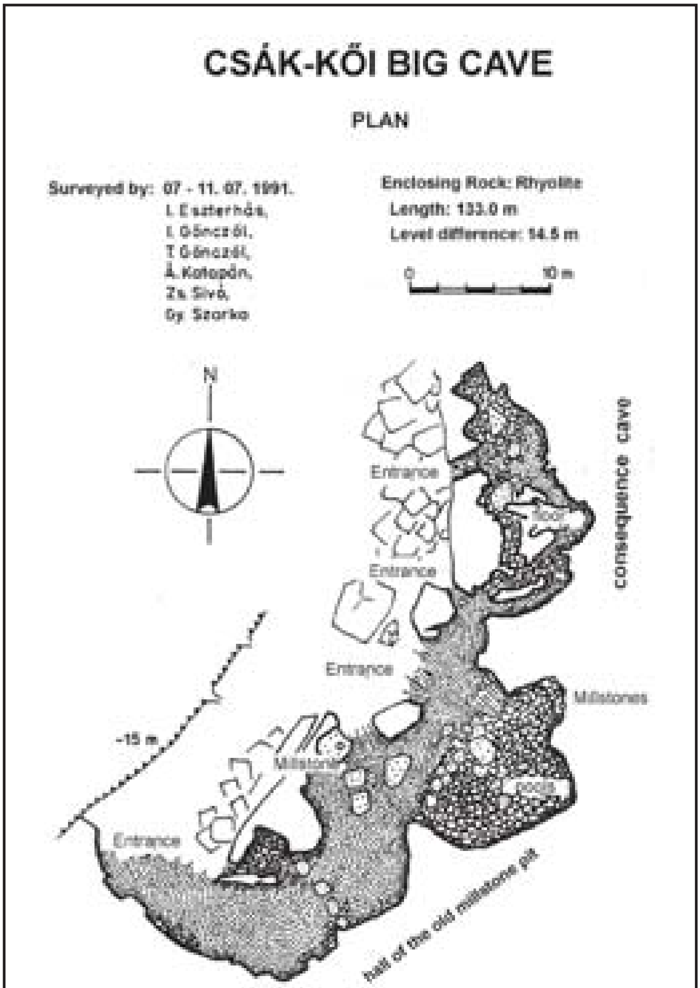


Fig. 7.: Survey of the Big Cave of Csák-kõ.

Csörgõ-pataki Pseudocave can be found in the Csörgõ Valley near the village of Mátraszentimre. It is a talus cave, a mass of fissures between the andesite boulders, which rolled down the valley. A stream flows through the open cavities in the valley. This pseudocave, which is 9.5 m long and an average of 1 m high, consists of two parallel passages, which are connected by a narrow fissure. (Eszterhás1996).

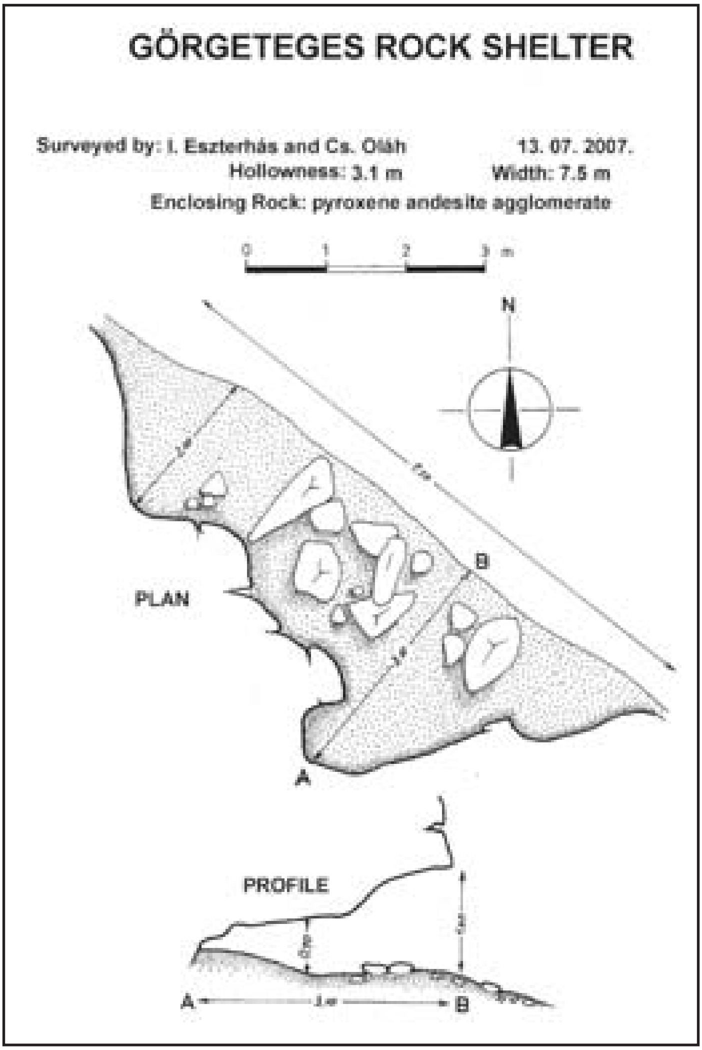


Fig. 8: Survey of the Görgeteges Rock Shelter

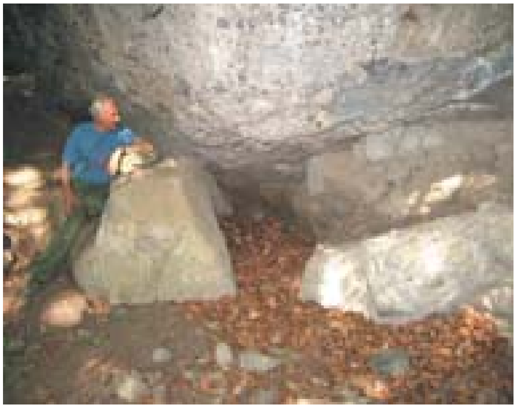
The Görgeteges Rock Shelter was formed near the village of Domoszló in the andesite agglomerate of the Tarjánka Gorge by the lateral erosion of the stream (Picture 7). Generally the width of cavities formed by lateral erosion exceed their depth. In this case the 1m high rock shelter is 7.5 m wide and is 3 m deep (Fig. 8). The floor is covered with rock fragments and andesite sand. It sometimes floods and the water transported gravel is helping to extend the cave.

The Macska Rock Shelter is a cavity near the town of Bátonyterenye in the Macska Valley. The rock shelter was shaped by the eversion in rhyodacite tuff below a waterfall. In the lower third of a 9 m high waterfall, there is a rock shelter with a depth of 3.1 m. In the rock wall several smaller hollows can be observed and spectacular horizontal tuff layers have formed due the selective erosion.

The Macska Cave can be found in the gorge of the Macska Valley. The cave was developed by rock extension in rhyodacite tuff. After the deepening of the gorge steep, backward sloping side had lost its lateral support and thus tension occurred in the rock mass. Later the rock cracked and the blocks separated from one another, forming a cave-sized fissure (Picture 8). The Macska Cave is 14.5 m long, 1 m wide and about 2 m high.

Rock fragmentation, which was caused by the temperature and moisture variation, created the Cserepes Rock Shelter in a cliff on Mount Cserepes near the village of Parád. The rock shelter is found in andesite agglomerate. It is 4.5 m wide, 4-1 m high and is 3 m deep

Picture 8.: The Main Passage in the Macska Cave was formed by extension



Picture 9: The Cserepes Rock Shelter.

(Picture 9). Andesite agglomerate breakdown has accumulated on the floor.

The Mismucska Cave opens in Miocene siliceous conglomerate in the Köszörû Valley near the village of Parádsasvár. The cave has formed as a result of the alkaline solution. Only a solution with a pH of over 9 would have been able to dissolve the passages in this cave The alkaline solution originated from the former geysers of Mount Gyökeres above the Köszörü Valley. Today the existence of these geysers can be identified only from the remains of the geyser cones. The seeping alkaline solutions from the former geysers dissolved several tube shaped cavities, both passable and impassable, in the conglomerate (Picture 10). One these is a the network of the 7.8 m long and 0.5-07 m diameter known as Mismucska Cave (Fig. 9).

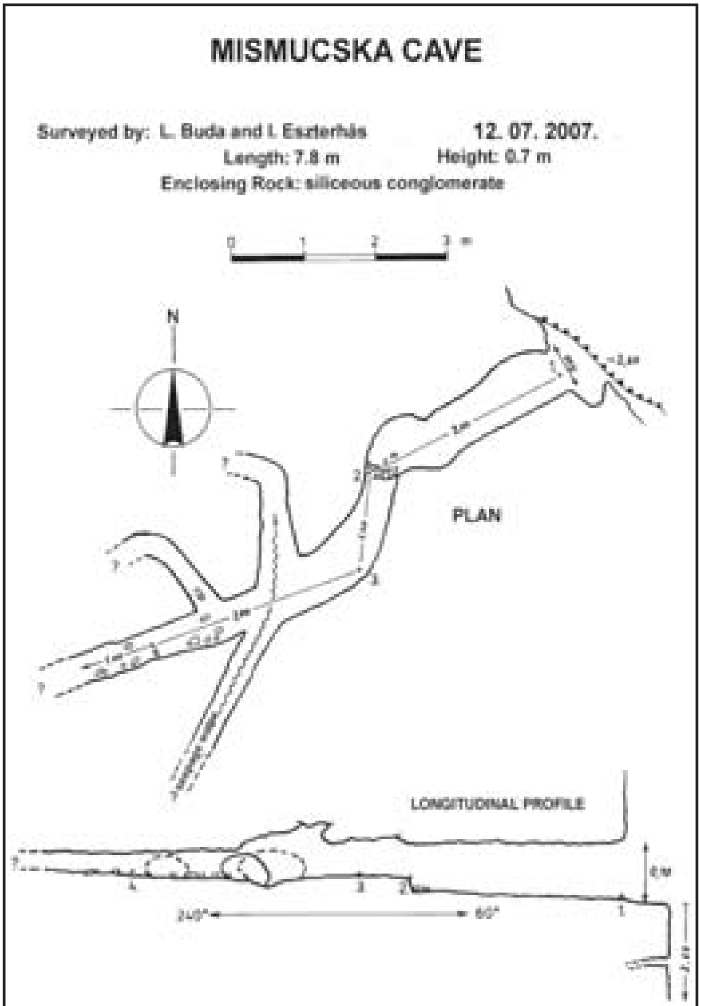


Fig. 9: Survey of the Mismucska Cave

Malomköves Hall is the largest artificial cavity in the rhyolite of Mount Csák-kö near the village of Gyöngyössolymos (Fig. 10). The rhyolite was originally used to produce millstones and as a result large cavities were cut in the rhyolite. The millstones were carved on-site from the rock face and when finished, were mounted on timber sledges, and lowered down the hillside. The most spectacular underground quarry which can be seen today is the Malomköves Hall. The entrance is 3 m wide and 1.8 m high, and inside it is 19.5 m long, 6-10 m wide and 1.8-3.3 m high. In the left hand wall, nine half-completed, but damaged millstones can still be seen (Eszterhás, Gönczöl, Szarka 1991).

Picture 10: Characteristic tube profile in the Mismucska Cave.

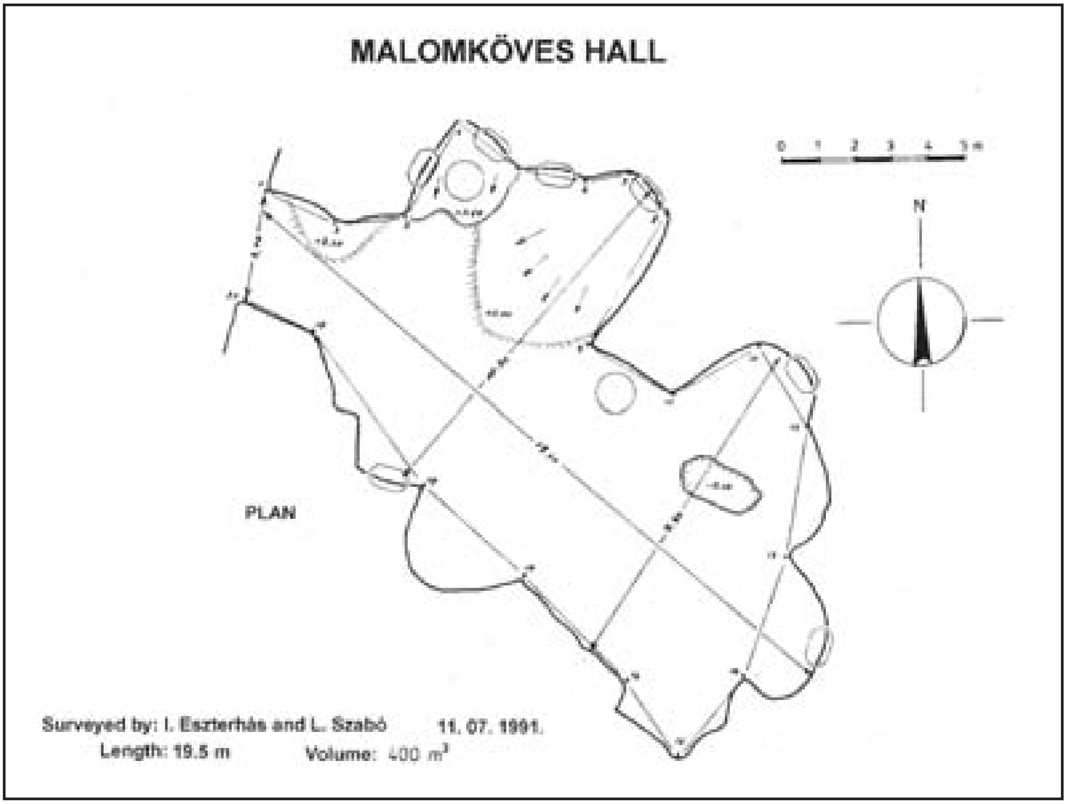


Fig. 10: Survey of the Malomköves Hall.

Summary

The 13 -21 million years old volcanic Mátra Mountains are situated in central part of the Northern Hungarian Mountain Range between the Tarna- and Zagyva Rivers. Here the highest summit in Hungary is to be found, the 1014 m high Mount Kékes. The oldest rock formations on the surface are the Triassic limestone and Eastern Mátra Mountains, the

pillow lava structured diabase which formed beneath the sea. Intense volcanic activity had already commenced in the Eocene, and this produced the biotic-amphibolic andesite, andesite- agglomerate and tuff in the northern part of the mountains. The hydrothermal ore occurrence near the village of Recsk village is related to this Eocene volcanism. The main volcanic activities took place in the Miocene. Initially, wide spread rhyolite tuff was deposited, followed by andesite volcanism. The andesite volcanism produced a stratovocanic sequence several hundred metres thick, composed of andesite lava, andesite agglomerate and andsite tuff. In the subsequent volcanic period, mainly in the north, andesite dykes were intruded into the existing rock formations. In the south rhyolite domes were formed. The quartz dykes and the geyser cones are proof of the intensive postvolcanic activity.

As a consequence of the denudation, the Mátra Mountains today are undulating block mountains. The original volcanic forms are rare and difficult to recognize them due to several million years of selective denudation. The cones and domes are mainly secondary forms. The alternation of the glacial and the interglacial periods were accelerated the fragmentation and extensive boulder fields were formed. The valleys as a result of erosion along the volcanic forms or the fault lines. On the foothills debris cones were deposited.

A few decades ago the Mátra Mountains were considered as "one-cave mountains". During the last 30 years, due to the steady speleological achievements of the Climbing and Caving Club of the town Salgótarján and the Vulcanospeleological Collective of Isztimér, 87 caves are known today. The total length of the caves is 1080 m. The two caving organizations have carried out extensive research and surveys in the caves of the Mátra Mountains. The present study summarizes the observations on the cave development. The following summarizes the various types of caves, together with the ratio of their occurrence.

I. Syngenetic originating caves 8 %

Crystal caves e.g. The inclined cave in the 250 m level of the ore mine

Gas bubble cavities e.g. Gyula Cave II. Postgenetic originating caves 77%

1. Caves formed by the mass movement 34%
   - a.) Tectonic caves e.g. Kék-útmenti Cave
   - b.) Atectonic caves e.g. Csörgõ Hole
   - c.) Collapsed caves e.g. Herceg-gödri Cave
   - d.) Consequence caves e.g. Csák-kõi Big Cave
   - e.) Leaning pseudocaves e.g. Kis-kõi Fissure Cave
   - f.) Talus caves e.g. Csörgõ-pataki Pseudocave
2. Caves formed by the corrasion 9%
   - a) Caves formed by the lateral erosion e.g. Görgeteges Rock Shelter
   - b.) Caves formed by the evorsion e.g. Macska Rock Shelter
3. Caves formed by the rock fragmentation 27%
   - a.) Caves formed by the rock extension e.g. Macska Cave
   - b.) Caves formed by the temperature and moisture variation e.g. Cserepes Rock Shelter
4. Caves formed by the chemical weathering 7%

Caves formed by the alkaline solution e.g. Mismucska Cave III. Artificial holes 15% e.g. Malomköves Hall

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GENETIC TYPES OF THE CAVES IN SANDSTONES OF THE SWIETOKRZYSKIE (HOLY CROSS) MOUNTAINS, CENTRAL POLAND

JAN URBAN[1], ANDRZEJ KASZA[2]

Abstract - Swietokrzyskie (Holy Cross) Mts constitute ranges of low mountains and hills formed of the sedimentary rocks: Cambrian quartzitic sandstones, Lower Devonian sandstones and quartzitic sandstones, Middle-Upper Devonian limestones and dolomites, Lower Triassic sandstones, Lower Jurassic sandstones and Upper Jurassic limestones. Apart from karst caves developed within the carbonates, about 40 caves occur in the siliciclastic rocks. They are rather short, 90% of them are shorter than 10 m, the longest, Jaskinia Ponurego cave is 25 m long (Urban 1996). All caves are connected with rock landforms: crags, cliffs etc. The main genetic factors responsible for cave formation are: gravitational mass movements, subsurface water erosion, and selective weathering connected with creeping of the weathered, loose material. The most numerous, but usually short cavities formed due to these last processes in the Lower Triassic and Lower Jurassic sandstones. They represent concavities developed in the lower parts of rock walls (owing to the microclimatic conditions stimulating weathering - see Alexandrowicz, Brzezniak 1989) or low, bedding type caves under the rock blankets formed in the less resistant parts of rocks (e.g. along the bedding planes).

The underground water, circulating along the joints in the time of heavy rains and snow thaws, disintegrates the rocks, previously weakened by the capillary water diffusion and - in this way - produces fissure type caves. These caves are not frequent and occur in the Lower Jurassic sandstones (Urban 2005). The crevice type caves, representing the joint surfaces widened due to the gravitational movements of hard rocks (lateral spreading or fall) were developed both in the Mesozoic sandstones and Paleozoic quartzitic sandstones.

Introduction

Non-karst caves are often (in many regions) rare and small, but they formed and evolved due to the specific processes, so they represent various genetic landforms. Therefore the investigations of these features can give important data on relief evolution of the area in geological past and currently (Urban, Oteska-Budzyn 1998). The study presents several genetic examples of the caves in siliciclastic rocks of the Swietokrzyskie (Holy Cross) Mountains, so as to illustrate the diversity of geomorphic factors and processes affecting the relief and evidence the significance of these small forms for scientific reconstruction of the morphological evolution of the region.

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Geological and geomorphological settings

The region of the Swietokrzyskie (Holy Cross) .Mts. is situated in Central Poland. It is the upland area comprising several hill and low mountain ranges. The mountain ranges are formed of the Paleozoic and Mesozoic sedimentary rocks: quartzitic sandstones, sandstones, limestones and dolomites (Fig. 1). They are elevated ca 400-600 m a.s.l. and 100-300 m above the flat and often wide valleys filled with the Quaternary, mainly glacifluvial, fluvial and aeolian sediments (Urban, Gagol 2008).

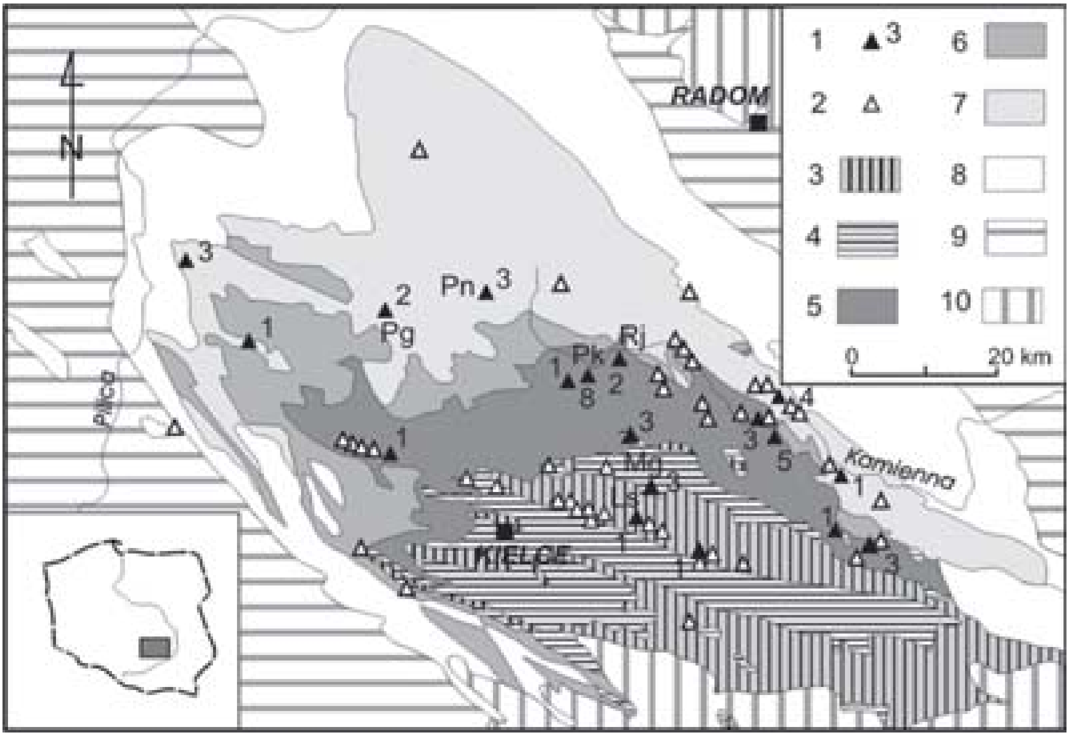


Fig. 1. Distribution of siliciclastic rock forms and caves in the Swietokrzyskie (Holy Cross) Mts. Explanations: 1 - sandstone, quartzitic sandstone and conglomerate natural rock forms with number of caves, 2 - sandstone, quartzitic sandstone and conglomerate natural rock forms without cave, 3 - Lower Paleozoic, 4 - Devonian and Carboniferous, 5 - Permian and Lower Triassic, 6 - Middle and Upper Triassic, 7 - Lower Jurassic, 8 - Middle and Upper Jurassic, 9 - Cretaceous, 10 - Paleogene and Neogene. The rock forms and caves commented in the text: Ls - Lysica Mt., Mg - Miejska Gora, Pd - Pieklo Dalejowskie, Pg - Pieklo-Gatniki, Pn - Pieklo pod Nieklaniem, Rj - Rejow.

The pseudokarst caves of this region were predominantly formed in the sandstones and quartzitic sandstones. In the lithostratigraphic sequence the quartzitic sandstones form thick formations (ranging several hundreds metres) in the Upper Cambrian and Lower Devonian, whereas sandstones with conglomerate inserts predominate in the Lower Triassic and Lower Jurassic series, which are also several hundreds metres thick, each.

The caves are principally connected with natural rock forms. Some 20 natural rock forms built of the Paleozoic siliciclastic rocks, ca 25 rock forms and groups of rock forms built of the Lower Triassic sandstones and 15 groups and single rock forms built of the Lower

Jurassic sandstones (conglomerates) are situated in the region (Fig. 1). The rock forms represent structural, ridge and side-ridge landforms genetically connected with gravitational slope processes developed mainly under the periglacial conditions, during the last Pleistocene glaciations, as well as aeolian and erosional processes (Alexandrowicz, Urban 2005)

General data on the caves

46 caves of summarised length 254 m, formed in siliciclastic rocks, have been found in the Swietokrzyskie Mts., up till now. Some of them were discovered even in this year, so their number seems not to be the ultimate one. Most of them occur in the Lower Triassic sandstones - 24 caves of total length 134 m. 14 caves (67 m) are formed in the Lower Jurassic siliciclastics, 6 ones (47 m) - in the Lower Devonian rocks and 2 ones (6 m) - in the Upper Cambrian formation. The distribution of caves in the rock forms (groups) is quite irregular. There are crags (groups) without any caves, whereas in other ones several caves have been found. The highest number - 8 caves - have been registered in the Pieklo Dalejowskie rock group (Fig. 1).

Almost half of the total number of caves represent very small, short forms: cavities and rock shelters less than 5 m. Only 3 caves are longer than 10 m, the longest is the Jaskinia Ponurego cave, 25 m long and formed in the Devonian sandstones. Despite small sizes, the caves represent several groups differing in spatial position, shape, microrelief and sediments. These variability are generated by different origin, age and evolution of the caves.

Examples of genetic types of the caves

Most of the caves represent genetically complex type, formed owing to the combination of processes. But among them characteristic genetic examples, accurately presenting the activity of specific geomorphic factors can be find. Several examples are presented hereafter.

Pieklo pod Nieklaniem group of rock forms

This rock group is formed of the Lower Jurassic sandstones and composed of three clusters of crags situated in the marginal part of the extensive hill (Lindner 1972, Urban 2005, Urban, Gagol 2008). Within the western cluster of crags, consisted of the side-ridge forms 5-8 m high of very spectacular shape (pulpits, bars and mushroom-like forms), two fissure-type caves (according to Vitek's, 1983, classification) occur (Fig. 2). The first cave - Jama Agi (Agnes Hole) - is a passage 8 m long, developed along the joints. It is high near the two entrances, but gets narrow in the short distance, ending with small chamber developed on the transversal joint. The second one - Tomkowa Dziura (Thomas Hole - 8 m) - is composed of the three chambers developed along the joints. Both caves are characterised by smooth, slightly concave walls with furrows formed only in places of joints outlets (Fig. 2). The floors of the caves are partly covered with sand blankets and dip toward the entrances.

The shape of the cave passages, dip of their floors, traces of water drops and flows on the bottoms, as well as lack of the gravitational movements of the rock blocks (forms) along the joints prove, that both caves were produced by the subsurface water circulation within the rock massif. The slow diffusion of capillary water causes selective disintegration of the sandstone, e.g. near the joint surfaces, whereas faster, gravitational infiltration of meteoric water (during heavy rains or snow thawing) down the joints is responsible for the erosion of the weakened rock and transport of loose sand grains out of the rock massif. This predominating process has been accompanied by gravitational collapses of rock particles and sand grains in the previously formed caverns (Urban 2005).

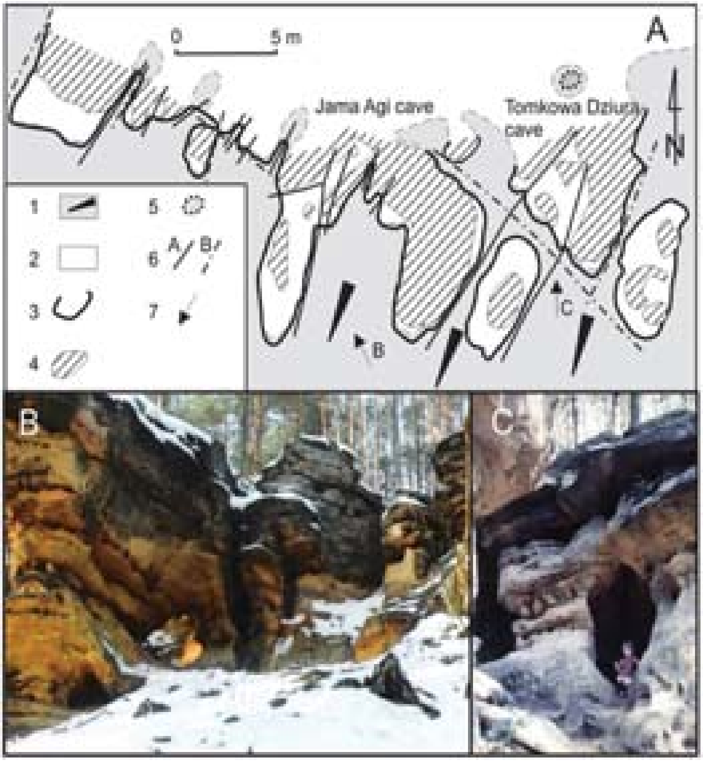


Fig. 2. The caves of Jama Agi nad Tomkowa Dziura in Pieklo pod Nieklaniem group of rock forms: A - map of the west part of rock group with the caves (after Urban 2005), B - entrances of the Jama Agi cave, C - entrances of the Tomkowa Dziura cave. Explanations of signatures on the map (A): 1 - slope (inclined ground surface with the direction of dip), 2 - plateau (horizontal ground surface), 3 - maximum contour of the rock forms (in the upper part of forms), 4 - minimum contour of the rock forms (in the lower part of forms), 5 - pseudokarst pothole, 6 - joints A - observed, B - probable, 7 - direction of photos B and C.

Pieklo Dalejowskie group of rock forms

Pieklo Dalejowskie is a group of the rock forms built of the Lower Triassic sandstones. The crags represent table-like forms and cliffs situated on the slope of plateau elevated ca 10 m above the valley (Fig. 3). Most of the cliffs are margins of the stable (in situ) rock massif, whereas table-like forms represent blocks moved downslope on the sandy-debris slope sediments. The principal type of the shift was creep similar to the lateral spreading (see Dikau et al. 1996). This process was presumably connected with the periglacial solifluction during the last, Late Pleistocene glaciation. It is suggested by relatively slight dip (less than 10°) of the slope, too less for the efficient slide in current climatic conditions.

Among 8 small caves located in this rock group at least two genetic types can be distinguished. The first type is represented by the crevice type caves (according to Vitek's, 1983, classification), formed due to the separation and displacement of blocks. The best example of this group is Rajska Brama (Paradise Gate), which is the gallery 4,5 m long, separating two large rock slabs and covered by the upper bed (layer) of the sandstone of one slab (Fig. 3A, C). The second cave of this type shown is Schronisko z Koscia (Shelter with the Bone) - a narrow, curvilinear fissure 4 m long, dissecting the rock massif in its marginal part (Fig. 3A). These two caves differ in the state and time of formation (block movements). The first one was produced by the relatively extensive displacement of blocks during the main phase of the gravitational movements, thus in the Late Pleistocene. The second cave developed owing to the propagation of joint in the stable (in situ) massif and its widening subsequent to the movements of the large blocks, probably in the Holocene.

Other caves in the eastern part of the rock group: Grzybowa Dziura (Mushroom Hole - 5,5 m) and Piwnica Zamkowa (Castle Cellar - 4 m) shown on Fig. 3, were initiated probably

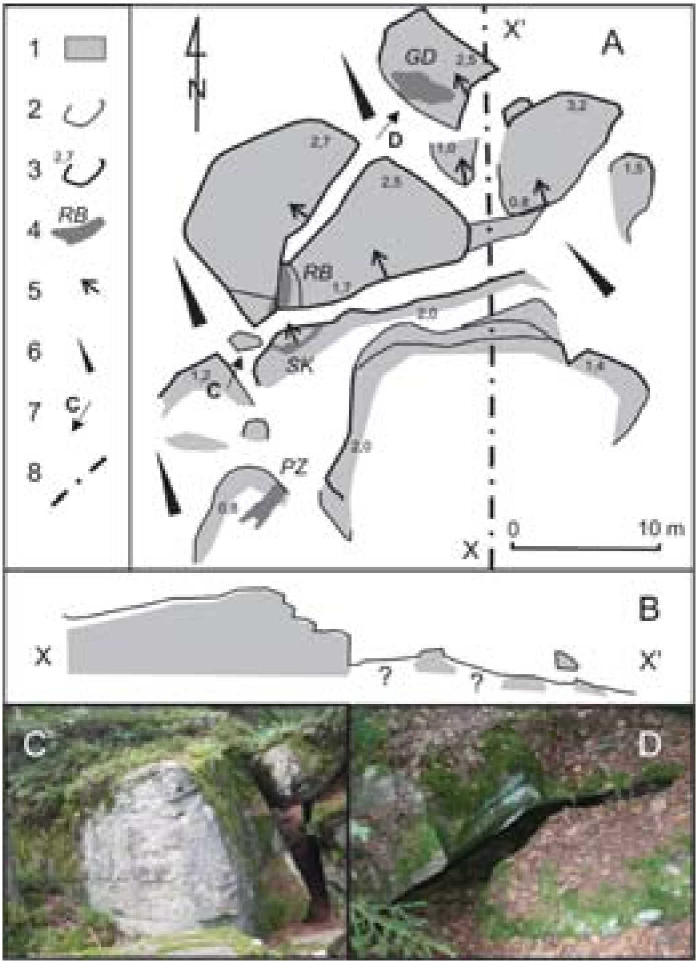


Fig. 3. The caves of the eastern part of the Pieklo Dalejowskie group of rock forms: A - map of the eastern part of the Pieklo Dalejowskie group of rock forms. B - cross-section of the slope and rock forms (X-X'), C - south entrance of the Rajska Brama cave and the block forming its western wall, D - entrance of the Grzybowa Dziura cave. Explanations of signatures on the map (A) and cross-section (B): 1 - rock form; 2 - contour of rock form lower than 1 m; 3 - contour of rock form higher than 1 m with the hight; 4 - cave with the abbreviation of its name: GD - Grzybowa Dziura, PZ - Piwnica Zamkowa, RB - Rajska Brama, SK - Schronisko z Koscia; 5 - possible movement of rock form (block); 6 - direction of slope dip; 7 - direction of photos C and D, 8 - cross-section X-X'.

due to different rate of the creep of rock blocks and sand (sand-debris) basement during the Late Pleistocene, resulting in formation of narrow cavities (zones of loosened sands). But these cavities must have been widened by animal and/or human activity in the (Holocene). Currently the large systems of burrows are produced by fox under many similar rocks slabs in the region. The abandoned systems of zoogenic hollows could have been enlarged in the entrance parts (thus accessible for people) by pluvial or other erosional processes.

Rejow group of rock forms

The rock group consists of cliffs (rock walls), small pulpits, rock blocks and large table-like form, which are built of the Lower Triassic sandstone and situated on the relatively high (ca 20 m) and steep slope. Among two caves located in this group, one - Schronisko pod Osiedlem (Shelter under the Housing Estate, 5 m long) - gives very interesting evidences on the evolution of the slope. It consists of the short and low (lenticular in cross-section) entrance gallery and transversal passage formed along the joint parallel to the slope extension (Fig. 4). The both walls of this passage form a wedge thinning upward (Fig. 4C). The passage accessible for people is rather short but connected with long network of fissures, as proved by air circulation in the cave during winter (Fig. 4).

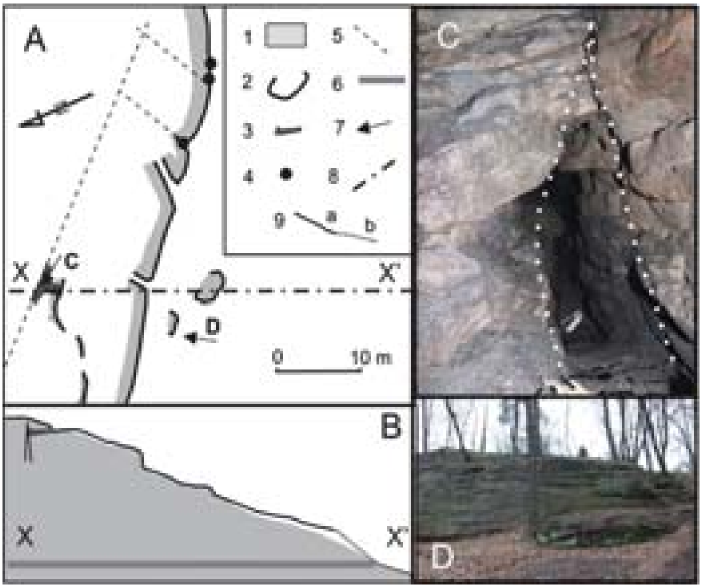


Fig. 4. Southern part of the Rejow group of rock forms: A - map of the southern part of the group of rock forms with location of the Schronisko pod Osiedlem cave; B - cross-section of the slope, cave and rock forms (X-X'); C - northern passage of the Schronisko pod Osiedlem cave (the wedge shape of the passage is marked by white dotted line); D - the rock wall below the cave and the place of the cave location marked by the man above the wall. Explanations of signatures on the map (A) and cross-section (B): 1 - rock form; 2 - contour of rock form; 3 - Schronisko pod Osiedlem cave; 4 - supposed openings of air circulation conduits 5 - hypothetic fissure network driving the air circulation; 6 - location of the clayey insert in the geological sequence; 7 - direction of photos C and D, 8 - cross-section X-X', 9 - ground surface (on the cross-section): a - natural, b - artificial (antropogenic).

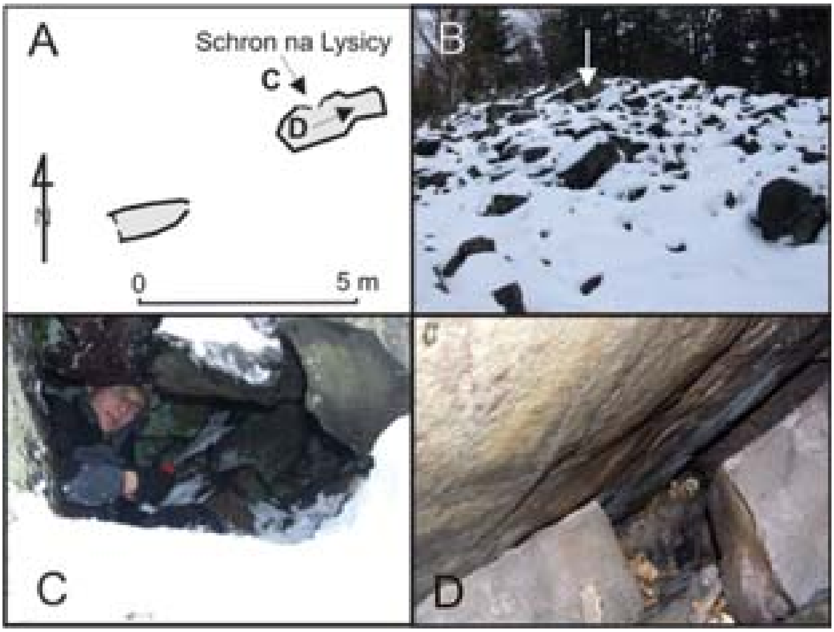
The wedge shape of the fissure parallel to the slope and long system of fissures within the massif suggest that the cave represents the accessible part of the fissure network, which was widened due to the small but apparent rotational slide (see Dikau et al. 1996) of rock blocks. This movement could have been facilitated by sliding along the clayey insert occurring in the lower part of the slope (cropped out there).

Lysica Mount

Lysica Mt. (612 m a.s.l.) is the highest culmination of the Lysogory Range, built of the Upper Cambrian quartzitic sandstones (also the highest summit of the region). The summit of Lysica Mt. is covered by block field, formed of angular rock blocks of the size ranging from several tens of centimetres to 2 m (Fig. 5A). The block fields of the Lysogory Range developed in the periglacial environment of the Late Pleistocene, due to the mechanical weathering and subsequent solifluction and pluvial erosion of the fine material (Klatka 1962).

Recently, several cavities have been noticed among the blocks. One of them, situated under one of the largest blocks, several metres far from the summit of Lysica Mt, reach the length 2 m, thus it is large enough to call them the cave of Schron na Lysicy (Shelter in Lysica). The second cavity situated nearby is too small to call it cave but, anyway, worthy to show it on the map (Fig. 5A), so as to illustrate that the movement of the blocks in the solifluction cover was not quite random, since the cavities are elongated in the same direction. Both the cavities represent the talus type according to Vitek's (1983) classification, although they differ from the typical talus type caves connected with landslide colluvia (as in the Carpathians - see Urban, Margielewski 2003), in the

Fig. 5. Schron na Lysicy cave: A - map of the cave and neighbouring cavity with the directions of the photos C and D (arrows); B - rock field on the summit of Lysica Mt. with location of the cave (white arrow);
C - entrance of the cave, D - NE part of the cave.



character of movements and age, because the transport of blocks in the weathering cover was probably slow and took place in the Late Pleistocene.

Pieklo-Gatniki group of rock forms

Fig. 6. Czarcie Wrota cave: A - entrance of the cave in the front wall of the rock block (marked with white dashed line); B - cross-section of the cave (white dashed line) on the background of the block, the probable movement of the block (toppling) marked with the white arrow).

The rock group is formed of the Lower Jurassic sandstones and represented by several table-like forms, cliffs and large block (ex situ), which are situated on the slopes of small, but relatively high ridge. The characteristic, although small cave located in this group - Czarcie Wrota (Devil Gate - 2 m) was formed owing to the complete toppling (see Dikau et al. 1996) of the large block, in a concave part of its face (Fig. 6). Thus, it represents specific, very simple talus type cave according to Vitek's (1983) classification.

Miejska Gora group of rock forms

The rock group is built of the Lower Devonian quartzitic sandstones and situated on the northern, steep slope of the Miejska Gora Mt. It is composed of mainly table-like slabs separated with joints, which were often widened owing to the gravitational displacement of blocks (Fig. 7). Most probably the main movements of the blocks took place under the periglacial conditions of the Late Pleistocene, when the slope processes (solifluction etc.) were significant geomorphic factors, as suggested by blocks ex situ situated several tens metres downslope. Three caves have been described in this rock group. One of them - Szczelina Bodzentynska (Fissure of Bodzentyn Town - 5 m) can be interpreted as a combined type cave. The southern passage of this cave was formed due to the translational movement of the lower slab (translational rock slide - see Dickau et al. 1996) (Fig. 7C), and according to the classification of Vitek (1983) it represents crevice type cave. But the south-western part of the cave is formed owing to the weathering recession of the rock walls with no movement of blocks (Fig. 7D). And this part of the cave can be called fissure type cave, according to Vitek's (1983) classification. Thus both parts of the cave formed owing to quite different processes.

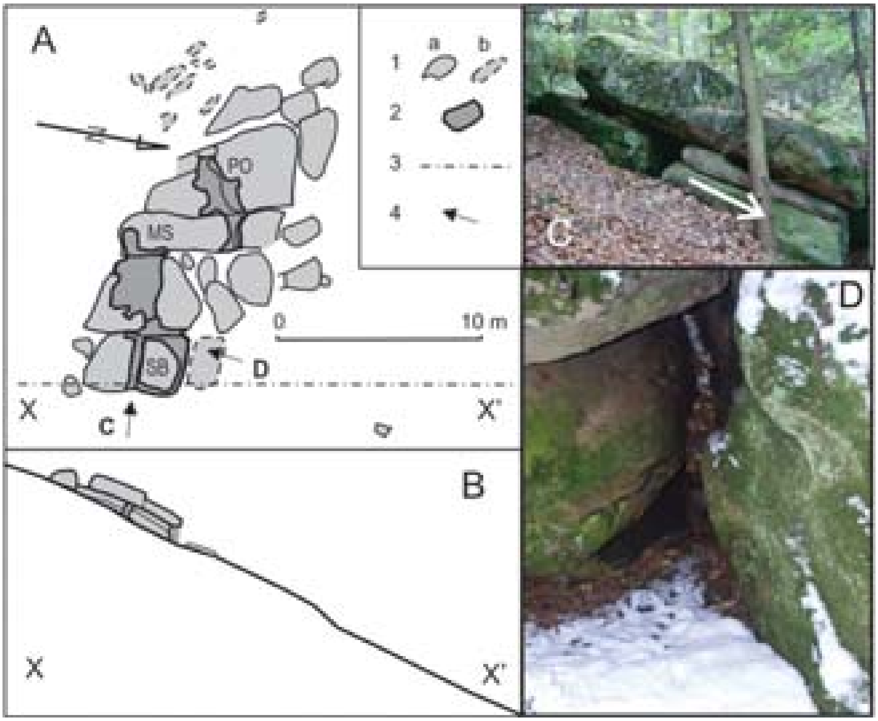


Fig. 7. Miejska Szczelina cave and other caves in the Miejska Gora group of rock forms: A - map of the group of rock forms and caves: Szczelina Bodzentyñska (SB), Miejski Schron (MS) and Podgorski Okap (PO); B - cross section of the slope and rock group (X-X'); C - eastern entrance and passage of the Szczelina Bodzentyñska cave, movement of the rock blocks marked with white arrow; D - northern entrance of the Szczelina Bodzentyñska. Explanations of the signatures on the map (A) and cross-section (B): 1 - rock forms: a - higher than 1 m, b - lower than 1 m, 2 - caves, 3 - directions of photos C and D, 4 - cross-section X-X'.

Discussion

The examples shown above accurate and clearly illustrate the diversity of forms and their origin. Most of the caves formed owing to the combination of weathering, erosional and gravitational processes (the discussed above example of the Szczelina Bodzentynska cave), but the predomination of one-two genetic processes and rock environments favourable for their development can be usually identified and defined.

The principal processes responsible for the development of numerous caves in the sandstones/conglomerates of the Swietokrzyskie Mts. are various gravitational movements of the hard rock blocks, as follow:

- translational slide or lateral spreading - e.g. Rajska Brama cave and part of the Szczelina Bodzentynska cave;
- toppling (forward rotation) - e.g. Czarcie Wrota cave;
- backward rotation (in the course opposite to the slope dip) - e.g. Schron pod Osiedlem cave, probably also Schronisko z Koscia cave;
- combination of slow creep of slope sediments, as solifluction and other processes as pluvial washout -. e.g. Schron na Lysicy cave.

The character, reasons and age of these gravitational movements are different. Most of them developed on the gentle slopes (as in the Pieklo Dalejowskie site) were connected with the processes active under the periglacial environments during the last glacial period. Thus the Rajska Brama cave represent the Late Pleistocene, relic form. Also the cavities in Lysica Mt should be accounted to the relict forms, initiated by the mechanical weathering and slope-gravitational processes of the Late Pleistocene and subsequently cleaned by pluvial processes. In turn, gravitational processes on the steep slopes (Rejow and Pieklo Gatniki sites) could have been active also in the Holocene.

Very interesting and not sufficiently interpreted group of forms are relatively numerous cavities formed under the large ex situ blocks, as Grzybowa Dziura and Piwnica Zamkowa caves (Pieklo Dalejowskie). As stated above, they could have been produced by different rate of the solifluction movement of large blocks and fine-grained, sandy (sandy-debris) material of their basement under the periglacial conditions of the Late Pleistocene and then, in the Holocene widened by animal or human activity.

The caves produced predominantly by current (Holocene) subsurface water erosion - as Jama Agi and Tomkowa Dziura caves in the Pieklo pod Nieklaniem site - are rare in the region. But pluvial and subsurface water erosion (washout) is often one of several factors participating in the formation and current (Holocene) evolution of caves (cavities). The effects of these processes are observed in the rocks forms of the relatively "soft" Lower Jurassic sandstones, rarely in the Lower Triassic and Lower Devonian rocks forms, never - in the Lower Cambrian "quartzites". Mechanical weathering followed by gravitational movements of the loose (weathered) material are other processes contributing to the cave development, currently.

Conclusions

The pseudokarst caves in the sandstones and quartzitic sandstones of the Swietokrzyskie Mts. are connected with the rock forms, but represent various genetic types. Although the set of processes has contributed to their development and evolution, the predominant factors can be often identified. Among several factors responsible for their development, the slope-gravitational movements of different character (rotational and translational slide, lateral spreading, toppling) and age have played important role.

They were especially active - as sand-debris solifluction and creep of blocks - under the periglacial conditions of the Late Pleistocene glacial period. Therefore numerous caves should be regarded as relic, Late Pleistocene forms, currently modified by weathering and pluvial processes. But there are also caves formed predominantly by subsurface water erosion accompanied by weathering and gravitational processes in the Holocene (currently).

The study of the genetic types of caves enables identification of processes responsible for the stripping and shaping of the rocks forms (groups of forms). It suggests that most of them were stripped during the cold climate of the Late Pleistocene glaciation, owing to the slope-gravitational processes. But in some cases the gravitational processes have been still active. In the Holocene, the shape of rock forms has been modified in various scale, depending on the lithologic character of rocks and local conditions. The main factors of this modification are water (pluvial) erosion and weathering.

Acknowledgements

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PSEUDOKARSTIC CAVITIES IN PYROCLASTIC ROCKS: SOME EXAMPLES FROM NORTH SARDINIA

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Abstract - This paper reports on some small pseudokarstic features occurring in Tertiary pyroclastic rocks outcropping in Sardinia. The cave of Su Niarzu (Bultei, Northern Sardinia) is the best example of this pseudokarst, but other smaller tube-like features have been noted in the same area, all between 10-20 m above the present altitude of the small streamlet Riu Cugadu.

A detailed morphological and minero-petrographical study has been carried out to unveil the genesis of these peculiar pseudokarst morphologies. Su Niarzu cave seems to have formed through physical and chemical weathering of the tufaceous rock and subsequent piping phenomena. A speleogenetic model for these pyroclastic caves and their relative dating is given in this paper.

Key Words: Pseudokarst, cave, pyroclastic rocks, piping, opal speleothems

Riassunto - Questo lavoro descrive alcune piccole forme pseudocarsiche in rocce terziarie piroclastiche in Sardegna. La grotta di Su Niarzu (Bultei, Nord Sardegna) è l'esempio più significativo di questo pseudocarsismo, ma altre più piccole morfologie a forma di tubo sono state trovate nella stessa area, tutte più o meno ad un'altezza di 10-20 metri sopra l'alveo del piccolo torrente Riu Cugadu.

E' stato condotto uno studio geomorfologico e mineralogico-petrografico di dettaglio per cercare di svelare la genesi di queste curiose morfologie pseudocarsiche. La grotta di Su Niarzu sembra essersi formata in seguito all'alterazione fisica e chimica della roccia tufacea e successivi fenomeni di piping. Viene avanzato un modello speleogenetico di queste piccole grotte pseudocarsiche ed una loro relativa datazione.

Parole chiavi: Pseudocarsismo, grotta, rocce piroclastiche, piping, speleotemi di opale

Summary

This study presents the research results on some small pseudokarstic features occurring in Tertiary volcanic products outcropping in North Sardinia. The cave of Su Niarzu (Bultei) is the main focus of this study. This 10 meter long and 1 meter wide tunnel is developed in tuff-like rock rich in pumice fragments and volcanic ash deposits interbedded in more resistant strongly welded ignimbritic rocks of Oligo-Miocene age. Other smaller tube-like features have been noted in the same area, all between 10-20 m above today's small brook bed

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of Riu Cugadu.

The volcanic sequence that hosts the pseudokarstic morphologies includes the manifestations of orogenic magmatism with rhyodacitic ignimbrites forming thick deposits and large plateaux, mainly filling the Sardinian Rift system. The siliceous rock hosting the caves is slightly weathered showing partially chlorite alteration of biotite, post-depositional weathering of pumiceous fragments by percolated fluids and relatively fresh zoned plagioclase crystals. Small mm-sized coralloid speleothems have been found and sampled close to the entrance of the cave and detailed mineralogical analysis has shown that these are formed of sub-amorphous silicate hydrates (opal-A) sometimes embedding small fragments of volcanic rock and minerals.

Pyroclastic materials are not favourable for the development of cave systems, but some have been reported in relatively small areas in Greece, Argentina, the United States of America, Czech Republic, Slovac Republic, Hungary, Japan and Kenya, although they must be present in many other areas. The most studied examples are the caves of Mount Elgon, in Kenya, formed by a combination of many processes such as groundwater sapping, chemical and physical weathering, breakdown and geophagy by elephants.

The origin of Su Niarzu cave and the other surrounding morphologies seems to be related to physical and chemical alteration-induced weathering of the ignimbritic bedrock and subsequent subsurface mechanical erosion by flowing water. These morphologies can thus be classified as piping pseudokarst. Their genesis can probably be explained by a relative still stand of the brook, now flowing 10-20 meters below the entrance of the cave, before it excavated its bed. Working with very rough estimates, assuming an average erosion rate of 2-3 mm/year, the caves have presumably been developed during Holocene.

INTRODUCTION

Karst in Sardinia is widely known and the Island's subterranean treasures have been visited by cavers from all over Europe. Although karst areas occupy only about 9% of the Island's surface (De Waele, 2003) several areas extend over hundreds of square kilometres and host among the most extensive cave systems of Italy (De Waele, 1997). Besides caves in carbonate rocks - the vast majority - there are some, generally small, caves hosted in rocks other than limestone and dolostone. The most important of these are cavities formed in volcanic rocks (De Waele & Muntoni, 1999).

Only a small number of caves has been found in the Oligo-Miocene basic volcanic rocks, while larger numbers are hosted in the acid-intermediate lavas of the same age, most of which of secondary origin and created by wind or water erosion. These pyroclastic rocks, mostly characterised by scarcely consolidated ignimbrites, present various erosion cavities especially in Central-Sardinia, but also in the SW (Monte Su Crobu, Carbonia, Sulcis), or great fractures successively eroded by the sea wave motion (Capo Marargiu-Bosa, Island of San Pietro). Some of these caves, as for example the Cave of the Pelicans (Bosa), show a significant development and are well decorated by calcite concretions, due to a Miocene limestone covering the volcanic rocks (Piras, 2007). The great wind-erosion caves (tafoni) of Central-Sardinia are normally used by the shepherds and can also represent archaeological interest. At Montresta, Villaperuccio and Bonorva vast underground settlements or necropolis formed by both natural and artificial caves in rhyolites, ignimbrites and other poorly cemented volcanic rocks are documented.

Also Plio-Pleistocene lavas are very abundant, and some lava tubes and bubble or pneumatogenic caves are known. Good examples are described from Nurri and from Cuglieri.

For a detailed description of these the reader is referred to the proceedings CD of the IXth Congress on Vulcanospeleology, held in 1999 in Catania (De Waele & Muntoni, 1999).

In 1999 cavers of the Gruppo Speleo Ambientale of Sassari discovered and surveyed a small cave in pyroclastic rocks (volcanic tuff) near Bultei (N-Sardinia) (Sanna & Bandiera, 2000). The morphology is different from most caves in the same host rock, and a detailed analysis has been carried out to understand its genesis.

Caves in volcanic tuffs are rather infrequent to find and have been reported only in a few areas such as Greece (Ramage et al., 2003), Argentina (Villarosa et al., 2006), the United States of America (Halliday, 2004, 2007), Czech and Slovac Republics (Bella & Gaal, 2006; Bella et al., 2004; Eszterhàs et al., 1996; Gaal, 2003; Vitek, 1983, 1989), Hungary (Eszterhàs & Szentes, 2004), Japan (Bella & Gaal, 2006; Bella et al., 2005; Gaal et al., 2004) and Kenya (Lundberg & McFarlane, 2006; Simons, 1998), although they must be present in many other areas of the world. The caves of Mount Elgon, in Kenya, are the most studied examples of pyroclastic caves. Their genesis is explained by a combination of many processes such as groundwater sapping, chemical and physical weathering, breakdown and geophagy by elephants. Also the caves of the Nagatani Valley (Japan) are hosted in volcaniclastic rocks, and their origin is explained by suffusion processes (Bella et al., 2005). In this paper the Su Niarzu cave is analysed and a hypothesis of its origin is formulated.

GEOGRAPHICAL AND GEOLOGICAL OUTLINE

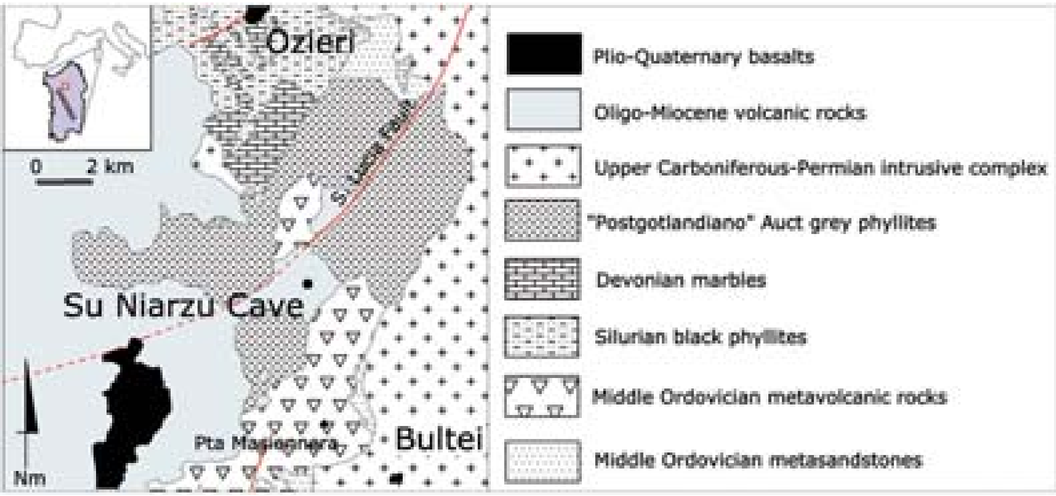

Fig. 1 – Geological sketch map of the area between Ozieri and Bultei (North-Sardinia) and location of the Su Niarzu area (based on Oggiano, 1994)

Volcanic rocks of the calco-alcaline cycle (Oligo-Miocene, ca. 32-14 Ma) crop out along the Tertiary Rift of Sardinia that crosses the Western part of the Island from South (Cagliari) to North (Sassari-Porto Torres). South of Sassari the landscape is characterised by volcanic plateaus some hundreds of meters thick and tilting northwestwards, that cover a Palaeozoic basement complex composed of phyllites, marbles, metavolcanic rocks and granites (Oggiano, 1994) (Fig. 1). This acid volcanism is linked to the Cainozoic geodynamic evolution of the western Mediterranean and the volcanic succession is composed of a sequence of dacitic to rhyolitic lava flows, ignimbrites and pyroclastic tuffs in which two ignimbritic

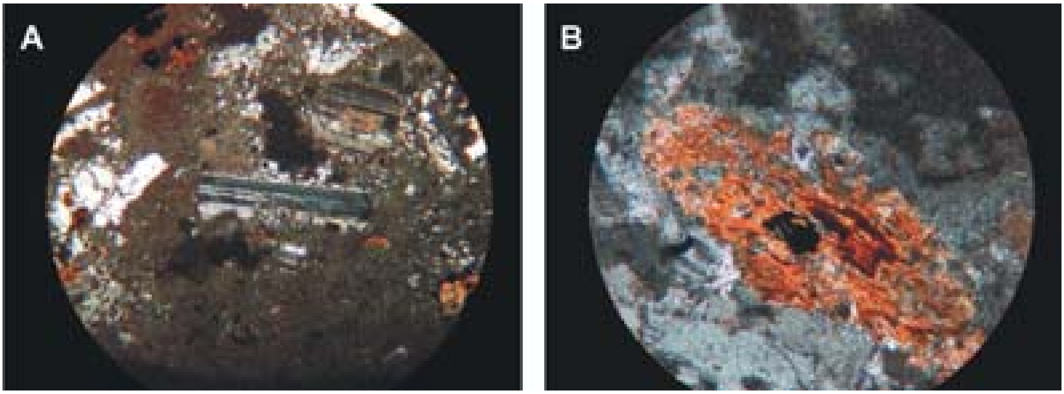

Fig. 2 – Polarised microscope images of the host rock in crossed nicols: A. geminated plagioclase crystal in a cryptocrystalline matrix (Ø image 5.7 mm); B. Biotite crystal with clear sign of weathering to Chlorite (Ø image 0.9 mm).

episodes with different degrees of welding and separated by an epiclastic layers have been identified (Cerri & Oggiano, 2002). The main regionale structures are NE-trending transcurrent faults in association with extensive fracturing in which hydrothermal fluids have circulated (Santa Lucia Fault).

The Su Niarzu cave and smaller pseudokarstic features are located in the Goceano region close to Bultei, on the NW facing slope of an ignimbritic-volcanic tuff hill on which the more than 2,000 year old Nuraghe Chiricuzzu is built. The entrance of the cave is hidden in the vegetation on the left side of a small brook, approximately 15 m above the thalweg.

The lower ignimbritic subunit in which all pseudokarstic morphologies are formed is a brown to purple eutaxitic pumice and ash flow deposit of rhyolitic composition with with different degrees of welding and cooling junctions. In optical thin section zoned sodium plagioclase phenocrystals enclosed in a cryptocrystalline to glassy groundmass prevail on sparse individual crystals of sanidine, quartz, chloritised biotite and seldom small crystals of amphiboles and epidote (variety piemontite) (Fig. 2). X-ray diffractograms have confirmed the presence of all these minerals in the host rock and have also shown the presence of tridymite and crystobalite, two high-temperature polymorphs of quartz. A porous tuff bed is intercalated in a succession of massive densely welded ignimbritic rocks which constitute an impermeable layer.

THE PSEUDOKARST FEATURES

Fig. 3 – Plan and longitudinal profile of Su Niarzu cave.

The Niarzu cave

Su Niarzu cave is a 10 m long and 1 m low tunnel developed in a homogeneous poorly welded tuff bed along a NW-SE fracture clearly visible on its roof (Fig. 3). The tufaceous layer, composed of soft and readily erodible volcanic ash containing abundant altered pumice fragments, is interbedded between vitreous and harder ignimbrite flows. The tunnel has an ascendant profile and the cross-section diminishes progressively becoming too straight at 10 m from the entrance, where floor and ceiling are composed of welded ignimbrites. The cave shows strong structural and stratigraphic controls. The typical morphology is that of a tunnel with flat bottom, occupied by earthy material such as saprolite, and a rounded roof (Fig. 4). There are no signs of past or present water flow and related erosion forms, though the shape of the conduit reminds that of a piping passage.

Fig. 4 – Su Niarzu cave: A. entrance; B. looking towards the squeezing end of the cave; C. the rounded cross-section of the tunnel.

Other features

Fig. 5 – Small pipes in the pyroclastic rocks close to Su Niarzu cave.

Su Niarzu is not the only example of pseudokarst in the neighbourhood. In the same area several smaller tube-like features have been found, but all of these are too small to be entered by man. Subhorizontal conduits with elliptical cross-section and descending trend, up to 3 m long and with diameter of two decimetres occur along Riu Cugadu's gentle slopes. Some examples of these morphologies are shown in Figure 5. Their position is similar to the Su Niarzu cave, hosted in the pyroclastic tuff and more or less at the same height above the streamlet. It appears that the genesis of all these features is related both to lithology and to altimetric position.

Speleothems

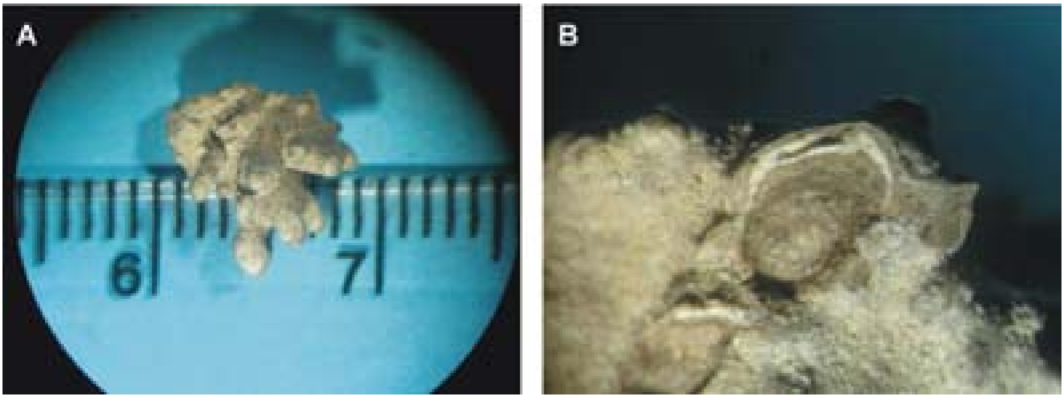

Fig. 6 – The opal-A coralloid (popcorn) speleothems: A. Normal view; B. Cross-section clearly showing whitish-brownish banding.

The Su Niarzu cave is characterised by bare walls composed of partially weathered volcanic tuff, but close to the entrance, where condensation water can deposit especially in periods with high daily temperature intervals, small popcorn-like speleothems have developed on the walls. These occur as millimetre-sized protuberances, similar to miniature cauliflower (Fig. 6). Thin section analysis of these formations have shown clear thin whitish-brownish multi-layers of amorphous material around a nucleus sometimes composed of a fragment of host rock. X-ray diffraction has shown the bands to be composed of Opal-A, the most common uncrystallised form of autigenic silica. Su Niarzu speleothems derive from the precipitation of amorphous silica previously slowly dissolved from pyrogenic phases by the water films percolating through the volcanic tuff rock. For understanding the growth of these speleothems, the dissolution of silica has to be taken into account. At room temperature the rate of quartz dissolution is extremely slow (about 10 mg/L) and approximately constant at pH values below 9 (Dove & Rimstidt, 1994). The solubility of other silicate minerals is higher than quartz and seasonal condensation-evaporation processes lead to SiO2 saturated water above the solubility limit of quartz, inducing opal precipitation in several layers. On the walls near the cave entrance of Su Niarzu, silica oversaturation might be due to the presence of silicate minerals like mica, feldspar and chlorite in the pyroclastic bedrock. Although opal speleothems have been reported from many countries (Hill & Forti, 1997) and some other silicates have relatively fast dissolution rates, they remain rare compared to carbonate minerals.

Morphogenesis

Local people, observing only the entrance of the cave, believed the cave was excavated by ancient populations known to have dug subterranean tombs (so-called domus de janas, or fairy houses) in the neighbourhood in similar rock types (Fig. 7). The morphology of the cave, instead, shows it to be a small ascending tunnel becoming almost horizontal after 5 metres and squeezing towards the end where penetration is no longer possible, thus excluding the tomb hypothesis. There is also no evidence whatsoever to sustain the tree-mold hypothesis, difficult to extend to the minor tunnels. The fact that the cave and the smaller pseudokarstic features are all hosted in the softer volcanic tuffs and do not develop in the hard ignimbrite rocks suggests that they have formed through physical and chemical weathering of the hosting rock. Su Niarzu conduits seem to have been developed directly along a friable and more altered level constrained by impermeable well-welded ignimbrite and the cave passage direction is determined by the intersection between sub-vertical cooling fractures and bedding planes in which flowing water was able to penetrate. The further observation that they are aligned at a certain altitude, about 15 metres above the present streamlet, makes the hypothesis that piping phenomena have played an important role very appealing (Fig. 8). The described morphologies can thus be classified as piping pseudokarst. This process is a subsurface erosion and consists of mechanical grain removal of particles by moving of groundwater, starting to form at the water-substrate interface and then propagating upstream along channels which become straighter the further away from the entrance (Martini, 2000). Piping speleogenesis in the Su Niarzu area can be interpreted as a two-stage process, similar from other caves hosted in silicate rocks (Correa Neto, 2000). In the first stage, the base level of Riu Cugadu streamlet was stable with low gradient at the altitude of the present cave entrance, favouring silica dissolution and alteration of pumice fragments and biotite crystals affecting essentially the mass of the less welded pyroclastic layer, specifically susceptible to hydrolysis. The initial softening of the pyroclastic rock by hydrothermal alteration along the Santa Lucia Fault, which allowed the rising of deep mineral water, is not to be completely excluded. The presence of piemontite in the host rock could in fact testify an hydrothermal activity. This red variety of epidote can be a low temperature alteration product of feldspars, especially on plagioclase, a phenomenon called saussuritization (King, 1993). During the second stage increase of the phreatic gradient due to lowering local base level converge sapping water flow along linear zones of cooling junctions and fractures. Cylindrical tubes are

Fig. 7 – "Domus de janas of Sas Concheddas" excavated by ancient populations in pyroclastic rocks not far from Su Niarzu cave.

created and enlarged by mechanical removing of the mineral grains. The presence in host rock of mica and feldspars with relative higher solubility also contribute to the increase of weathering of unwelded ignimbrite into a soft saprolite and to weaken the rock allowing extensive piping. The application of this model to pyroclastic caves from Goceano region is based of features such as tube levels, squeezing of section conduits and silica speleothems. If their genesis can be correlated to the streamlet flowing 15 meters below before it excavated its bed, than a rough estimate of the age of their formation can be ventured. In fact, although there has been no absolute age determination of erosion rate in the study area, assuming an average erosion rate of 3 mm/year, similar to recent findings of Northern Corsica (Fellin et al., 2005), the caves could have formed 5,000 years ago. In Sardinia, where rainfall is slightly lower than in Corsica, erosion rate could be slightly lower, but the cave has most probably formed during Holocene (last 10,000 years).

Fig. 8 – Riu Cugadu brook and location of Su Niarzu cave and smaller pseudokarstic pipes. (Footnotes)

Conclusions

The detailed geomorphological study of the Su Niarzu cave and its surroundings combined with a petrographical and mineralogical study of both the host rock and small popcorn-like speleothems sampled near the entrance has allowed to reconstruct the genesis of these pseudokarst features. The cave and the other smaller tunnels, all formed in pyroclastic tuffs associated with an incipient and pervasive alteration of pyroclastic rock between 10-20 metres above the small brook flowing in the valley below, are not directly created by dissolution, but have been formed by piping after preliminary weathering of the rock, along joints and cooling planes in the borders of the brook at a time before incision of the small valley. For such process the term “piping pseudokarst” is applied. If cave levels are used as an evolution and age indicator, estimating an incision rate of 2-3 mm/year, their genesis would have happened less than 10,000 years ago, giving thus a Holocene age to the features and the cave. The pyroclastite caves from Goceano region have been formed by a sequence of processes involving initial silica dissolution, increase in porosity, pipe formation, conduit enlargement due to mechanical erosion by flowing water and silica dissolution-precipitation cycles with opal speleothem deposition on the cave walls near the entrance. Silica speleothems also make Su Niarzu cave very significant, especially as it is, up to now, the only example of piping pseudokarst in Sardinia.

Acknowledgements

We are grateful to Franco Bandiera of the cave association “Gruppo Speleo Ambientale Sassari” and Graziano Dore for supporting the research in 1999. We would also like to thank Stefano Andreucci and Laura Dotti for their help during field work and Guido Cerri for his constructive discussions.

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PSEUDOKARST IN SANDSTONES OF THE LENINGRAD REGION

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Abstract - A number of pseudokarst caves have developed in the Cambrian and Devonian sandstones of the Leningrad Region owing mainly to such processes as erosion, piping, and gravitational mass movements. Hidden pseudokarst caves can be formed in fractured sandstones by way of filtration of underground waters near their outlet on the surface as springs. It should be taken into consideration if building is planned. Pseudokarst caves represent geological heritage sites and they need to be protected. In the modern conditions in Russia, the main conception of geosite protection is organization of nature-protecting excursion-tourist centres. Necessary facilities and geosite protection are provided, using benefits from a regulated tourist activity. State nature conservative or speleological bodies are organizers and owners of such centers. They conduct excursions with scientific-educational directivity, manage and protect geosites.

Key words: Russia, Leningrad region, pseudokarst caves, mines, Cambrian and Devonian sandstones, geosite protection

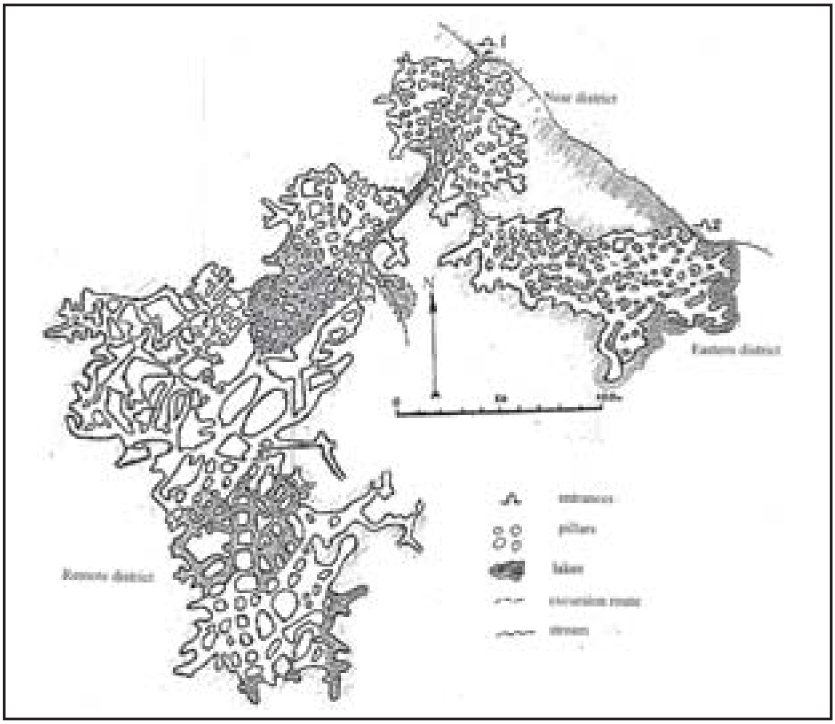

Fig. 1. Sablino Complex Monument. Plan of the Levoberezhnaya Mine

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Fig. 2. Sablino Complex Monument. Levoberezhnaya Mine, Main Gallery of the mine with a stream

Fig. 3. Sablino Complex Monument. Levoberezhnaya Mine, the collapsed hall

The Leningrad Region is located in the NW of Russia. The area is referred to the joint zone of the Baltic Shield, composed of metamorphic Precambrian rocks, and the Russian Plate, where Precambrian rocks are overlain mainly by Cambrian, Ordovician, Devonian and Carboniferous sedimentary rocks. Until recently, pseudokarst in sandstones of the Leningrad Region was observed only in the old mines, worked out in the Cambrian quartz sandstones. For example, 40 km south of St. Petersburg, in the vicinity of the Sablino railway station, there are 12 mines cut into the sandstones (Fig.1). A natural drainage system consisting of streams and lakes formed in the mines (Fig.2). The processes of erosion, piping, and gravitation essentially reworked the mining pits, and natural cavities with abundant secondary collapsed halls formed there (Fig.3). In some Sablino mines stalactites and stalagmites are formed. The colonies of night bats of eight species are inhabited in mines for many years.

The area near the Sablino mines is also very interesting from geological and geomorphologic viewpoint. It is situated on the margin of the Ordovician plateau, where rivers form many beautiful exposures of the Cambrian and Lower Ordovician sediments with fossils. These sections are considered as stratotypes for the north of the Russian Plate (Fig.4). The-

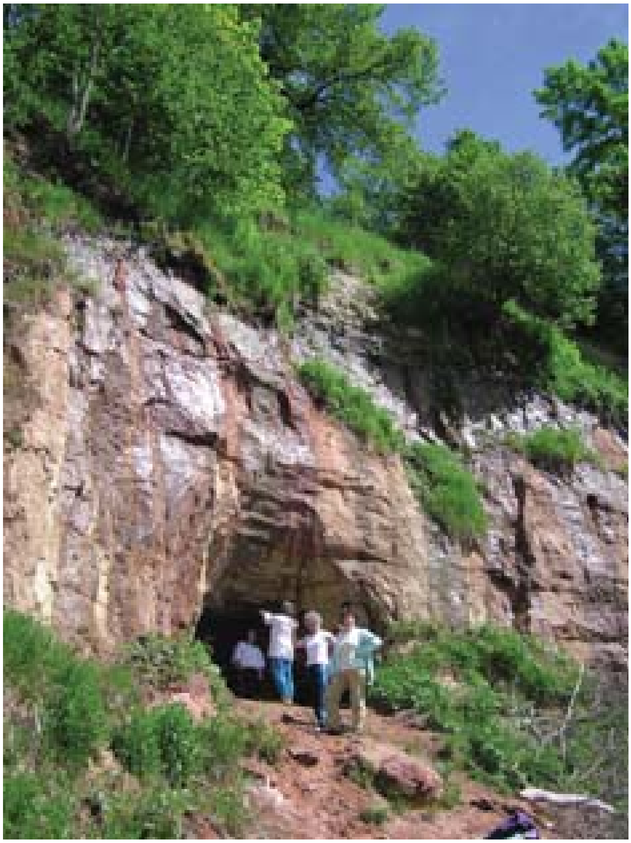

Fig. 4. Outcrop of $Є_3$-O_2 deposits and the entrance into the Grafskaya Mine

re are also two waterfalls, canyons of the Sablinka and Tosna rivers, mineral springs, and places associated with Russia's history and culture. The area has got the official status of the Sablino Complex Nature Monument. The Saint-Petersburg State University students have got geological and geomorphologic practice there.

Recently, speleologists of Saint-Petersburg have found several natural caves that have developed in the Devonian red sandstone in the south of the Leningrad Region. Svyataya Cave situated in the bank of the Grezenka River is the largest of them (Fig.5). It is a beautiful grotto, formed in the vertical riverside cliff and resembles a typical karst cave in appearance (Fig.6). The height of the Svyataya Cave near the entrance is 4 m, its width is 5 m, and its length is about 120 m. There is a large stream, flowing from the cave and many little tributaries inside of it (Fig.7). The Svyataya Cave formed in the fractured ferriferous quartz sandstone as a result of processes of erosion, suffosion (piping) and gravitation. Slit cavities and rather small collapsed halls are typical. Apart from the Svyataya Cave, at the same riverside cliff there are a few smaller grottos. The largest of them, which has 10 m length, resembles the Svyataya Cave in appearance.

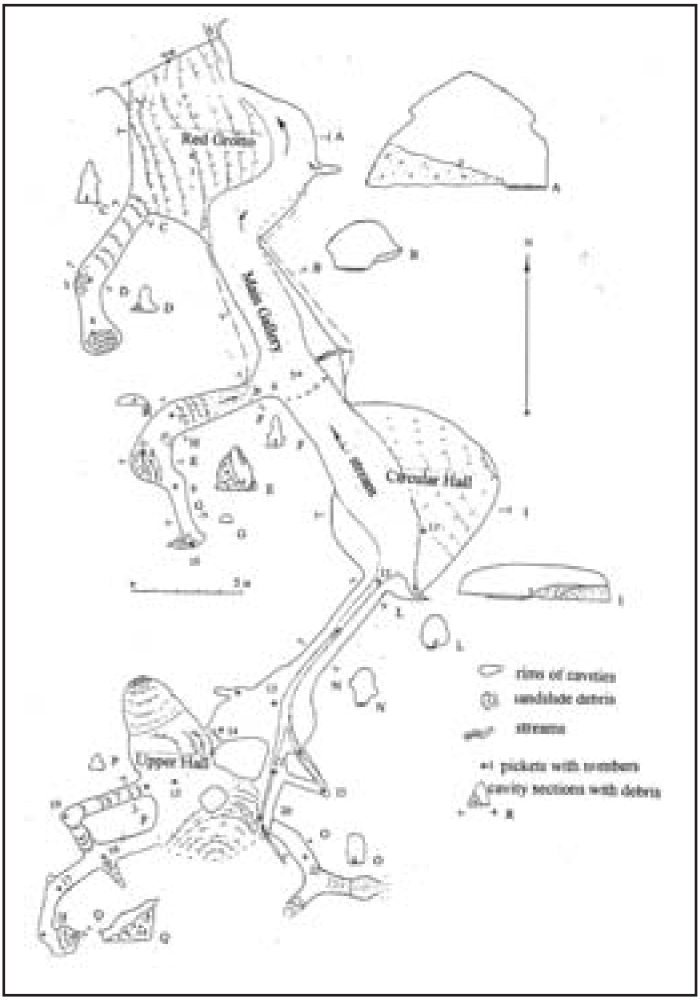

Fig. 5. Svyataya Cave, plan of the cave

After complex studies of the Svyataya Cave the recommendations for provision of the necessary facilities for the cave usage have been elaborated by Yuri Lyakhnitsky. They include the tourist path in the entrance grotto for excursions. The internal part of the cave can not be used for tourism because of unstable cave roofs and small size of cavities.

The area is also of interest owning to the mansion of the famous Russian writer Vladimir Nabokov (1899-1977), which is situated one kilometer west of the Svyataya Cave. The organization of the museum-reserve in the area of the Svyataya Cave and the mansion of V. Nabokov has been planned.

In summer of 2007 Yu. Lyahnitsky discovered a small six-meter long pseudokarst cave

Fig. 6. *Svyataya Cave, the entrance*

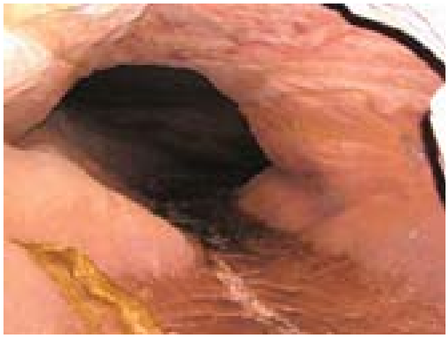

Fig. 7. Svyataya Cave, the stream

Fig. 8. Cave in the Lava riverside slope

in the Lava riverside slope. The cave formed along the contact of the argillaceous glauconite limestone and Cambrian quartz sandstone due to mainly gravitational mass movements, but it is located only in sandstones (Fig.8). There are also many small grottos in riverside cliffs of the Luga, Lava, and Tosna rivers in the southern Leningrad Region.

Recently, in the Gatchina District of the Leningrad Region another pseudokarst cave named the Arkhimedovskaya Cave has been found by speleologist Alexander Ostashenko (Fig. 9). It is located in the Devonian ferriferous quarts sandstone, but initially it did not have an entrance. The cave has been opened with an artificial manway of about 4 m long (Fig. 10). The cave of 40 m long consists of a set of small cavities and halls up to 3 m high. Their walls have complicated surfaces with caverns and niches that make them scenic (Fig. 11). The stream, flowed in the cave, flows out near the artificial manway as a spring. Discovery of the Arkhimedovskaya Cave testifies the possibility of finding new hidden pseudokarst caves in fractured sandstone by way of filtration of underground waters near their outlet on the surface as springs.

Developing the pseudokarst caves in the Devonian sandstone, especially the hidden ones, is a very important factor, which should be taken into consideration when building is planned.

The pseudokarst landforms represent geological heritage sites and they need to be protected, because they are carriers of scientific information, and their study enables us to trace the evolution of a landscape and to study such phenomena as pseudokarst. However in Russia, protection of pseudokarst caves as well as other geosites does not correspond to their importance. In spite of geosite preservation is a very important national task there are only few practical scientific elaborations aimed at the harmonic combination of protection and positive humanistic usage of nature. It is necessary to bear in mind that it is impossible to renew geosites, and loosing them, we also loose unique scientific information.

Caves are very attractive for commercial usage owing to their aesthetic properties and great interest of tourists. At the same time they are very vulnerable objects. There are several excursion caves in Russia, but sometimes they are used and arranged without agreement with governmental and nature-conservative bodies and what is more important, without competent project based on detailed studies and elaboration of usage rules.

The elaboration of the speleological underground excursion route must be based on detailed study of morphology, stability of natural roofs, hydrology, hydrochemistry, mineralogy, microclimatology, mi-

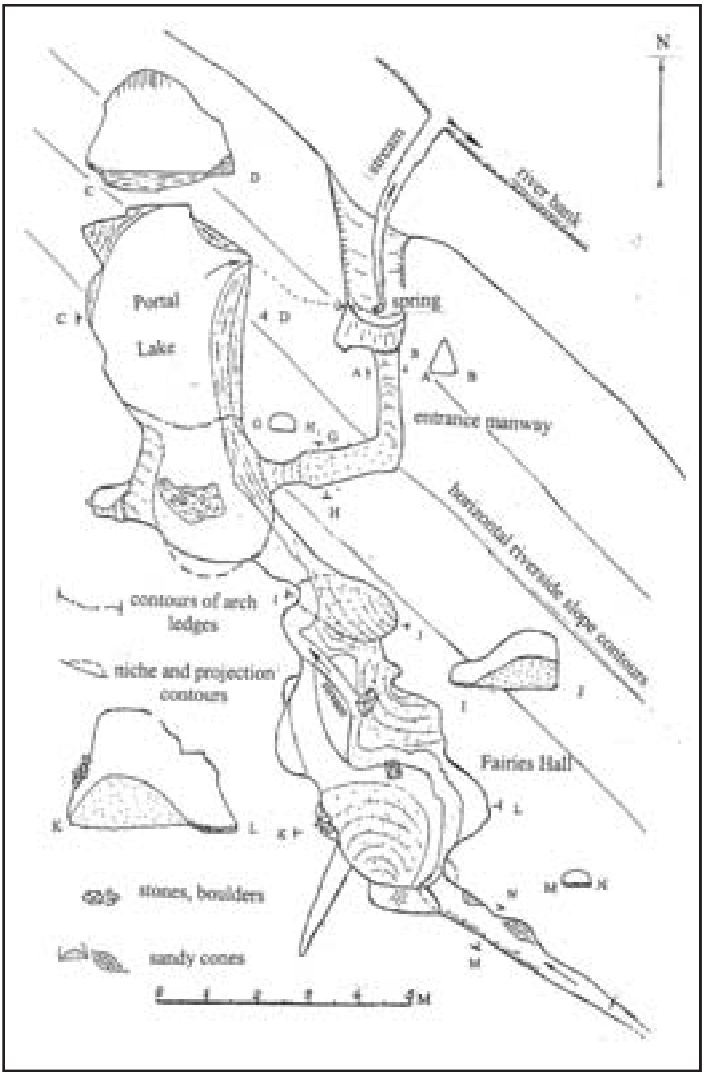

Fig. 9. Arkhimedovskaya Cave, plan of the cave

Fig. 10. Arkhimedovskaya Cave, artificial manway

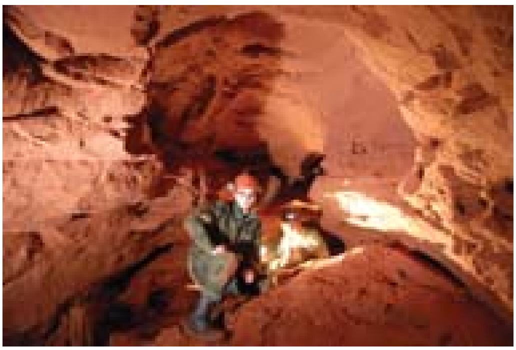

Fig. 11. Arkhimedovskaya Cave, caverns and niches on the walls of the cave

crobiology, peculiarities of the radiation background. These questions can be solved by specialists but not by commercial companies or tourists-speleologists.

The area of the Sablino Complex Nature Monument with mines mentioned above had been announced to be a nature monument as far back as 1976, but it was little protected and it was built on and degraded. The cave ceilings were crushing, and it was very dangerous to conduct tours inside of caves. Now the situation is quite different. In the early 90s, on the initiative of speleologists, geologists and ecologists under the leadership of Dr. Lyakhnitsky the set of investigations including topographic, biological, speleological, microclimatic, radiation, radon, hydrological, hydrochemical, mining and other studies were conducted.

Fig. 12. Sablino Complex Monument. Levoberezhnaya Mine, the entrance

In the Levoberezhnaya Cave an underground tour route was prepared including concreting of upper parts of entrances (Fig.12), fastening of unstable areas (Fig.13), regulation of hydrologic and microclimatic regimes, and creation of the excursion paths. After that, stone staircases on steep slopes of the route were made. The established regime favors the conservation of the ecosystem localizing the visitors' flow on the routes in the cave and in the recreation halls.

For the control of the geosite state and its protection, a public non-governmental organization was created with the participation of speleologists, geologists, ecologists, tourists, and cultural workers. Based on the agreement with the Government of the Leningrad Region, this organization has been conserving the geosite and conducting tours there. The work is made using funds received from tourism. Now the area of the monument is patrolled, the tours are conducted all the year round. In addition to the cave, visitors can see two canyon-like river valleys, waterfalls (Fig.14), picturesque cliffs, mineral ferriferous hydrosulphuric springs. They are shown outcrops of blue Cambrian clays with pyrite crystals, Ordovician organogenic limestone with orthceratites, brachiopods, trilobites and other fossils as well as interesting historical places (Lyahnitsky, et.al. 2007).

The geosite is visited by tens of thousands of schoolchildren, family groups, people of various ages and professions. During the excursions they listen to 3 or 4 hour lecture and examine remarkable natural objects. The educational benefit of such excursions exceeds the results of visiting museums and school lessons.

Thus the nature-protecting excursion-tourist centre set up on the base of the Sablino Complex Nature Monument is an example of well-organized geosite protection.

In conclusion it is necessary to say that according to the opinion of the authors in the modern conditions in Russia, the main conception of geosite protection is creation of such nature-protecting excursion-tourist centres. The main idea of the centers is organization of geosite protection and provision of necessary facilities, using benefits from a regulated tourist activity. State nature conservative or speleological bodies can be the organizer and owner of such centers. They conduct excursions with scientific-educational directivity, manage and protect geosites.

Fig. 13. Sablino Complex Monument. Levoberezhnaya Mine, the fastening of the unstable part of ceiling

Fig. 14. Sablino Complex Monument. Waterfall on the Sablinka River

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CULT CAVES AND SETTLEMENT PATTERNS IN THE ROCKY LANDSCAPE OF THE ELBSANDSTONE MTS. (SAXONY / BOHEMIA)

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Abstract - The Elbsandstone Mts. in the Czech-Saxon Switzerland National Parks create a natural geographic ridge between the old settlement areas of the Dìèín Basin in Northern Bohemia and the Dresden Basin in Saxony. The sandstone landscape is also characterized by extraordinarily diverse geomorphological forms of the rock surface, a dense network of deep ravines, and hundreds of rock shelters. The axis of this landscape forms a natural geographic connecting line for the two historical areas of the Elbe River Canyon. The archaeological excavations of the past decade and the new processing of older finds have produced a great deal of new information concerning the prehistoric past of the landscape and enable the study of the archaeological sites in relation to various types of landscape (Elbe Canyon, internal rocky areas and areas outside of the rocks) and to various natural formations (rock shelters, caves, prominent rock formations, plateau mountains, rock towers, and others). Of particular interest is the connection between the archaeological finds in small caves in a segment of the Elbe Canyon between Děčín and Bad Schandau. The size and nature of these caves rule out settlement and they are instead generally regarded as cult sites. Finds are considered to be sacrificial offerings tied to the existence of the "Elbe Route" through the Elbe River Valley. The author's new processing and surveying of these locations showed that the majority of these small caves are located near prominent rock formations (rock towers, a rugged ridge, rock spurs) whose shapes draw attention, or which are also significant orientation points. The site with finds of jewels from the Migration period near Hřensko was accessible only from the banks of the Elbe, while other locations (Dolní Žleb, Kleiner Winterberg) were accessible from flat land above the sunken canyon, thus proving that the "Elbe Route" was not only limited to the Elbe River and its banks, but to an approximately 3 km wide corridor surrounding the river. The phenomenon of the cult caves with finds of intact vessels is dated to the interval from the Late Eneolithic Period (ca. 2300 BC) up to the Migration period (beginning of the 5th century).

The sandstone landscape of the Elbsandstone Mts. is interesting not only for its settlement topographical location between two areas - the Děčín Basin in Northern Bohemia and the Dresden Basin in Saxony - populated through the entire course of prehistoric times, but also for its extraordinary division and variety of rock formations and sandstone reliefs. The issue of the development of long-range routes has been discussed repeatedly over the past decade (Coblenz 1950, 1956, Zápotocký 1969, Simon – Hauswald 1995, Salač 1997, 2006, Peša 2008), but the lack of known sites has prevented a deeper study of the settlement structure of the area. New information was obtained between 1999-2005 from excavations of the rocky cliffs in the Czech Switzerland National Park (the southeast section of the Elbsandstone Mts.) by J. A. Svoboda's

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team (Svoboda et al. 2003) and from the revision of the majority of prehistoric sites on the Saxon side of the Elbsandstone Mts. and in the Saxon Switzerland National Park by the author of this work in 2006-20071.

The working hypothesis assumes that the character of the divided landscape and settlement conditions could influence the selection, significance and function of the archaeological locations, many of which are connected with plateau mountains, solitary rock formations, prominent rock ridges, fissure caves, and rock shelters. The landscape of the Elbsandstone Mts. also enables categorization into three zones according to geomorphological characteristics: the Elbe River Valley, the internal rock area of both national parks and the external agricultural landscape with plateau mountains and rocky ravines surrounding the internal zone. The first zone represents the Elbe River Valley between Děčín and Pirna, which, in this segment, is a deep canyon carved into the thick-bedded sandstone. The most exposed segment between Děčín and Bad Schandau features several small caves and rock crevices where intact deposited vessels without additional finds or evidence of human dwelling were discovered. The sites are from various prehistoric periods (the Late Eneolithic, the Early, Middle and Late Bronze Age, and the La Tène period) and will be described in the second part of this work. There is currently agreement on their cult function and the deposition of vessels with sacrificial offerings (not preserved today) related to the "Elbe Route." These offerings were made to ensure that the difficult passage over the Elbsandstone Mts. would be successful (Simon – Hauswald 1995, Peša 2006, 69-71).

The internal forested area with a dense network of rock ravines forms the core of the Elbsandstone Mts. Prehistoric sites are primarily located beneath rock shelters and contain cultural layers from the Mesolithic and Eneolithic periods and the Urnfields of the Late Bronze period up to the Hallstatt period. The concentration of these sites in the main ravines indicates that they could be connected with the local routes running through the rocky labyrinth. While it appears that the intensity of settlement was balanced throughout the entire region during the Mesolithic period - the Buschmühle rock shelter in the Køinice Valley (I. Kraft2 – no published), the Jezev čí and Švédův rock shelters (Svoboda et al. 2003), the Šibenièní kámen (Hangman's Rock) rock shelter (J. A. Svoboda 2 – no published) – in the post-Mesolithic period these sites inside the rocks are conspicuously lacking finds and indicate repeated visits without a greater accumulation of waste deposited in weakly developed cultural layers (in Saxony the rock shelters Kirnitzsch K-65a, Lorenzsteine, Hickelhöhle – tentatively Peša – Kraft 2007; in Bohemia the rock shelters Táborový kotel, Šibeniční kámen, Pod Šaunštejnem, Čínská zeï I and others – Peša 2008, Peša – Jenč 2003). One of the cult caves with ritually deposited vessels, the Tonkrughöhle Cave at Kleiner Winterberg, is located on the periphery of the inner area and approximately 1.5 km from the Elbe.

On the other hand, the archaeological recognition of the outer area is better on the Saxon side. While finds in Bohemia are recorded only at rock shelters in the Kamenice Valley and surface sites are entirely absent, we have finds on the Saxon side from various types of locations. However, larger surface sites are rare also here (the Mesolithic settlement at Kiefrecht-Schomberg in Bad Schandau) and locations with unique stone tools or small assemblages (primarily Neolithic to Eneolithic) as well as the archaeological situation on the plateau mountains Pfaffenstein and Lilienstein are tied to their proximity to the Elbe Valley. According to the new comprehensive processing of all preserved finds, the assemblage of Lusatian culture finds at fortified Pfaffenstein (Coblenz 1956, Neugebauer 1986) fall significantly into the area of cult activities (funeral vessels without the presence of burials, the absence of storage vessels, and the presence of a large number of grain beaters and bronze ornamentation: V. Peša – L. Nebelsick in preparation). While prehistoric finds from Lilienstein are less numerous, they stem from more periods. Nevertheless, their position, mainly in alluvial fans beneath rock walls, does not permit a more detailed interpretation. Unique flint artefacts from the Großer Zschirnstein and Rauenstein plateau mountains are evidence of the use of these excellent lookout points in the landscape. The Nonnenfels rock tower near Weissig is a remarkable site with exceptional finds of Hallstatt ceramics. It is evident that fortifications of nearby Rathen Castle existed here in medieval times; in the Early Modern period traditional pilgrimages were linked to the rock (Neugebauer 1999).

Of particular interest is the link of the archaeological finds to small rocky hollows in the section of the Elbe Canyon between Děčín and Bad Schandau, which due to their size and character rule out settlement and are generally regarded as cult sites. Finds of sacrificial offerings are tied to the existence of the "Elbe Route" through the Elbe River Valley. The finds are comprised of intact vessels from various prehistoric periods without traces of their original contents and without the presence of additional finds or cultural layers (Simon – Hauswald 1995, Peša 2006, 69-71). The author's new processing and surveying of these locations in 2006-2008 determined that the majority of these small caves are located near prominent rock formations (rock towers, a rugged ridge, rock spurs) whose shapes draw attention, or which are also significant orientation points. The Tonkrughöhle Cave at Kleiner Winterberg contains the oldest find of a ceramic pot from the Late Eneolithic Period. A low cave is located in the upper level of the rocks and is accessible along a narrow ledge several metres above the base of the rock. Groups of rock towers visible from a distance are typical for Kleiner Winterberg; one of these towers is located near the cave. The pot from the Middle Bronze Age was discovered in a small hollow of a smaller rock formation that had collapsed and was taken apart for building material. The site is located between two colluvial spurs with small rocks, of which the northern part has been mined, featuring a quarry. An amphora from the Lusatian culture of the Late Bronze Age is the latest find of this type. The vessel comes from a small recess in the wall of a rock shelter, the bottom of which is a sloping rock bench. A chronological summary of deposited vessels dates the pot to the beginning of the La Tène Period (vessel finds resumed in Coblenz 1986, 1988 and Simon – Hauswald 1995). The find was discovered beneath a rock overhang in a 1-2 metre-wide crevice near the natural Schrammtor Pass in the Torsteine rock formation that projects in a rugged crest over the Elbe riverbed. The most recent find was bronze jewellery with glass beads from the beginning of the Migration period in Hřensko. The jewellery was found in a low cave on a slope beneath the rocky cliffs of the canyon and could only have been carried to this site from the river (Jiřík – Peša. – Jenč in print). It is also one of the few reliable records of the presence of man on the banks of the Elbe River and the existence of the Elbe Canyon as a prehistoric route, which is questioned by certain authors. On the contrary, the caves mentioned above, like many other small sites - particularly those from earlier prehistoric periods - allow for the possibility that the "Elbe Route" was not limited strictly to the Elbe River and its banks, but to an approximately 3 km wide band around the river that formed a natural corridor between the Krušné Mts. and the rocky core of the Elbsandstone Mts.

In the past, the banks of the Elbe River were passable along the entire length, with the exception of the segment near Hřensko at the site of the Czech-German border, where rock walls descended right down to the riverbed. At this location, it was necessary to circumvent the rocks on the western slope of the Großer Winterberg. Rock shelters in this area have produced several sites with finds of prehistoric ceramic fragments (the alcove Kipphornfuge Cave at Schmilka – a Late Eneolithic culture with string pottery, Lusatian culture of the Late Bronze period; the Stříbrné stěny (Silver Wall) and Čínská zeď I (Chinese Wall I) rock shelters at Hřensko – the Urnfield period). Historical names such as Pascherweg ("Trail of Thieves" or Zlodějská stezka in Czech) and Diebssteigbach document the crossing of borders at these sites.

Footnotes

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POSEIDON - THE PSEUDOKARST SYSTEM IN THE SANDSTONES OF THE CZECH REPUBLIC: GEOMORPHOLOGICAL STRUCTURE AND BIOGEOGRAPHICAL IMPORTANCE

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Abstract - The Poseidon system, which is the pseudokarst system that was developed in sandstones in NE Bohemia, is described. The fissure labyrinths, abysses, and block accumulations can be found in an area of approx. 26,800 m^2. The total length of the man-accessible underground spaces of the Poseidon system is at least 27.5 km. The vertical range amounts 105 m.

Thanks to its enormous dimensions, the Poseidon system is able to store an inside cold microclimate. This cold microclimate supports the occurrence of cold adapted plants and invertebrate animals, five glacial relicts (four spiders and one mite) included.

By its structure, microclimate and communities of cold adapted organisms, the Poseidon system represents an important object in speleology, geomorphology, biology, and nature conservation.

Key words: Sandstone, pseudokarst, cave, root stalagmite, spider, beetle, mite, biogeography, glacial relict

Summary: Large areas of sandstone are found in the temperate zone of Europe. The most extensive area with a high frequency of sandstone monuments in Europe is probably the Bohemian Cretaceous Basin, which stretches mostly across northern Czech Republic but also extends to Poland and Germany.

The "Adršpašsko-teplické skály" National Nature Reserve rock complex that developed in block sandstones is situated in the "Broumovsko" Protected Landscape Area in northeast Bohemia. The inaccessible and unexplored systems of underground spaces, which are hidden within the complex of the "Teplické skály" cliffs, was found in 2006. A speleological survey in the subsequent two years revealed a complicated system of deep fissures in combination with debris caves, which was named Poseidon.

The Poseidon system - there are broken, mutually connected labyrinths of deep fissures and open abysses. Very often there are mounds of debris here, which fill up the wider fissures. The impacted blocks of stones and debris that are laid atop them create multile-

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vel cave spaces in the fissures up to a depth of many metres.

The Poseidon system is approx. 740 m long in direction N-S, and approx. 550 m wide in the cross direction. Fissure labyrinths and abysses can be found on an area of approx. 26 800 m^2. From the viewpoint of the morphological and genetical typology of the pseudokarst, the following cave types are present in the surface area of the Poseidon system: fissure-type caves (55%), crevice-type caves (5%), debris-type caves (15%), and combined-type caves (25%). The total length of the man-accessible underground spaces of the Poseidon system is at least 27.5 km. The vertical range amounts 105 m.

A dense system of narrow and deep gorges supports a highly diverse mosaic of specific habitats with a specific microclimate: sun-exposed rock margins and rock walls, shaded rock walls, dark bottoms of gorges and aphotic underground spaces. We registered three special life forms in the Poseidon system. Shady underground spaces enable the occurrence of root stalagmites, and a cold microclimate in deep gorges enables the occurrence of cold-adapted mountain plants, beetles, and spiders, and boreal spiders and mites (glacial relicts).

By its structure microclimate and communities of cold adapted organisms, the Poseidon system represents an important object in speleology, geomorphology, biology, and nature conservation.

Introduction

The pseudokarst phenomenon includes surface as well as subsurface forms that are morphologically analogous to karst phenomenon that occurs in carboniferous rocks. In the relief of the sandstones, pseudokarst is the most dominating feature. Selective denudational processes have modelled their relief rather significantly (Härtel, Cílek et al. 2007).

The sandstones of humid tropical climates are usually transformed into secondary quartzites (Venezuela). A few sandstone occurrences are known in the arctic zone. Large areas of sandstone are mostly found nowadays in arid and semi-arid environments (USA, Arabia, and North Africa) and in the temperate zone of Europe (Cílek et al. 2007).

The most extensive area with a high frequency of sandstone monuments in Europe is probably the Bohemian Cretaceous Basin, which stretches mostly across northern Czech Republic but also extends to Poland and Germany (Balatka & Sládek 1984; Härtel, Adamovič & Mikuláš 2007).

The "Adršpašsko-teplické skály" rock complex that developed in block sandstones has a National Nature Reserve status. It is situated in the "Broumovsko" Protected Landscape Area and represents, due to its relatively high altitude and very prominent inversion sites, a unique phenomenon when compared to other rock areas in the Czech Republic (Mikuláš et al. 2007).

Access to a rock labyrinth in the central part of the "Teplické skály" cliffs was possible after a widespread fire in 1824. Since 1845 there has been a tourist path, and then in 1868, a whole circle through the rock labyrinth was made accessible. The fissure cave "Skalní chrám" (Rock Cathedral) was the only one accessible to turists (1846-1958), which is non-karst cave in the Czech Republic (Sýkora & Mlejnek 2008). Within a large project about the phenomena in block sandstone in north-east Bohemia (Vítek 1979) and in other surveys, 179 m of underground spaces in the peripheral parts of the current Poseidon system were documented (Mlejnek & Ouhrabka 2008).

The first person to realise that there are inaccessible and unexplored systems of underground spaces, which are hidden within the complex of the "Teplické skály" cliffs, was

Roman Mlejnek in 2006. A speleological survey in the subsequent two years revealed a complicated system of deep fissures in combination with debris caves, which was named Poseidon. The speleological phenomenon that was raised from an ancient sea is unique not only for its geomorphology, but also even for its microclimate wherein animals and plants are thereby dependent on.

A dense system of narrow and deep gorges in sandstone areas supports a highly diverse mosaic of specific habitats with a specific microclimate: sun-exposed rock margins and rock walls, shaded rock walls, dark bottoms of gorges and aphotic underground spaces. The diversity of communities on a steep microclimatic gradient was documented e.g. for vascular plants (Sádlo et al. 2007; Härtl, Sádlo et al. 2007), mosses (Zittová-Kurková 1984), earthworms (Pižl 2007), and spiders (Růžička 2007). We registered three special life forms in the Poseidon system. Shady underground spaces enable the occurrence of (1) root stalagmites, and a cold microclimate in deep gorges enables the occurrence of cold-adapted (2) mountain plants, beetles, and spiders, and (3) boreal spiders and mites.

(1) The root stalagmites are living root forms that resemble cave stalagmites. We can also distinguish between root matts, root pillows, and root stalagnates. However, stalagmites are the most numerous. The root stalagmites are formed by a dense root network of various tree species (birch, Norway spruce, pine, etc.) that are growing towards the source of dropping water. They can grow up to 60 cm high and 10 cm or more in diameter. Root stalagmites develop in shallow caves, and can be found mainly in sandstone areas, often under large collapsed sandstone blocks where there are sources of dropping water, flowing through the rock mass along hardened sandstone layers (Jeník 1998; Mlejnek 2007). Root stalagmites are well documented in sandstone terrains in Bohemia, Germany, and Poland. The "Broumovsko" Protected Landscape Area represents a centre of research and documentation of root stalagmites since 1980s (Kopecký 1998).

(2) Climatic inversion in deep valleys enables the descending of montane species at lower altitudes.

(3) Species exhibiting a disjunct distribution area composed from the main subarea in the boreal zone, and isolated, island populations in Central Europe are designated as glacial relicts. Disjunct occurrences of these species today are a reminder of the moving of its range during the changing glaciation of Central Europe in the Pleistocene.

The description of the system presented here is the first, original description in the English. Data concerning the life in the Poseidon system represent the review, a synthesis of all our present knowledge, which also includes new findings.

Methods

The system was speleologically documented from 2006-2007. The speleological single-rope technique was used for moving through the underground. The climbing technique, including the rope bridging, was used during surface exploration.

A specific system of documentation was utilised according to the extent and complicity of the whole system. The documentation was performed in combination with the classic speleological methods of mapping with the methods of aerial photogrammetry and measurements by GPS. With the detailed mapping 1:100 (1:200), there were documented only selected localities, which represented each kind of underground space. The aerial ortophotomap (GE = 0,2 m) was used for the assignment of the extent of the whole system. This map was supplemented with other photography from a motor-parachute.

The pictures from a low height (300 m) were taken by Mr Libor Jenka from Police nad

Metují. These pictures were transformed onto identical points of ortophotomaps that were used for creating the drawing of the basic fissure system's skeleton and for clear identification of some localities, which are normally difficult to determine or that are inaccessible.

The area boundary is provided by the net of detailed points as shown by GPS, which were placed onto the maps and photographs.

The handheld GPS (GARMIN - Etrex-Summit) was equipped with a barometric altimeter and at the same time it was used for the determination of how high above sea level some parts of the system are, and it was used for the verification of denivelations, which were established by the trigonometric nivelation.

Results

Structure of Poseidon

Total characteristic

The central part of the "Teplické skály" cliffs is unique because of its rock walls, which continue for several hundred metres (Fig. 1). The border parts of the plateaus are formed by a heavy frequency of upright fissures. We can now discuss all of the fissure zones (Fig. 2).

The basic characteristic of the Poseidon system - there are broken, mutually connected labyrinths of deep fissures and open gorges that are based upon the vertical fracturing of the block sandstone's direction NNW-SSE and ENE-WSW. Very often there are mounds of debris here, which fill up the wider fissures. The impacted blocks of stones and debris that are laid atop them create multilevel cave spaces in the fissures up to a depth of many metres (Fig. 3).

The particularity of the Poseidon system is something that shows a significant resemblance to extremely narrow gorges on the one hand, and fissure abys-

Fig. 1. The Poseidon system, a general view. Photo by L. Jenka.

Fig. 2. The central part of the Poseidon system, a bird's eye view. Photo by L. Jenka.

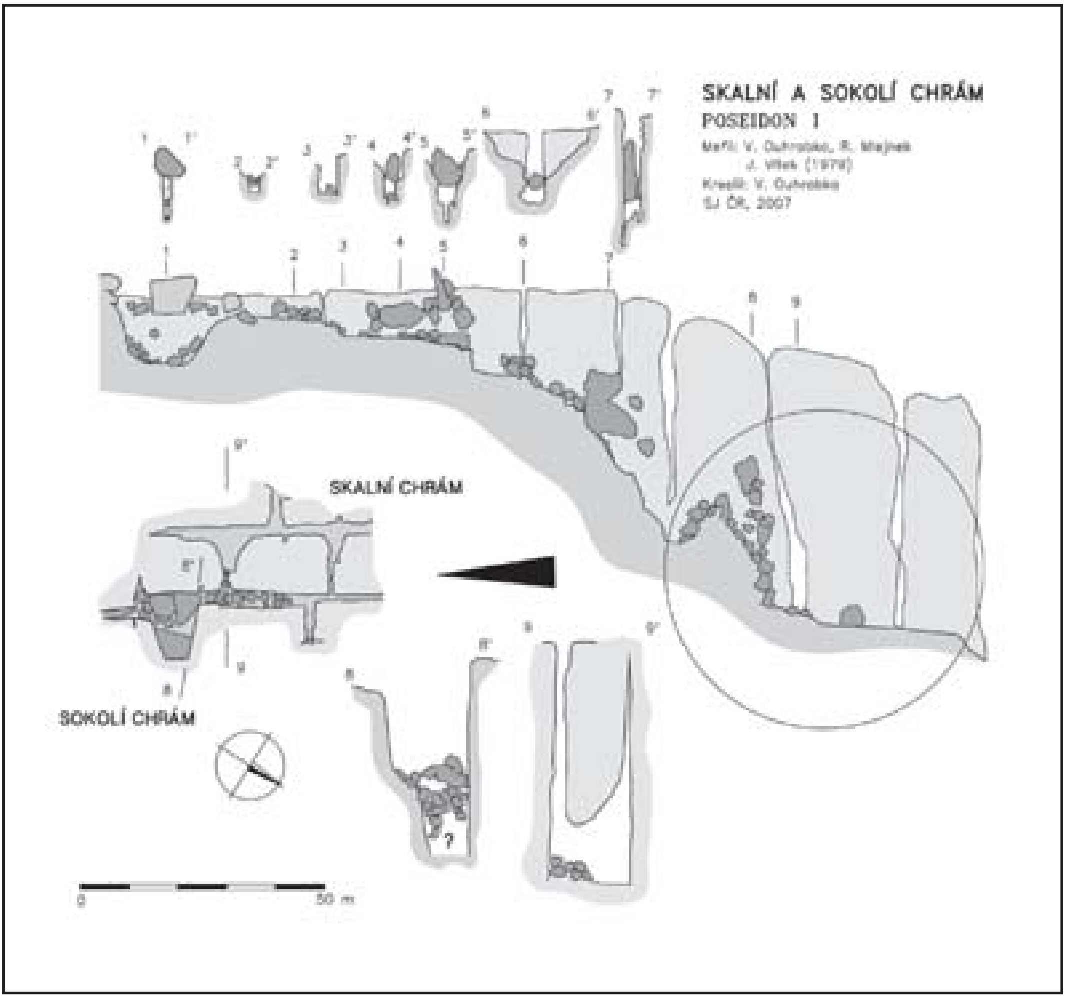

Fig. 3. "Skalní chrám" and "Sokolí chrám" (Rock and Falcon Cathedrals). Drawn by V. Ouhrabka.

Fig. 4. The Poseidon system, a cross-section. Drawn by V. Ouhrabka.

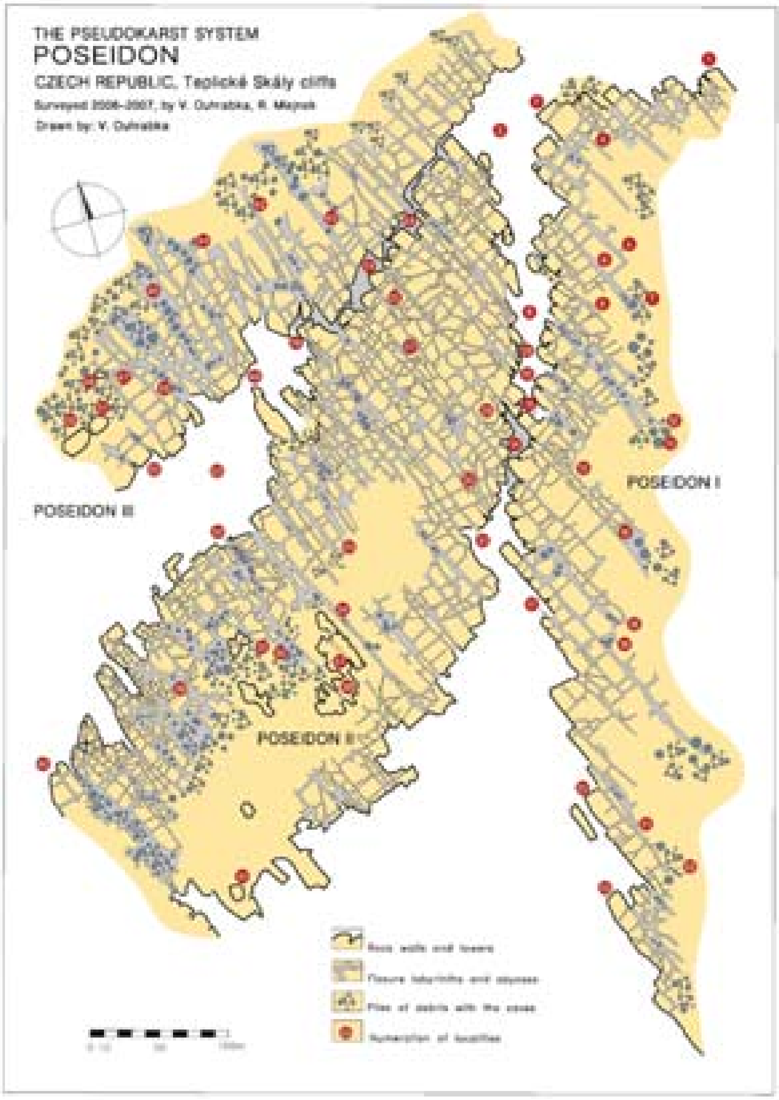

Fig. 5. The Poseidon system, a ground plan. Drawn by V. Ouhrabka. 1 - Šahrazád Tower, 2 - "Hláska" (Guard) Tower, 3 - "Skalní" (Rock) Square, 4 - "Oldova" (Olda's) Abyss, 5 - Hermit Cave, 6 - Street under "Branka" (Gate), 7 - "Mokrá" (Wet) Cave, 8 - "Lednová" (January) Abyss, 9 - "Velké chrámové" (Big Cathedral) Square, 10 - "Malé chrámové" (Small Cathedral) Square, 11 - "Průvodcovská" (Guide) Cave, 12 - Passageway and Small Cave under "Kořenka" Cave, 13 - "Kořenka" Cave, 14 - "Lví klec" (Lion's Cage) Gorge, 15 - "Dunivá" (Thunderous) Abyss, 16 - Tundra Labyrinth, 17 - "Skalní chrám" (Rock Cathedral), 18 - Street under "Matka" (Mother), 19 - "Sokolí chrám" (Falcon Cathedral), 20 - "Martinské" Walls, 21 - "Teplická" Abyss, 22 - Small and Big Cave at the "Teplická" Abyss, 23 - "Měsíční" (Moon) Tower, 24 - "Sibiř" (Siberia) Gorge, 25 - "Dračí" (Dragon) Abyss, 26 - "Strážce Sibiře" (Guard of Siberia) Tower, 27 - "Bloková" (Block) Passage II, 28 - "Snežná" (Snowy) Abyss, 29 - "Stupňovitá" (Stepformed) Abyss, 30 - "Křížová" (Cross-shaped) Abyss, 31 - "Žíznivá" (Thirsty) Cave, 32 - "Bloková" (Block) Passage, 33 - Cave at Three Monuments, 34 - Cave at the Barrier, 35 - Cave and Overhanging Rock at the Beast, 36 - Cave at the Fallen Head, 37 - Cave at the Crawl Space, 38 - "Větrný" (Windy) Passageway, 39 - "Mechové" (Moss) Square, 40 - "Krápníková" (Dripstone) Tower, 41 - "Hladomorna" (Dungeon) Tower, 42 - "Ztracenka" Cave, 43 - "Kyklop" (Cyclop), 44 - Cave at the "Vyhlídka" (Lookout), 45 - "U Roklin" (At the Ravine) Labyrinth, 46 - Magic Stone Tower, 47 - Street under Magic Stone Tower, 48 - "Pavoučí" (Spider) Cave, 49 - Spring, 50 - Cave at the Passageway, 51 - Gorgon Cave, 52 - "Pavla" Tower, 53 - "Anenské" Valley.

ses on the other hand. Their denivelation (depth) is often more than 60 m.

The whole system is divided into three parts by narrow gorges (Fig. 4). The typical "SibiY" gorge (Siberia) is only approx. 50 cm wide in some places.

The Poseidon system is approx. 740 m long in direction N-S, and approx. 550 m wide in the cross direction. Fissure labyrinths and abysses can be found on an area of approx. 26 800 m^2. From the viewpoint of the morphological and genetical typology of the pseudokarst (Vítek 1979, 1982), the following cave types are present in the surface area of the Poseidon system: fissure-type caves (55%), crevice-type caves (5%), debris-type caves (15%), and combined-type caves (25%).

The total length of the man-accessible fissures was estimated to be 19,655 m, based on the ground plan of the system (Fig. 5). However, the length of the multi-level debris caves, which can be found partly in fissure labyrinths, and partly separately, is not included. Therefore, the underground spaces in several model debris accumulations were measured using a laser rangefinder. With a recount of the total area of debris, the total length of the underground spaces in these accumulations was estimated to be (at least) 8 km. The total length of the man-accessible underground spaces of the Poseidon system is at least 27.5 km.

Poseidon I

This part is situated on the northern and western part of the "Ostruha" plateau. The northern branch stretches over the entrance valley and is created by short fissures, which run into the massif maximally at the distance of 25-30 m.

The border points are the "Šahrazád" tower and "Hláska" (Guard Tower), which loom high over the "Skalní náměstí" (Rock Square). The southern branch, which continues from the "Hláska" tower to the "Martinské stěny" walls, is created by a system of fissures, that can be seen in the middle part (between the "KoYenka" cave and the "Teplická propast" abyss) up to a distance of 100 m from the edge of the plateau. In this part, Poseidon I and Poseidon II are separated by a very narrow gorge, which is only 60 cm wide between the "Lví klec" (Lion's Cage) and Branka. The length of the open fissures decreases to 15-20 m further to the south. The edge of the plateau rises from the north (654 m a.s.l.) to the south. The fissure-debris complex is situated approx. 80 m SE from the "Měsíční věž" (Moon Tower) and represents the highest point (704 m a.s.l.). The lowest part of the system is represented by debris formations under the "Oldova propast" abyss (612 m a.s.l.). The total denivelation of the Poseidon I part amounts to 92 m. The denivelation (the vertical range) of selected localities: "Teplická propast" abyss, crevice-fissure-debris part included - 52 m, "Sokolí chrám" and "Skalní chrám" (Falcon and Rock

Fig. 6. The "Skalní chrám" (Rock Cathedral). Photo by M. Audy.

Cathedral) including the fissure spaces above the “Sokolí chrám” - 65 m (Fig. 6), “Dunivá propast” (Thunderous Abyss) - 61 m, “Oldova propast” (Olda’s Abyss) - 42 m.

Mostly open fissure systems that go down gradually are typical for the area of Poseidon I. In the highest parts, they are 5-20 m deep, 1-3 m wide, and they form labyrinths, in which small streams flow through. These systems go deeper towards the edge of the plateau and they change than into narrow fissure abysses. In these parts, the fissures are partly filled or overlaid with boulder debris, or single boulders. There are mostly narrow, almost vertical fissures here, 0.3-0.6 m wide. In the upper part, they are narrow and on the bottom they are filled with debris and sand. Some of these fissures have small streams that flow through all year long (“Tundra”, “Dunivá propast”). The fissures of the direction SSE-NNW with a frequency 10-20 m form the character of the system. They are connected by cross fissures of a NE-SW orientation in an irregular frequency (5-15 m). The crevice cave spaces are formed especially in these cross fissures, and mostly on the edge of the plateau. These cross commissures can be seen very irregularly at various depths, in which by the surface they are often almost completely closed, or they are overlaid by debris and soil and they become larger in lower parts. However, some of them are not visible in the deeper parts and open only a few metres under the surface. The accumulations of block debris are specific phenomenon here. They are connected to fissure systems and many small mutually connected caverns and larger cave spaces can be found here (e.g. “Kořenka” cave).

Poseidon II

This part is situated on the structural plateau, which is called “Skalní ostrov” (Rock Island). This plateau is delimited by narrow gorges in the northern part. The southern border of Poseidon II is formed approximately by the line between “Krápníková věž” (Dripstone Tower) and “Hladomorna” tower. The denivelation of Poseidon II, 105 m, represents the maximal denivelation of the whole system. The lowest place is at the mouth of “Sibiř” gorge (Siberia) on the “Skalní náměstí” (Rock Square) (605 m a.s.l.). The highest place is the ceiling of the narrow fissure, which is called “Větrný průchod” (Windy Passageway) (710 m a.s.l.). Denivelations of selected localities: “Dračí propast” (Dragon Abyss) - 71 m, “Křížová propast” (Cross-shaped Abyss) - 61 m, “Bloková chodba” (Block Passage) - 55 m (Fig. 7).

Fig. 7. “Bloková chodba” (Block Passage). Photo by P. Zajíček.

The cave and abyss-shaped systems of the Poseidon II have a different character in their eastern and western part. The fissure abysses (“Stupňovitá propast”, “Křížová propast”), which are accessible only at the crossing of the fissures, are characteristic on the eastern edge of the “Skalní ostrov” (Rock Island). These 50-70 m deep and 0.80-3.00 m wide fissures are in the direction NNW-SSE and approx. 15-20 m long. In the deeper parts - direction into the massif - they close completely. They are mostly separated by a wall of rock blocks or rock towers from the main valley and lead into it via narrow fissures at the bottom. In the southern part of the "Skalní ostrov" (Rock Island), the fissures cannot be seen towards the NNW (to the centre of the massif), in which they are usually filled with soil. In the middle and especially in the northern part of the "Skalní ostrov", the fissure abysses change into 5-20 m deep fissure-crevice labyrinths, which go through the whole massif. On its NW margin, they change again into very narrow fissure abysses ("Dračí propast") and lead overhead into the "Sibiř" gorge or the "Anenské údolí" valley. The fissure zones are influenced by the extensive destruction of the original rock massif, in turn resulting in the formation of deep block accumulations, which are typical for the middle and southern part of NW plateau's edge. The multilevel systems of debris caves were created in these block debris (e.g. "Bloková chodba"), and they run through the fissure zones up to the edge of the massif.

Poseidon III

The northern boundary is represented by the fissure, which was created at the same line as the fissure near the "Hláska" tower. The southern boundary is represented by fissures and debris caves near the "Pavlač" tower. The Poseidon III and adjoining Poseidon II are separated by a very narrow gorge - "Sibiř" (Siberia). Moreover, the lower part of the gorge is covered with block debris, which forms the cave space. The total denivelation is 90 m. The lowest place (605 m a.s.l.) is identical with the lowest place of the Poseidon II. The highest place (695 m a.s.l.) can be found in the fissure abyss in the "Pavlač" tower.

Extensive block accumulations containing debris caves prevail in this part of the system. The block debris descends into the deep depressions in the fissure zones. The fissure caves (abysses) change gradually into open fissures on the edge of the massif. A series of extensive underground spaces ("Sluj u vyhlídky", "Pavoučí jeskyňe"), and also smaller caves ("Kyklop", "Ztracenka", "Sluj Gorgon") are formed in the block debris.

Life in Poseidon

Root stalagmites

Poseidon system is rich in root stalagmites (Fig. 8). The first record of a root stalagmite in the Czech Republic was documented here, in the Kořenka cave, and the highest root stalagmite, reaching 60 cm, was also documented here. We registered here recently 67 root forms in 19 localities.

Fig. 8. The root stalagmite (25 cm) and stalagmite (31 cm). Photo by R. Mlejnek.

Montane species

The local flora of the Adršpašsko-Teplické Skály rock complex contains 326 species (Sýkora & Hadač 1984). Montane species occur here at low altitudes, e.g.

Homogyne alpina (L.) Cassini, 1821, *Cicerbita alpina* (L.) Wallroth, 1822, *Viola biflora* L., 1753, due to the climatic inversion in deep gorges.

The arachnofauna of the "Adršpašsko-teplické skály" rock complex was studied by Ružička (1992) and Růžička & Kopecký (1994). Recently, we registered 75 spider species in the Poseidon system. *Anguliphantes tripartitus* (Miller & SvatoH, 1978) is a typical mountain species.

Hamet & Vancl (2005) cataloguised the beetles of the "Broumovsko" Protected Landcape Area. *Trechus striatulus* Putzeys, 1847 and *Carabus sylvestris sylvestris* Panzer, 1793 represent typical mountain species. Mountain *Leptusa flavicornis* Brancsik, 1874 was collected quite recently.

Glacial relicts

We registered four spider species and one mite species with a typical disjunct distribution in the Poseidon system.

Having a distribution centre in Siberia/North Asia, *Bathyphantes eumenis eumenis* (L. Koch, 1879) occur only in the region of sandstone rocks along the Czech-Polish border in Central Europe. Its occurrence was firstly recorded here in Poland (1984), then in Bohemia (1986). This fully pigmented subspecies colonise here in masses moist, cold, shady rock surfaces in deep gorges, fissures, and caves (Růžička 1992). The depigmented and long-legged subspecies *Bathyphantes eumenis buchari* Růžička, 1988, adapted to life in subterranean spaces, inhabits the deep layers of scree slopes in the whole Central Europe just before the Alps (Růžička 1994).

The main subarea of three spider species, viz. *Diplocentria bidentata* (Emerton, 1882), *Oreonetides vaginatus* (Thorell, 1872), and *Sisicus apertus* (Holm, 1939), is in boreal forests. In the Poseidon system, they were usually collected in the coldest part, in the "Sibiř" gorge.

The "Sibiř" gorge in the Poseidon system was the place of the first recording of the northern predatory mite *Rhagidia gelida* Thorell, 1872 in Central Europe (1986); up to that time, this species was known to occur above the arctic circle only. The material served for the detailed redescription of the species (Zacharda 1993).

Discussion

Chabert and Courbon (1997) presented data on the longest European pseudokarst systems in sandstones. The system "grotte de Pézenas" (grotte de Pisenas) in France is 5,850 m long and the cave "cova del Serrat del Vent" in Spain is 4,273 m.

The spider *Sisicus apertus* (Holm, 1939) is widely distributed in the boreal forests of Alaska, Canada, Siberia, Scandinavia, and Estonia up to the northernmost section of Poland. In Central Europe, this species was recorded only in the Alps and in High Tatras in moss and screes at an altitude of 1,150-2,300 m. In the Poseidon system, it occurs at an altitude of 600 m. The remaining four glacial relicts and other cold adapted species occur in the Czech Republic either in higher altitudes, or on the lower margin of scree slopes with ice formation (Zacharda et al. 2007; Růžička & Klimeš 2005). *Rhagidia gelida* is considered to be an indicator of permanently frozen cor in scree slopes with ice formation at an altitude of 300-600 m (Zacharda et al. 2005).

Conclusions

The Poseidon system, which is the pseudokarst system that was developed in sandstones in NE Bohemia, is described. The fissure labyrinths, abysses, and block accumulations can be found in an area of approx. 26,800 m². The total length of the man-accessible underground spaces of the Poseidon system is at least 27.5 km. The vertical range amounts 105 m.

Thanks to its enormous dimensions, the Poseidon system is able to store an inside cold microclimate. This cold microclimate enables the occurrence of cold adapted plants and invertebrate animals, five glacial relicts included. Sandstone rock labyrinths in the "Broumovsko" Protected Landscape Area, and especially the Poseidon system, should be classified among the habitats, that support the occurrence of cold adapted mountain and boreal species at lower altitudes in the temperate zone of Central Europe.

By its structure, microclimate and communities of cold adapted organisms, the Poseidon system represents an important object in speleology, geomorphology, biology, and nature conservation.

Acknowledgements

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MITTELALTERLICHE HÖHLENMÜNSTER IN UNGARN

ISTVÁN ESZTERHÁS[1]

Abstract:
Mediaeval Cave-monasteries in Hungary
The Author gives a presentation and comparation of the mediaeval monasteries in Hungary, which were created in caves and artificial cavities. In Hungary, according to our present knowledge are three groups of cavities, which were used as underground monasteries. These are the Monk-Dwellings in Tihany, the Hermiteges in Nagymaros and Hermiteges in Szentkút. The three location are quite a distant from each other, however their appearence and history are very similar. They were built e.g. carved in the hillsides along one line and their entrances are very closed to each other. These smaller monasteries were composed of chapels, refectoriums, living-cells, stores and workshops. They were supervised by the adjacent higher Church authority. They legal activity was limited between the 10th and the 14th century. After that period only few eremites and zealous belivers continoued their life in these cavities. Recently these remains are relatively demolised and ruined. A legal protection tries to secure their conservation.

Schlüsselswörte (Key words): Höhlenmünster, ausgemeisselte Rume, Felsenkirche, Wohnzelle, basilionische und benediktinische Mönche, Einsiedler

Einleitung

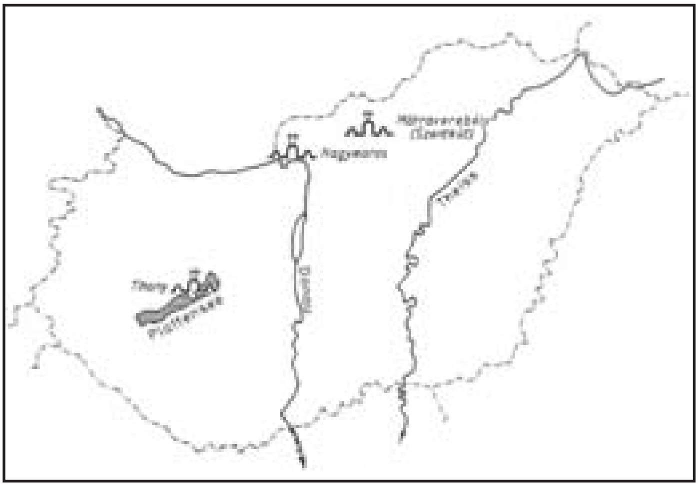

Abb. 1.
Lage der ungarischen Höhlenmünster.

Die Verbindung zwischen den Höhlen und der Menschheit ist schon seit sehr langer Zeit bekannt. Die Dunkelheit oder das Halbdunkel der Höhle gibt ihr etwas Geheimnisvolles, das mit dem griechischen Wort Mystik zu umschreiben ist. Das Wort Mystik steht nicht nur

[1] Prsident der Pseudokarst Kommission der UIS, Köztársaság u. 157,
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für Geheimnisse, sondern auch für eine Fühlungnahme mit übernatürlichen Geschöpfen. Neben dem Geheimnisvollen steht jedoch auch ahnungsvolle Ttigkeit der Eingeweihten. Die Verbindung zwischen dem Höhlenmilieu und der Religionspraxis zeigt sich so in der Wirklichkeit wie in der Etimologie.

Religionspraktiken in Höhlen gibt es schon seit Urzeiten. Prhistorische Otrte mit Höhlenritualen kennen wir von auslndischen Funden. Mehrere Beispiele von Höhlenbestattungen und ihren Ritualen kennt man sowohl aus dem Ausland wie auch aus Ungarn. Wenn unsere Ahnen keine angemessenen natürlichen Höhlen für ihre Religionspraxis antrafen, so schufen sie diese selbst. In smtlichen Gegenden der Erde, von Asien über Europa bis nach Amerika kennt man Höhlenheiligtümer, welche aus verschiedenen Zeiten und Religionsgemeinschaften herrühren (KUSCH 1993). Es sollte genügen, wenn ich auf gyptische Felsenkirchen, auf die chinesische Longman-Höhlen mit ihren zehntausend Buddhadenkmlern oder auf die kleinasiatische Kappadokein-Höhlengruppe verweise.

Auch in Ungarn kennen wir natürliche Höhlen und künstliche Rume, in denen Felsenheiligtümer errichtet wurden, auch wenn diese keine Weltsensation darstellen wegen ihrer geringen Ausmasse und da sie kaum sehenswert sind. Die meisten sind in ziemlich verwünstetem Zustand. In Ungarn gibt es etwa 15 kultische Höhlen und künstliche Hohlrme. Unter diesen befinden sich drei christliche Höhlenmünster (Abb.1.), welche eine Gruppe bilden, die übrigen waren Lebenspltze kleinerer religiöser Gemeinschaften (ESZTERHÁS 2004).

Mönchwohnungen bei Tihany

Orosz-kõ (Russenstein) nennt man die nördliche Felswand des Óvár-tetõ-s (Altburgplateau) auf der Tihanyer-Halbinsel. In dieser gibt es eine Raumgruppe, die Barátlakások (Mönchwohnungen) heissen (Abb. 2.). Über ihre Entstehungszeit gibt es keine Überlieferung. Es gibt einen Hinweis, wonach der mhrische Fürst Rastislav (846-870) Mönche in sein Imperium rief, welche die Rume aus dem Fels gehauen haben, und der bulgarische Bischof Method - einer Gründer der slawischen Schrift - traf bereits zur Zeit seines Besuches (869) ein blühendes Kirchenleben an. Flóris RÓMER (1868) und László ERDÉLYI (1908) waren der Auffassung, dass das Wort "Petra" aus dem Tihanyer Gründerbrief mit den Mönchwohnungen gleichzusetzen ist ("Est in eodem lacu locus qui vocatur Petra cum ceretis inibi pertnens"), welches Dokument König Endre I. im Jahr 1055 ausfertige. Die Ausdrücke

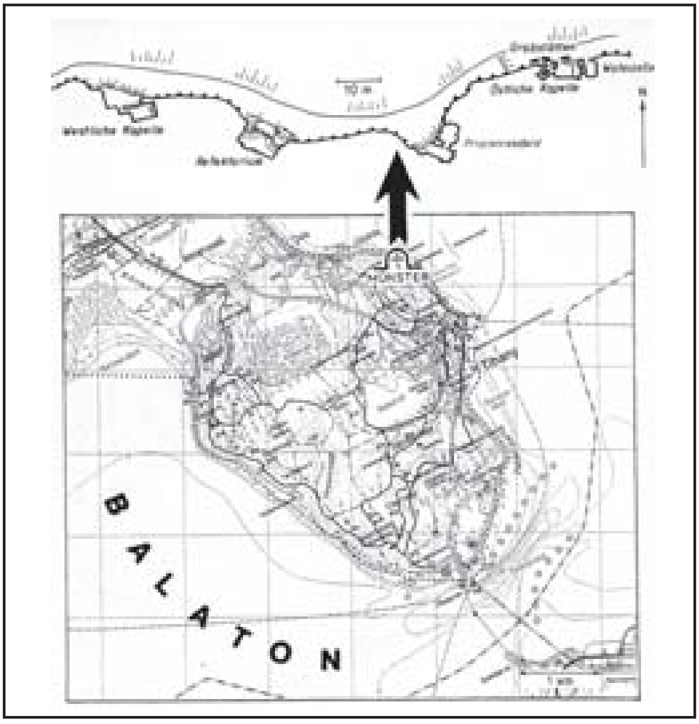

Abb. 2: Plan der Mönchwohnungen bei Tihany.

“petra” und “petro” kan man aus dem altgriechischen Wort “petros” ableiten, was den Stein bedeutet, und so das auf der Verbindung zum Stein weist. Eine berühmte altertümliche Stadt Jordaniens heisst ebenfalls “Petra”, welche aus Stein gehauen ist. Diese Forscher halten es für wahrscheinlich, dass König Endre I. auf Wunsch seiner russischstmmigen Frau jene orthodoxen Mönche herbei rief, welche die Siedlung anlegten. Eine ungefhre Zeitbestimmung ist möglich durch eine Kupfermünze aus der Zeit des Königs Béla III. (1172-1196), welche András UZSOKI im Jahr 1984 in der Grabkammer einer Zelle fand. Danach gibt es eine schriftliche Überlieferung aus dem Jahr 1211, der besitzanzeigende Brief des Königs Endre II. erwhnt ausser der Tihanyer Sankt-Kelemen-Basilika auch die Orosz-kõer Sankt-Nikolaus-Kirche (“Ecclesia Beati Nicholai de Horozcueh”). Die Dokumente zwischen 1211 und 1339 erwhnen die Tihanyer Sankt-Nikolaus-Kirche stndig, die Namen der Prioren, welche die Gemeinschaft leiteten, sind aufgezhlt, spter verlor sich ihre Bekanntheit. Das Münster wurde von griechisch-orthodoxen Mönchen unter der Aufsicht des Benediktinischen Ordens geleitet. Dies wird bestrkt durch die 1. und 2. Bulle des Papstes Kelemen IV. aus dem Jahr 1267, welcher das Tihanyer Benediktinische Münster und die Orosz-kõer Klausnerei unter seinen Schutz nahm (DORNYAY 1942, UZSOKI 1984). Ein Verzeichnis des Königs Sankt Ladislaus aus 1390 erwhnt nicht, dass Orosz-kõ zu dieser Zeit bewohnt war.

Es gilt als wahrscheinlich, dass ein grosser Felssturz zwischen 1339 und 1390 das Münster unbewohnbar machte. Die Bergstürze wiederholten sich mehrfach, so um das Jahr 1810, spter in 1859 und zuletzt im Jahr 1952. Zu dieser Zeit wurden einige Rume des alten Münters vernichtet. Nun gibt es noch fünf aus dem Basalttuff gehauene Rume, von denen anzunehmen ist, dass diese zum Münster gehörten (CSEMEGI 1944-48, ESZTERHÁS 1987, FÜSSY 1900, SÖRÖS 1911). Weiterhin gibt es noch zwei Rume, die Leánylakások (Mdchenwohnungen), welche aber wahrscheinlich jünger sind. Wir wissen nicht, wie viele Rume das Münster ursprünglich hatte, aber in der Schrift von Mathias BÉL (1737) kommen noch 10 vor. Die Zellen bildet Flóris RÓMER (1868) noch bis zum Plafond reichend mit den Frontmauern ab, auch auf dem Plan von Jenõ CHOLNOKY (1932) sind Vorrme abgebildet, welche seit jener Zeit schon teilweise eingestürzt sind. Die Rume, welche benediktinische histoische Zeitzeugen darstellen, werden nicht nur durch Felssturz verwüstet, sondern auch durch verantwortungsolse Menschen beschdigt. Die mutwilligen Beschdigungen hat schon der Wiener Archologieprofessor EITELBERGER im Jahre 1856 erwhnt, welche sich bis heute fortsetzen.

An bekannten Rumen gab es zwei Kapellen, in der ersten konnte man einen bemalten

Abb. 3: Vorraum der mittelalterlichen Westlichen Kapelle in Tihany.

Abb. 4: Front des mittelalterlichen Priorenresidenzes in Tihany.

Mörtelrest und einen Altar finden (Abb. 3.), im andern gibt es Grabhöhlungen. Beide besitzen eine östliche Orientierung. Ferner könnte eine grössere Zelle das Refektorium sein, welche halb von Schutt ausgefüllt ist. Einen anderen grösseren geteilten Raum halten wir für die Priorenresidenz (Abb. 4.). Ein kleinerer Raum kann eine einfache Wohnzelle sein. Die archologischen Grabungen von DORNYAY (1942) und UZSOKI (1984) haben Grabhöhlen mit Skeletten zum Vorschein gebracht, ferner sind Gebrauchsgegenstnde (Mörser, Keramikbruchstücke, Glasscherben, Knochenpfeifen etc.) und viele Holunderkerne, Muschelschalen (Congeria ungula capre), ferner das vorerwhnte Kupfergeld gefunden worden.

Einsiedlerhöhlen bei Nagymaros

Der Sankt-Michael-Berg erhebt sich beim Dorf Nagymaros in der grossen Schleife der Donau (Abb. 5.). Im südlichen Hang dieses Berges befinden sich die Remete-barlangok (Einsiedlerhöhlen). Diese Höhlen sind teils natürlichen Ursprungs, teils wurden sie von Menschenhand erweitert. Mit der Umformung der Höhlen begann man mit grosser Wahrscheinlichkeit in römischer Zeit. Zu jener Zeit errichtete man eine Befestigung aus Stein vor den Rumen, deren Überreste bis heute erhalten sind. Die römische Anwesenheit besttigen auch die archologischen Grabungen von László ZOLNAY. Es ist auch in diesem Fall unsicher, seit wann die Höhle als Münster benutzt und umgestaltet wurde. Wir wissen nur, dass König Endre I. ein russisches basilionisches Münster für den byzantiliturgischen Vasul-Orden im Jahr 1053 im nahen Visegrád gründete, ferner Prinz Álmos, Bruder des Königes Koloman der Bücherfreund eine benediktinische Propstei im Jahr 1101 auch nahe Dömös errichtete, welche die Einsiedelei auf dem gegenüberliegenden Hang ins Leben rief. Lajos KOLACSKOVSZKY schrieb im Jahr 1938: “Die Kampflinie in der Umgebung Zebeénys wurde durch die neuen Mönche gestrkt. Sie lebten entsprechend den stregen Regeln des Sankt Benedikt und zogen die Einsamkeit der wilden Wlder dem geselligen Klosterleben

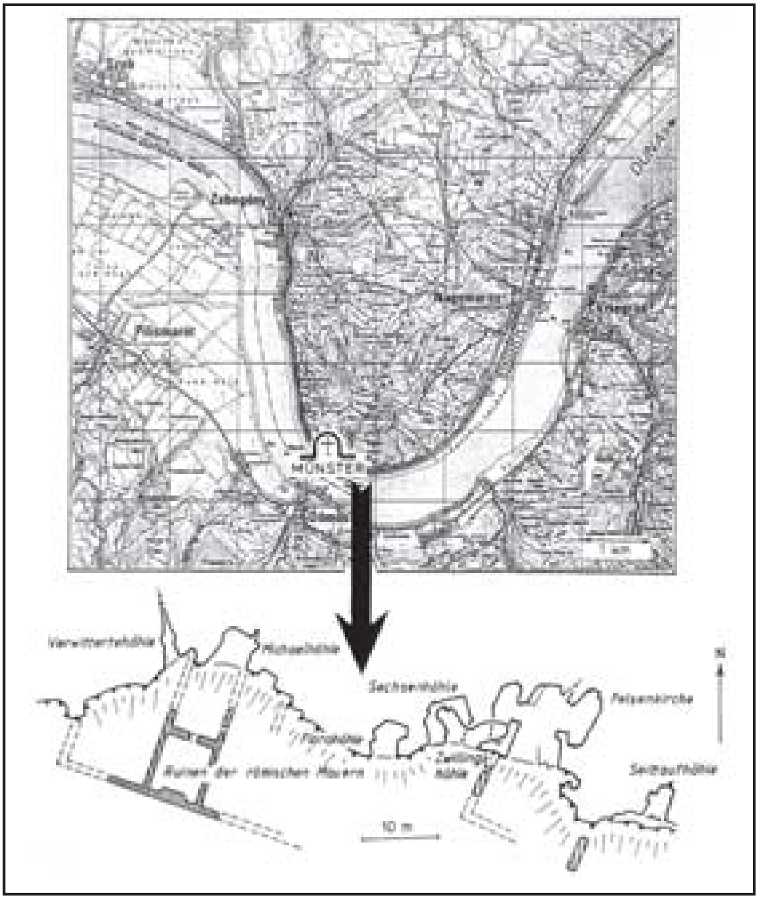

Abb. 5: Plan der Einsiedlerhöhlen bei Nagymaros

Abb. 6: Innerraum der Nagymaroser Felsenkirche

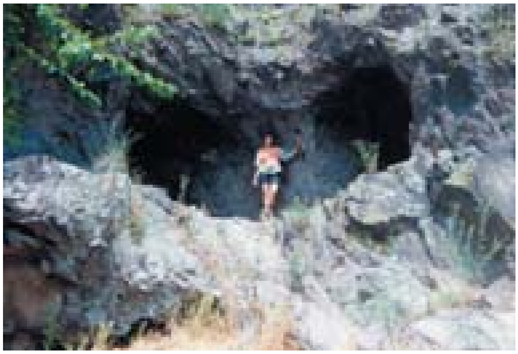

Abb. 7: Zwillingshöhle im Hang des Sankt-Michael-Berges

allemal vor. Man nannte sie gewöhnlich Olivetaner (nach dem Oliveti-Berg bei Siena, wo das erste Ordenshaus stand). Sie lebten am Hang des Sankt-Michael-Berges als Einsiedler, welcher sich nach dem Dorf Dömös erstreckt, und in den Tiefen der dortigen Höhlen teilten sie ihre Lagerstttten mit den wilden Tieren des Waldes gemss ihrer religiösen Anschauung..." Laut den Einwohnern von Dömös lebte auch in den Jahren nach 1800 ein "gottesfürchtiger Mann" in den Höhlen, dessen Esel nach der Sage ihm das Wasser aus der Donau hinauf trug (ESZTERHÁS 1999, KOLACS-KOVSZKY 1938, PÁPA 1943), aber dies wurde weder durch die Unter-suchungen von Flóris RÓMER (1868), noch durch die Ortsnamenssammlung von Frigyes PESTHY (1875) besttigt.

In 220-230 m Höhe im Sankt-Michael-Berg befinden sich 10 Höhlen in einer Gruppe. In den mittleren 5 Höhlen sind Spuren der Umformung (Einbuchtungen, Zellen, Löcher) zu sehen (Abb. 6.). Die grössten Umgestaltungen sind in der Sziklatemplom (Felsenkirche) zu sehen, in der die Wnde des Mittelschiffes geebnet, der Plafond zum Gewölbe ausgestaltet und beide Seitenschiffe völlig künstlich sind. Am Ende des rechtes Seitenschiffes gibt es eine Zelle, in der Spuren eines alten Wandgemldes unter der neuzeitlichen Graffiti auszumachen sind. Die Mihály-barlang (Michaelshöhle) konnte meiner Meinung nach ein Platz für die Allgemeinheit sein, die weiteren Rume waren wahrscheinlich Wohnzellen (Abb. 7.), obgleich diese Funktion unmöglich sicher zu belegen ist.

Einsiedlerhöhlen bei Szentkút

Szentkút ist ein alleinstehender Siedlungsteil östlicher der Flur des Dorfes Mátraverebély am Fuss des Meszes-Gipfels. Im südlichen Hang des Meszes-Gipfels gibt es eine Gruppe künstlicher Rume, die als Szentkúti-remetebarlangok (Einsiedlerhöhlen bei Szentkút) bekannt sind, aber auch diese enthalten ein kleines Münster, genannt Zönobium (Abb. 8.). Nach geomorphologischen Untersuchungen ist es sehr wahrscheinlich, dass es auch natürliche Höhlen in diesem Teil des Hanges gab, die jedoch aufgrund der Vernderung der Gelndeoberflche und der Erweiterung der Rume nicht mehr sichtbar sind. Der Beginn der Ausgestaltung der Rume versinkt auch in diesem Falle im Dunkel der Vergangenheit (ROZNIK 1948). Die erste konkrete Angabe ist aus 1757 bekannt, wonach ein Mönch, names Antal Belák die Höhlenbauwerke mit seinen Gefhrten restaurierte (DAMÓ 1998). Demnach bestanden diese bereits früher, bedurften zu dieser Zeit jedoch der Erneuerung. Aus früherer Zeit gibt es nur Angaben über das Höhlenmünster bei Szentkút, die mit diesen Bauwerken aber nur in losem Zusammenhang stehen. Demnach gründete König Béla II. (der Blinde) ein benediktinisches Kloster in der nahen Stadt Pásztó im Jahr 1134, bald darauf begann Imre Vereb-s Sohn des örtlichen Besitzers ein Einsiedlerleben um 1231 auf dem eigenen Besitz. Die Einsiedler verbargen das Altarbild der zerstörten Verebély-Kirche im 15. Jh. und beerdigten die vielen Toten im Jahr 1604 nach dem Feldzug der Heiducken (DAMÓ 1998). Der letzte "Berufseinsiedler" des Felsenmünsters war Jozafát Dobáth, der 1767 starb und in der Kirche Szentkút-Kelch beerdigt wurde. Spter, bis Mitte des 20. Jahrhunderts, gab es ein paar unternehmungslustige Mnner, die das Einsiedlerleben auf dem Meszes-Gipfel whlten.

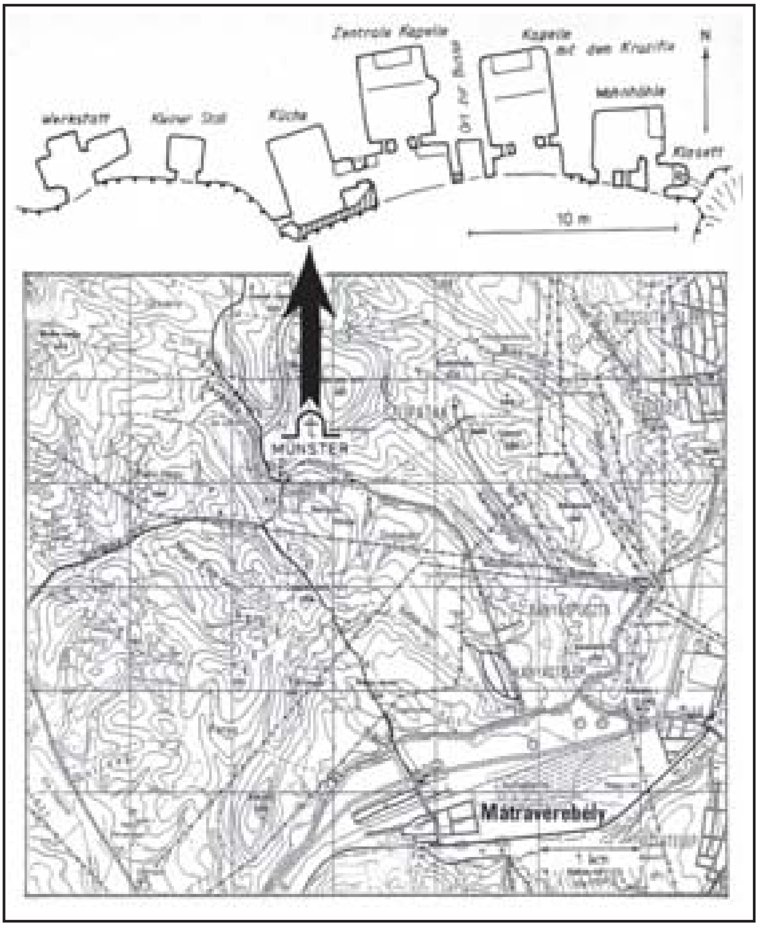

Abb. 8: Plan der Einsiedlerhöhlen bei Szentkút

Die Gruppe der Höh-

Abb. 9: Front der zentralen Kapelle im Hang des Meszes-Gipfels

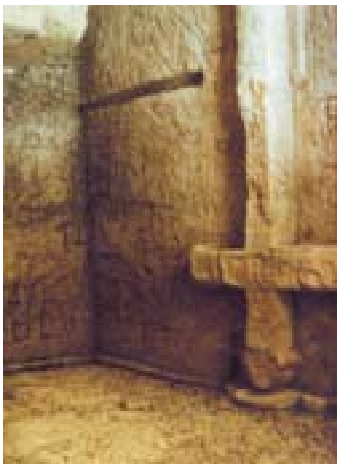

Abb. 10: Kruzifix an der Hauptwand der einen Szentkúter Kapelle

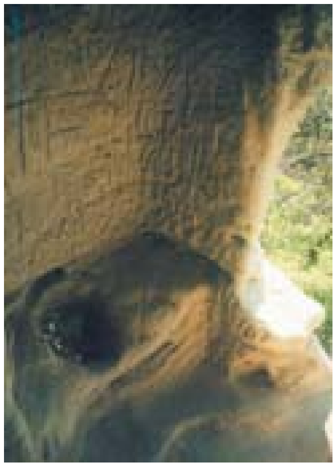

Abb. 11: Das Steinklosett ist der Teil der Szentkúter Einsiedler höhlen

len bei Szentkút enthlt derzeit sieben Rume (von West nach Ost: Werkstatt, kleiner Stall, aus dem gemeinsamen Vorraum heraus Küche und zentrale Kapelle, ein Ort zur Busse - früher vielleicht Ikonostas, eine Kapelle mit Kruzifix, und die Wohnhöhle mit Klosett - Siehe Abb. 8.). Die ersten zwei Rume sind anspruchslose fensterlose Zellen, die übrigen Rume sind mit hochgradigem technischem Wissen und verfeinertem sthetischen Sinn ausgemeisselte Stuben (Abb. 9. und 10.). Es ist zu bedauern, dass die Monogramme der kulturlosen Besucher beinahe alle Wandflchen vom Kruzifix des Altars bis zum Sitz des Klosetts bedecken (Abb. 11.). Dieser bedeutende Ort der Kirchengeschichte wurde im Jahr 1996 teilweise renoviert.

Vergleich

Die drei mittelalterlichen Höhlenmünster Ungarns hneln sich auch in ihren Positionen, in ihren Formen und in ihrer Historie (Abb. 12.). Alle befinden sich in steilen Hngen aus Tuff, Agglomerat und Sandstein, welche Gesteine leicht zu bearbeiten sind. Die Rume befinden sich in einer Reihe, davon weicht nur die Höhle auf dem Sankt-Michael-Berg etwas ab. Die Zahl der Rume ist relativ klein, zwischen 7 und 10, und dürfte auch zu Zeiten ihrer Unversehrtheit nicht mehr als doppelte betragen haben. Hier ist also von kleinen Münster die Rede, diese waren als "Zweiganstalten", lateinisch als Zönobium, laut dem Wortgebrauch der östlichen Kirche als Laura unter der Aufsicht eines nahen grösseren Münsters. Unter den ausgeformten oder umgeformten Rumen gab es ein oder zwei Kapellen, Gemeinschaftsorte, Ikonostasen, Wohnzellen und Depots. Ihre Geschichte begann kurz nach dem Erstarken des Christentums (ca. 900-1000). Die Rume haben forthin basilionische Mönche der östlichen Kirche für kirchliche Zwecke ausgeformt und eingerichtet. Spter, nach dem Kirchenschisma (1056) übernahmen die Benediktiner diese Münster und fortan wirkten hier östliche und westliche Lehren verkündende Mönche bis zur Zeit des ungarischen Mongolensturms (1241). Nach dem Mongolensturm waren das Tihanyer und das Nagymaroser Mün-

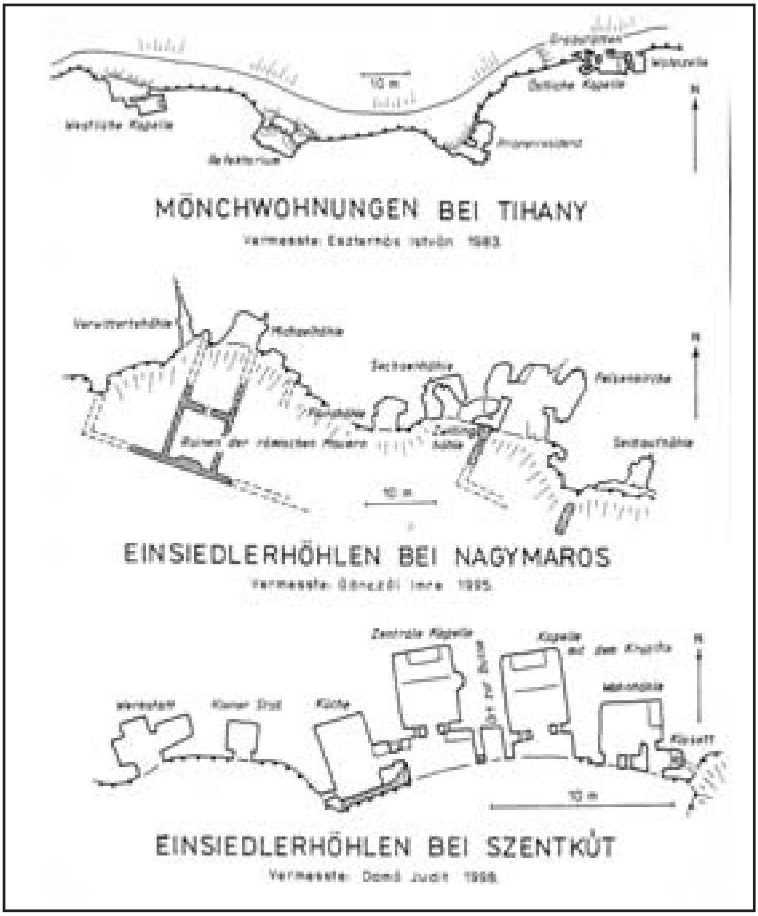

Abb. 12: Die Plne der drei Höhlenmünster zum Vergleich

ster unter der Aufsicht der Benediktiner, das Szentkúter Münster beaufsichtigen die Zisterzienser, die es aber bald wieder verliessen, da die römische Kirche die Einsiedelei nicht mehr gutheissen wollte. Das organisierte Kirchenleben der Höhlenmünster hielt zirka bis ins 14-15. Jahrhundert an. Einige Mönche und gottesfürchtige Glubige fanden sich auch noch spterhin, die das Eisiedlerleben in den Ruinen der Höhlenmünster freiwillig auf sich nahmen.

Schlussgedanke

Die Spelologie ist eine synthetisierende Wissenschaft, die sich zur Untersuchung der veschiedenen Rume zahlreicher Wissenszweige bedient. Für die Foschungen an den Höhlenkirchen stützte ich mich auf die Methoden früherer Untersuchungen aus der Geologie, Geographie, Archologie, Geschichte und weiterer Fachgebiete. Aus diesem Grund möchte ich hier ein breiteres Schema der jetzigen Kenntnis und Bedeutung der ungarischen Höhlenmünster geben.

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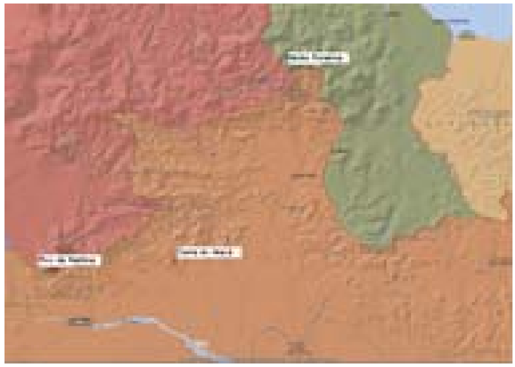
GEOLOGY AND GEOMORPHOLOGY ASPECTS OF THE DEEPEST QUARTZITE CAVE IN THE WORLD (AMAZON, BRAZIL)

SORAYA AYUB [1]

Summary - After the results of four years of research and recognition in a territory with more difficulty: the Amazon, the staff of AKAKOR GEOGRAPHICAL EXPLORING has been discovered some caves located in a Brazilian plateau with medium altitudes of 1300 meters a. s. l. One of these caves is the Guy Collet Abyss (670 metres), which is the deepest cave in South America and the deepest in the world in quartzite rocks.



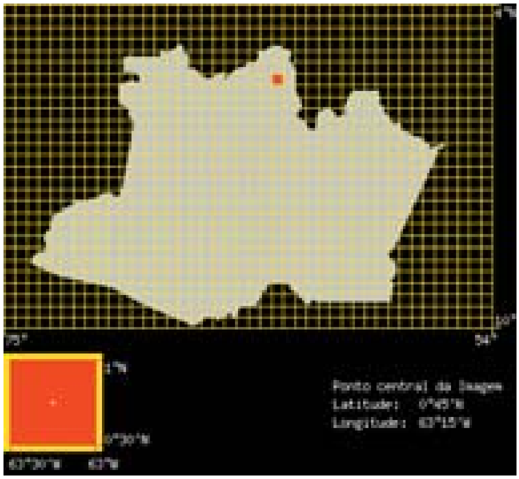


Figure 1, 2, 3, 4 e 5
Localizzazione dell'area di studio

"Serra do Aracá" is a Brazilian *tepuys* and is located in the north-west of the Amazon State, in the border between Venezuela and Brazil.

"Serra do Aracá" belong to the Neblina's filed, with deposition after to the Super-group Roraima.

The development of the complex is a little more than 800 meters and it can be said that the cave is a single channel with only one piece of positive inclination, with few branches

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and many wells.

Introduction - In recent years Venezuela has become famous in the caving research after the discovery of surface and underground karstic area on the quartz plateaus.

Since 1993, with the "La Venta" team, many cavers have realized research on Venezuelans' *tepuys*.

In 2004 Charles Brener-Carias discovered the biggest quartzite cave in the world.

In 2006 an expedition called "Amazon 2006" has been done at Brazilian tepuys and during which it is discovered *"Abyss Guy Collet"*, who reveals at the end of topographical analysis to be the deepest cave in South America and most profound of the world in quartzite rocks.

During the expedition was given a series of geological and geomorphologic observations and here we explain the first results. In the future, we are going to do a set of publications, when it will be possible to collected samples of rocks and water on the ground.

The area of study has been always reached with the help of boats and then with climbing into the forest, spending every time about 6 days only for the rapprochement.

In these years many authors are studying the genetic phenomena in rocks until then recognized as insoluble. In the last period was discovered the biggest, Charles Brener (in Venezuela), and deepest, Abyss Guy Collet, caves in the world made of quartz; in the case of the last one it's important to underline that the discovery has been done for the first time in Brazilian's country.

The access of the *tepuys,* at Brazilian and Venezuelan side, is difficult and in the case of Serra do Aracà the rapprochement of the top takes many time.

This is an area completely isolated and unexplored, not only as speleological way, demonstrating the existence of great underground systems below the surface of the *tepuys.*

Geographical location

"Serra do Aracá" is a Brazilian tepuys and is located at north-west of the State of Amazonas, on the border between Venezuela and Brazil, between the coordinates 63°19'41" - 63°21' longitude West and 0°51'38" - 0°52'12" latitude North.

This area is within the State Park of the Serra do Aracá, town of Barcelos, founded in March 1990 (Decree 12836). The park takes its name from the river Aracá, which creates the homonymous waterfall (365 meters a.s.l.)

To reach the area of study, you need take a ship or a plane from Manaus to Barcelos, then others 3 - 4 days by boat and at the end by walk for another 2 days in the forest. Having the opportunity you can reach the Serra by helicopter from Manaus.

The civilization on the Serra do Aracá is completely absent and the indigenous areas are very remote. The access to these places is very difficult and needed a complex logistics shipment.

Geomorphology

The Serra is a plateau at tabular structure ("tepuys" means "table" in Macuxi indigenous language), isolated testimony of geological formation of Mount Roraima (coverage post-Roraima), and is the Southern tepuys of Amazon region, with characteristics similar to the Pico da Neblina.

The "Serra do Aracá" is part of *Guyana Shield*, portion of the South American craton, with the oldest rocks of the earth's surface. They are pre-Cambrian, igneous and ultra-metamorphic, appear in the central portion of the Shield and have an age coming to 3.5 Ga

These lands have been called in 1915 "Brazilian Complex", by J. C. Branner; they are also named as crystalline basement.

The average altitude of the plateau is around 1300 meters, with the highest elevations around 1500 m located in the north-west sector (the maximum altitudes are indicative because there are no topographical maps of the area).

Geology

The whole area of tepuys is known by Venezuelans as "Gran Sabana," and presents vegetation as savannah, with medium altitudes between 1050 and 1300 meters a.s.l.

The rocks of the study area are silicon-clastics as quartzites ortoquartzites and quartz-sandstones, with grained form media to thin, color from white to yellow. They are very heterogeneous, worked by weathering conditions and have many veins of quartz. Due to the great diversity of rocks, the degree of erosion is very high, but this is not only a genetic-erosive but also a dissolution process. The age of these sedimentary rocks are between 1.70 to 1.33 Ga .

The rocks of the basement of the Aracá have not yet a limit well defined. These rocks are granite, granodioriti and tonaliti bands, grouped in Cauaburi Complex, which have granitei parts inclusions of the suite Igarapé Reilau, Rio Içana, Marauiá, Uaupés, Tiquié, Marié-Mirim and Tapuruquara.

The granite rocks like *Uaupé* (1.55 Ga) and *Marauiá* (1652 ± 57, Rb-Sr), when influenced by *K'Mudku* fractures (1.33 Ga), are difficult to distinguish from graniti like Cauaburi. There were no defined criteria (structural and composition) to distinguish the rocks from the units and for this there are many differences between the maps of the region. The basement appears very well in Venezuela and therefore there are few problems.

Stratigraphy

Some stratigraphical units called Tunuí, Aracá, Neblina and Daraã are isolated testimonies of Roraima formation. These units have in common the Lithologic constitution and the same stratigraphic position. They are essentially units of sandstone and river origin, where the main system is meanders. A part Tunuí Group, the units have been correlated and identified with the Roraima Super-Group (Pinheiro *et al.* 1976; Montalvão *et al.* 1975; Giffoni and Abraão, 1969; Giovannini and Larizzatti, 1994). The area of Serra do Aracá, from the top to bottom of the plateau appear exclusively rocks that belong to Roraima Group.

The dating of Roraima Super-Group deposition rocks in 1875 ± 5 Ma (age of two layers of tuff interspersed with Uaimapué formation; Santos *et al.* 2003b) and Cauaburi Complex (1810 to 1796 Ma; Santos *et al.* 2003b) has determined that the units Tunuí, Neblina, Daraã and Aracá, located over the Cauaburi Complex , can not be oldest than 1796 Ma. This fact shows the impossibility of correlation with Roraima Super-Group, because they are at least 75-80 Ma younger. Santos *et al.* (2003b) and Bizzi et al (2003) suggest that the units Tunuí, Neblina, Aracá, Serra Surucucus and Daraã are part of a later basin of Roraima Super-Group, called Basin Neblina.

In the area the lithologic observations made on the cavity have recognized a variety of facies, more than it appears on the surface, due to weathering conditions that modify the rocks outside the cave. This event makes difficult the observations of the fabric facture and structural character from Lithologic point of view in the surface area.

At the limit of the cave has been recognized and described that the entry was originated by erosive processes in the families of cross fractures, there exist and so this event has opened the abyss. The lithology surface and the first 10-20 meters are quartz-sandstones of dark gray color, with layers and banks from decimeter to meter with a grain from medium to thin.

Along the walls in direction to the bottom of the cave, the rocks appear less altered and concludes that the abyss has been dug in compact quartz-sandstone with color from white to cream, inserted by bands of ochre color.

Tectonic setting

Due the logistic problems of the inhospitable research zone, where many days are needed only for reaching the cave, we have been done few stations for measures the direction of the fractures.

At the base we have observed many vertical fractures systems that divide the plateau into blocks of quadrilateral forms, while the bedding stratification is constantly horizontal with inclinations very low, approximately imperceptible.

The main fractures have NE – SW direction and along these families of fractures is developed the Abyss Guy Collet.

Abyss Guy Collet surface morphology'

In 1912, Arthur Conan Doyle wrote the book "The Lost World" describing the plateau of *tepuys* as a place isolated from the rest of the world. Doyle, to write his book, has used the report of the botanist Everard Im Thurn, that was the first man to reach the top of the legendary Roraima Mount in 1884, from the Venezuelan side.

Romance a part, the reality is that the *Serra do Aracá* is remained static from tectonic point of view (from the end of Cretaceous) and where there are only atmospheric phenomena that processing the morphological evolution. The plateau's surface was formed in the Jurassic and presents a low inclination across the area that reduces the erosive processes.

It is noted that to begin the genesis of caves, it needs the dissolution of siliceous cement content in quartz-rocks, and this involves long periods. Once the rocks are disrupted by erosive and dissolution processes, the waters carrying away the resulting material.

This idea is recovered from Urbani (1986) and Piccini (1994), where, in their research on Venezuelans tepuys, they had already identified forms and processes that could no be classified as pseudo-karst.

The mechanisms of karst genesis in silicon-clastic rocks are not yet totally clear, but with the latest discoveries in *Abyss Guy Collet* and in *Charles Brenner cave* appear data of speleo-themes and real karst forms.

Despite the presence in all *tepuys* of *"simas"* (large yawn in closed perimeter usually elongated in the direction of fractures from which have originated and presenting a circular entry) *Abyss Guy Collet* has a chapel entry-shaped and this is a single abyss, with nine wells at 90 °, in a very short development of just 900 metres. This is not a real "sima", because its widths are small, but the process of genesis is similar to this phenomenon in initial phase.

Abyss Guy Collet is approximately 300 meters from the platform's edge and it is an early stage of formation of shelves erosion between the platform's surface of Serra do Aracá, where there is the entry, and the bottom of the valley. Along the tectonic fractures and thanks to an erosive process, the cave was opened following collapsing events.

Infact, between the Tatunca Nara's well and the Akakor's well there is an extremely dangerous conduit and during the expedition *"Amazon 2006"*, it has risked for the safety of speleologists, for landslides and large blocks collapsing. It means that in that area, the cave is opening up and when will reach the surface will become a *"sima"*. The collapsed material or the boulders that obstruct the way are disaggregated by rain water that flowing in the direction of the bottom.

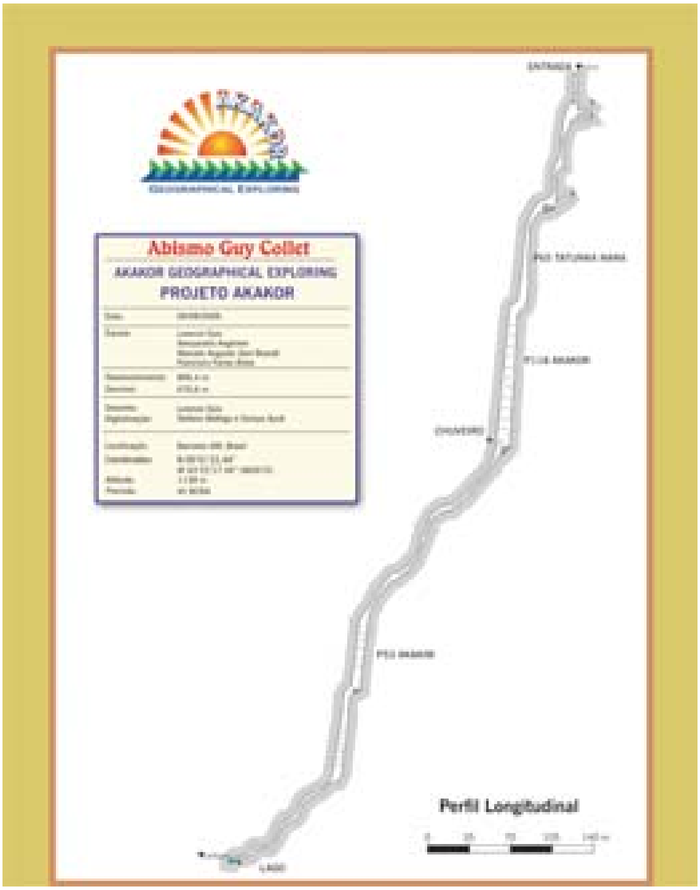
The drainage of the bottom is formed from water infiltration that found a lithologic change or better the existence of a rock more waterproof. In the case of *Abyss Guy Collet,* families of fractures are very evident near the surface while at the bottom the lithologic become more compact.

On the plateau's surface have been detected karst forms as Karrens, but different to the others *tepuys* it has not been observed forms of relief as towers or depressed forms that suggesting the area of study of these tepuys corresponds to an area less fractured than other; but any conclusion is premature because so far it was not possible to do a deepen reconnaissance.

Despite the erosive process clearly mechanical of the *Abyss Guy Collet* genesis, at 65 meters of deep were found stalactites and stalagmites, formed through the dissolution process. So we can conclude that these processes cooperate.

Conclusions

The *Abyss Guy Collet* was formed by families of fractures which are open due the infiltrated water and that have triggered erosive processes that have produced the extension of cavities underground. This rift in the rock facilitates the separation of boulders in the conduits.



Despite the erosive process clearly mechanical of the *Abyss Guy Collet* genesis, there are interesting phenomena formed by the process of dissolution.

The underground environment studied is checked by systems of fractures and notes that the abyss is primarily vertical. We can say that the cave is set along the fracture plans while the layer plans are less developed in this area, due the great thickness of the layers.

The *Abyss Guy Collet* can not be classified as *"sima",* but the processes of its formation are very similar, and from geological point of view, we can say that it is at the embryonic stage of a *"sima".*

The discovery of forms of dissolution leads to the conclusion that these processes and those of erosion, cooperate.

At this point it becomes mandatory re-discuss the term of *pseudo-Karst* and reconsider some old classifications.

Acknowlegments

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THE FAMILY OF KARST PHENOMENA: SOME PHYSICAL-CHEMICAL PARAMETERS OF SOME ROCKS CONCERNED OUTSIDE THE CLASSICAL KARST

ARRIGO A. CIGNA[1]

Abstract – Within the framework of the of karst phenomena a number of different processes are present. Different classifications have been proposed by taking into account various aspects observed in the environment. A classification based on physical-chemical parameters has the advantage to be independent from subjective points of view. The main scope of this paper is to collect physical-chemical parameters, as the solubility in function of temperature or the mixture corrosion (Boegli effect), of some rocks involved in the above mentioned phenomena which may be used for quantitative evaluation of the time scale of the evolution of the processes outside the classical karst.

These data were obtained mainly by experiments carried on natural samples and not on pure chemical compounds in order to supply data as close as possible to the conditions found in nature.

As representative of the parakarst, hypokarst and pseudokarst processes, the following types of rock are considered to this purpose: quartzite, gypsum, anhydrite, halite and ice.

Keywords: classification of karst phenomena, hyperkarst, pseudokarst, parakarst, hypokarst, gypsum, anhydrite, silica, halite, ice, solubility.

Riassunto – (La famiglia dei fenomeni carsici: alcuni parametri chimico-fisici di alcune rocce estranee al fenomeno carsico classico). Nell'ambito dei fenomeni carsici coesistono parecchi processi differenti. Una classificazione basata sui parametri fisico-chimici ha il vantaggio di essere indipendente da assunzioni soggettive. Viene così riproposta questa classificazione che è basata sul numero dei componenti che entrano in gioco nell'equilibrio delle fasi della reazione più importante dell'intero processo.

Lo scopo del presente lavoro è stata la raccolta dei parametri chimico-fisici più importanti, quali la solubilità in funzione della temperatura e corrosione per mescolanza (effetto Bögli) di alcuni tipi di roccia estranei al fenomeno carsico classico.

In questo modo sarà possibile effettuare una valutazione dei tempi necessari per l'evoluzione del fenomeno.

Per questo motivo sono stati utilizzati perlopiù dati sperimentali ottenuti da campioni naturali e non da composti chimici puri in modo da avvicinarsi per quanto possibile alle condizioni che si incontrano in natura. In relazione ai processi paracarsici, ipocarsici e pseudocarsici sono state presi in considerazione rispettivamente i seguenti tipi di roccia: quarzite, gesso, anidride, salgemma e ghiaccio.

Parole chiave: classificazione dei fenomeni carsici, ipercarso, pseudocarso,paracarro, ipocarso, gesso, anidrite, silice, salgemma, ghiaccio, solubilità.

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Introduction

When the investigations outside the limestone areas typical of the classical karst were developed, a number of features more or less similar to those observed in the classical karst were found. This fact led to some classifications of such features in order to take into account both similarities and differences. An exhaustive list of papers concerning these aspects is reported in Cigna (1978) and Halliday (2007).

Obviously environmental processes are always rather complex and involve a number of factors with different levels of importance.

Therefore any tentative to establish a classification implies necessarily a simplification and therefore an approximation.

To avoid a subdivision into classes as non-arbitrary as practicable was proposed by relying on the physical-chemistry of the main process involved. The reference to the prevalent process is due to the fact that, as reported above, the whole process generally includes a number of less relevant aspects.

The number of the components of the phase equilibrium was the basic criterion adopted (Cigna, 1978; 1983; 1984/5).

Then in the classic karstic phenomena the components of the phase equilibrium are three; calcium carbonate, water and carbon dioxide. In rocks as, e.g., quartzite of gypsum, the components are two, i.e. the mineral of the rock and water. For ice and lava there is obviously only one component, and there is also a class where there is no phase equilibrium since the development of the phenomenon is due purely to a mechanical process.

On the other hand there is a class where the number of the components of the phase equilibrium are more than three due to the presence of more chemical species in addition to water and carbon dioxide. In Table 1 the classification described above is summarised.

The main scope of this paper is to collect physical-chemical parameters, as the solubility in function of temperature or the mixture corrosion (Boegli effect), of some rocks involved in the above mentioned phenomena which may be used for quantitative evaluation of the time scale of the evolution of the processes.

These data were obtained mainly by experiments carried on natural samples and not on pure chemical compounds in order to supply data as close as possible to the conditions found in nature. In any case it must be taken into account that any description of natural phenomena is always affected by a certain degree of uncertainty due to a number of factors, which are not considered. E.g., Dreybrodt & Kaufmann (2007) described the dissolution of soluble rocks by flowing water films, where the global balance of the process is different from the results obtained when the rock is dissolved in a becker. Nevertheless the data supplied by this paper, which were obtained mainly by experiments carried on natural samples and not on pure chemical compounds in order to supply data as close as possible to the conditions found in nature, must be used for comparative estimations more than for absolute evaluations.

Another relevant source of data is given by Palmer (2007) who reports an exhaustive and detailed review of the processes of dissolution of rocks from the point of view of speleogenesis, with quantitative parameters.

As representative of the parakarst, hypokarst and pseudokarsy processes, the following types of rock are considered to this purpose: quartzite, gypsum, anhydrite, halite and ice.

Table 1- Classification of the karstic phenomena (Cigna, 1984/5)

Class	No. of components phase equilibrium	Sub-class	Examples
Hyperkarst	>3	Enhanced	Hydrothermal environment, contact calcite/dolomite
		Reduced	Dolomite
Karst	3	Karst (*sensu strictu*)	Pure limestone
Parakarst	2	Semikarst	Marly limestone
		Brady -	Quartzite, tufa
		Tachy -	Gypsum, halite
Hypokarst	1	-	Ice, lava flow tubes
Pseudokarst	0	Syngenetic	Gas-filled lava cavities
		Epigenetic	Tectonic and erosion caves

Silica

Caves in siliceous rocks are well known all over the world and complex cave systems may develop in rocks usually considered insoluble. In some chemical handbooks silica is reported to be insoluble in water and very slightly in alkali. It was also postulated that the deep weathering of siliceous rocks might be related to a period of Tertiary alkaline hydrolysis (Duchaufour, 1965; Marker, 1976).

If the solution of siliceous rocks would be influenced by the pH of the meteoric or the percolating water, the process should be included in the class of karstic phenomena (three-components phase equilibrium) (Cigna, 1978). But a study of the silica geochemistry pointed out that the solubility of all SiO_2 polymorphs are virtually independent of the concentration of dissolved salts and of the pH of aqueous solutions up to nearly pH 9 as reported in Fig. 1 (Alexander *et al*., 1954; Anderson, 1972; Condie, 1972-74). The rate of dissolution, only, is strongly affected by pH: at pH values below 5 the dissolution process is very slow and may take months to reach the saturation, while at pH 8 the gel may dissolve to saturation overnight (Condie, 1972-74).

For quartz the solubility is about two orders of magnitude lower than those reported in Fig. 1.

It must be stressed that in case of a two components process the "Boegli effect" due to the mixture of waters cannot exist. The unique variable affecting the equilibrium of the solution of silica is temperature as it is reported in Fig. 2 (Alexander, 1954; Alexander, 1972).

The solubility of silica polymorphs varies within a rather wide range (over an order of magnitude between quartz and amorphous silica). Therefore the behaviour in weathering of silicates corresponds closely to their abundances as detritus. The less soluble silica, i.e. quartz, is almost the sole constituent of the most mature detritus, the quartz-rich sandstones.

The solubility of various forms of silica in water obtained from experimental data are here reported (Anderson, 1972):

Quartz
$$C = 60.08 * 1000 * 10^{\left(\frac{-1310}{273.15+T}+0.42\right)}$$
Chalcedony
$$C = 60.08 * 1000 * 10^{\left(\frac{-1032}{273.15+T}-0.09\right)}$$
Cristobalite
$$C = 60.08 * 1000 * 10^{\left(\frac{-1000}{273.15+T}\right)}$$
Silice gel
$$C = 60.08 * 1000 * 10^{\left(\frac{-731}{273.15+T}-0.26\right)}$$

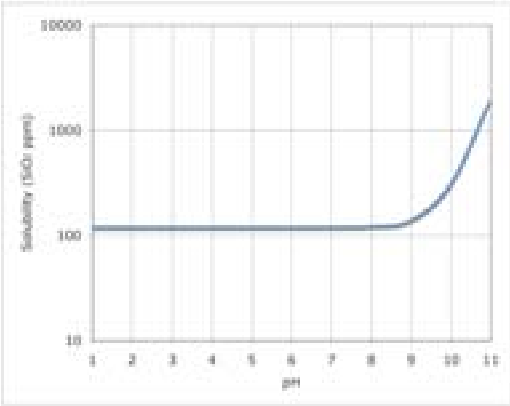

Fig. 1 - Solubility of amorphous silica in water at 30°C (Alexander et al*, 1954, modified)*

where *C* is the concentration in ppm and T is the temperature in °C. The curves for chalcedony and silica gel should be considered as zones of uncertain width rather than lines on account of a smaller number of experimental results. In Fig. 2 the four equations reported above are plotted.

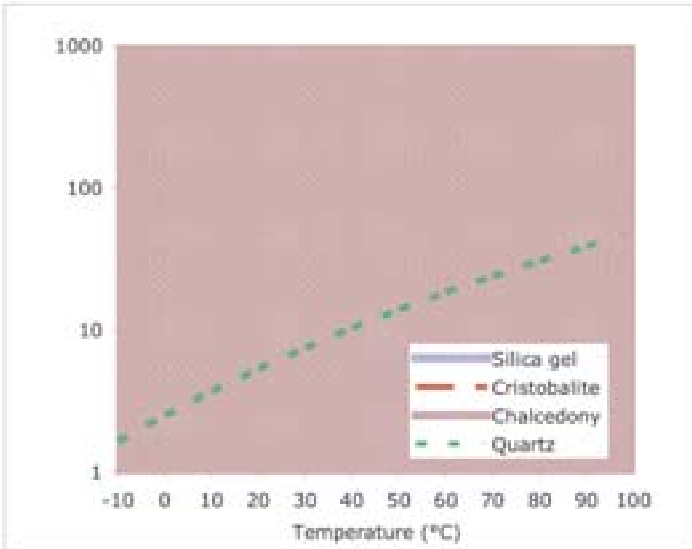

Fig. 2 – Solubility of silica polymorphs as a function of temperature. The curves for chalcedony and silica gel should be considered as zones of uncertain width rather than lines (data: from Anderson, 1972)

The dissolved silica concentrations in groundwater range between a few ppm to almost 100 ppm (Condie, 1972-74). An estimate of the concentrations to be found in a temperate region is given by the analysis of over 5000 samples of surface waters in Italy. A value of 11 ppm with a standard deviation of 10 ppm was obtained (Dall'Aglio, 1968). In hot springs the waters tend to have rather higher silica concentrations up to almost 400 ppm (White et al., 1956), which are higher than these commonly measured in a limestone environment.

According to the criteria reported in this paper the solution of silica should be considered a parakarstic phenomenon at pH below 9, while it enters the karstic domain only when the pH becomes very alkaline.

Gypsum and anhydrite

A critical review of the data of the solubility of gypsum obtained from experiments on natural samples was carried on. Some data reported by Trombe (1952) and Lange (1961) had been published earlier by Niggli (1926) and Hulett & Allen (1902), respectively. Later, Blount & Dickson (1973) processed data obtained at temperatures also higher than 100°C to calculate an empirical equation for the solubility of gypsum in water; therefore only values corresponding to temperatures below100°C are considered here. In 1977 Jakucs (p. 78 and 79) reported the solubility of calcium sulphate from Trombe (1952) but he wrongly assumed the headings in the original table (Trombe, 1952, p. 139). In fact he gave, respectively, the solubility of anhydrite and gypsum while Trombe intended to express the solubility of gypsum as g/litre of both $CaSO_4$ and $CaSO_4*H_2O$.

The review by Seidell (1958) listed some data found by Hill in 1937 and by Sborgi & Bianchi in 1940 but these values do not agree with any other data and therefore they were not considered further here. The values from 70° to 100°C derived from an empirical equation obtained for anhydrite by Blount & Dickson (1973) (under the same conditions reported above for gypsum) were also calculated. The results by Innorta et al. (1980) were in good agreement with the others previously reported and with the diagrams published by Hardie (1967, p.186) and Blount & Dickson (1973, p. 325).

The gypsum solubilities reported in the above mentioned papers were fitted by means of a least squares procedure with a 3rd degree polynomial :

$$Sgypsum = (1.9*10^{-6})T^3-(4.16*10^{-4})T^2+(2.2*10^{-2})T+1.75$$

where S is the solubility expressed in g/litre of CaSO4, T is the temperature in °C and the correlation coefficient is 0.931.

Similarly, the solubilities for anhydrite were fitted with a linear best fit:

$$Sanhydrite = - 0.027*T + 3.32$$

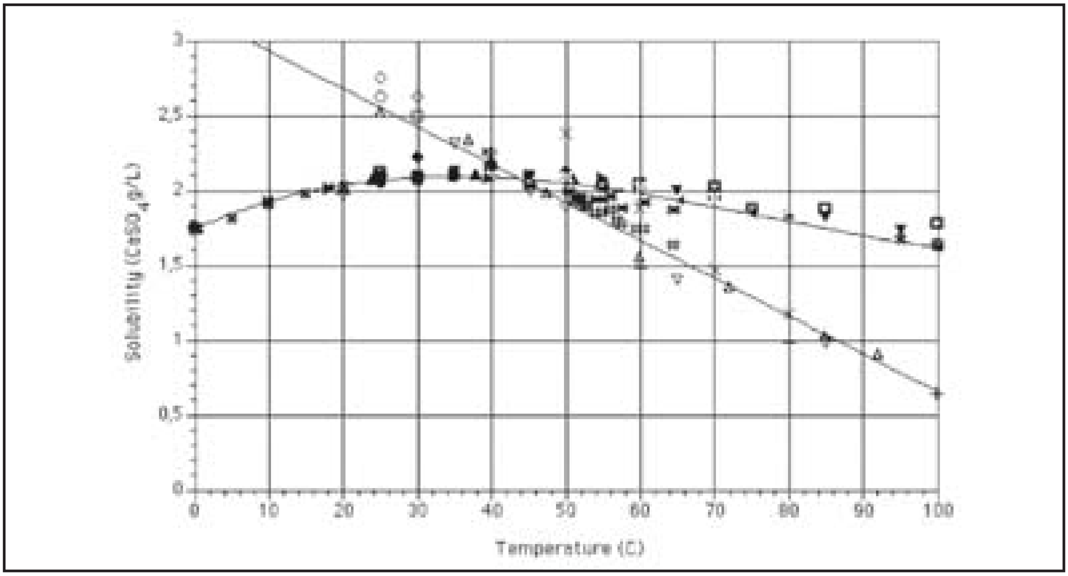

Fig. 3 – Solubility of $CaSO_4$ (g/L) as a function of temperature from 0° to 100 °C. (Gypsum: Hulett & Allen, 1902; Niggli, 1926; Posnjak, 1938, 1940; Trombe, 1952; Madgin &Swales, 1956; Bock, 1961; Lange, 1961; Power et al.*.1966; Marshall &Slushes.1966; Block & Waters, 1968; Bloun & Dickson, 1973; Freier, 1976; Innorta* et al., *1980. Anhydrite: Posnjak, 1938, 1940; Madgin & Swales1956; Bock, 1961; Power* et al,*1966; Blount & Dickson, 1968; Freir, 1976; Innorta* et al., *1980).*

and the correlation coefficient is 0.979.

The experimental points and the interpolating functions are shown in Fig. 3. The equilibrium temperature between gypsum and anhydrite, according to the equations given above, is + 46.0 ± 1.5 °C. This value is in perfect agreement with the theoretical value of 46°C obtained by thermodynamic calculation (Hardie, 1967) even though such agreement is of minor significance since the uncertainty affecting the thermodynamic value is rather large: ± 22°C.

A critical review of the data available on the solubility of gypsum and anhydrite shows the existence of a consistent set of values. On the other hand

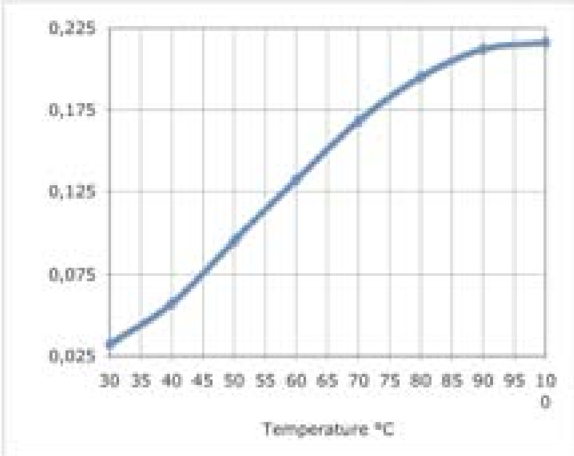

Fig. 4 - Increased solubility of CaSO4 in a 1:1 mixture of a cold saturated water (10°C) and warm saturated waters at different temperatures vs. the temperature of the warm water.

Table 2 - Calculated solubility of gypsum and anhydrite in pure water

Temperature°C	Gypsum *	Anhydrite*
0	1.75	3.32
5	1.85	3.19
10	1.93	3.05
15	1.99	2.92
20	2.04	2.78
25	2.07	2.65
30	2.09	2.51
35	2.10	2.38
40	2.09	2.24
45	2.08	2.10
50	2.06	1.97
55	2.03	1.83
60	1.99	1.69
65	1.96	1.56
70	1.91	1.43
75	1.87	1.29
80	1.83	1.16
85	1.79	1.02
90	1.75	0.88
95	1.72	0.75
100	1.69	0.61

(*) Expressed in g of CaSO4 per litre of water.

Table 3. Increased solubility of $CaSO_4$ in a 1:1 mixture of saturated waters at different temperatures.

"Cold" water °C	"Warm" water °C	+Δ $CaSO_4$ g/L
10	30	0.033
10	40	0.058
10	50	0.096
10	60	0.133
10	70	0.169
10	80	0.196
10	90	0.213
10	100	0.217

there was some variability in the experimental results even when the experiment was carried out carefully (e.g. in the case of the gypsum solubility as reported by Innorta *et al.*, 1980) and these differences are unexplained. The solubility of gypsum and anhydrite calculated by the best fit functions reported above are given in Table 2.

Since the concavity of the curve representing the solution of calcium sulphate is towards the unsaturated region, the dissolution of calcium sulphate can be enhanced by the effect of mixture corrosion by waters at different temperatures. Of course such an effect can play a major role when thermal waters are involved and the mixture occurs between “cold” (e.g. vadose or phreatic) waters and “warm” deep waters.

To evaluate the result of the effect, the aggressiveness for a 1:1 mixture between a saturated water at 10° C and another one at a temperature ranging from 4O° to 100° C was calculated as an example. The results are reported in Table 3 and plotted in Fig. 4. The solubility referred to the resulting mixture is increased from 2 to 13% in the range of temperatures here considered. Such an effect may explain the existence of some chambers at the confluence of thermal waters in a gypsum karstic system.

Halite

The concentration of sodium cloride in water at different temperatures as given by Liley *et al.*(1963, p. 3-93) is reported in Table 4:

The best fit function:

$C_{NaCl} = 0.0032T^2 + 0.085T + 357$

Table 4. Solubility of NaCl in water

Temperature°C	NaClg/L
0	357
10	358
20	360
30	363
40	366
50	370
60	373
70	378
80	384
90	390
100	398

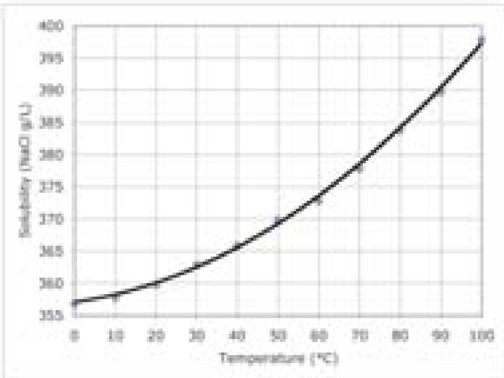

Fig. 5 - Solubility of NaCl in water.

Table 5. Super saturation of NaCl in a1:1 mixture of waters at different temperatures.

“Cold” water°C	“Warm” water°C	-△ NaClg/L
10	40	1.0
10	50	1.2
10	60	1.5
10	70	2.2
10	80	3.3
10	90	5.0
10	100	7.0

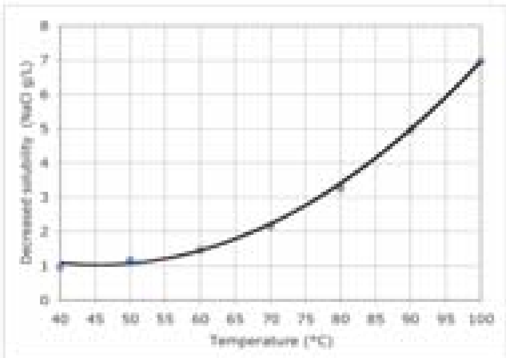

Fig. 6 - Super saturation of NaCl in a 1:1 mixture of a cold saturated water (10°C) and warm saturated waters at different temperatures vs. the temperature of the warm water.

is slightly non-linear only, with its concavity towards the side of the saturated solution (Fig. 5). Therefore no mixture solution can occur and the only effect due to the non-linearity may give rise to sodium chloride super saturation (Cigna, 1984-85).

From a practical point of view, due to the rather high solubility of halite (in comparison to other karstifiable rocks), a negative Boegli effect due to the mixture of waters with different origins will not imply any relevant reduction of the size of the cavities. On the other hand in the vicinity of confluence of saturated waters at different temperatures, some sodium chloride deposition may occur.

As an example the decreases of solubility for a 1:1 mixture of a cold saturate water (10°C) and a warm (40 to 100°C) saturated water are reported in Table 5 and plotted in Fig. 6.

The amount of mineral deposed, referred to the temperature of the warm water ranges between 0.3 and 2 % in the temperature interval here considered.

Ice

Speleogenesis in the ice apparently is very simple since there is only one component of the phase equilibrium: it can be classified as Hypokarst. Therefore only temperature plays a role in the dissolution of the rock, i.e. ice. In general, in alpine glaciers speleogenesis depend on the water energy. This energy is delivered both as heat (if its temperature is higher than ice temperature) and by friction leading to an increase of 2.34 °C per km of drop. On account of the difference between the specific heat of water: $c_{water} = 4.217*10^3\, Jkg^{-1}°C^{-1}$
and the heat of fusion of ice: $c_{ice} = 3.34*10^5\, Jkg^{-1}$
it is evident that in general a relatively large amount of water is necessary to melt the ice.

In addition to the change of phase, also a purely mechanical process of erosion may contribute to the further development of a passage, particularly if the water flow includes also some solid particles. Obviously such a process cannot be defined quantitatively on account of the wide range of variation of the quantities involved in. An exhaustive description of the drainage phenomenology in glaciers is found in Badino (1992; 1995).

A comparison between the main parameters of the Karst and Hypokarst domains is summarised in Table 6.

Table 6 - Comparison between the main parameters of the Karst and Hypokarst (Badino, 1991)

Quantity	Unit	Hypokarst	Karst
Rock solubility	mg/L	10^6	10^2
Solution energy	J/kg	$3.3*10^5$	$5*10^6$
Typical difference of height	km	0.1	1
Water flow rate	kg/km^2*s	10^2 -10^3	10
Air flow rate	$m^2/s/km^2$	1	10
Thermal gradient	°C/km	0	-3.5
Δ T between air and water	°C	?	0.5
Condensation flow rate	$g/km^2/s$	1-10	10-100
Time scale	y	$10^2 – 10^3$	$10^7 – 10^8$
Water energy flow rate	kW/km^2	10^3	~50
Air energy flow rate	kW/km^2	0.1–1	10-100
Air current energy flow rate	kW/km^2	1	100

But nevertheless it is very interesting to the whole process more closely because speleogenesis may develop also without the transition into a liquid phase. In fact if the temperature of the environment is always below 0°C no dissolution would occur and no cave should develop. But, on the contrary, during the XVI Italian Antarctic Expedition Badino and Meneghel discovered some caves without any connections with the volcanic activity that exists in the region (Badino & Meneghel, 2000). The mean yearly temperature is -14°C and in the warmer month, January, the mean temperature is -2°C. In these conditions liquid water cannot exists and it could be assumed that caves cannot develop. Since such caves do exist the process involved in their development had to be investigated.

During another visit to the same ice cave after ten day from the first one, it was discovered that a small niche dug in the wall to obtain an ice sample, was found rounded and grooved as a result of a karstic process at -20°C. Then some temperature profiles were obtained in the walls about 1 m above the floor and in the floor. The results are reported in Fig. 7 and 8 for Campbell 1 (Campbell Glacier) and Nordbacker 1 (Backer Rocks) respectively. From these measurements the heat flux was calculated and included in Table 7.

The floor is always some degrees warmer than the walls, and heat is released while the walls absorb it. In the conditions found in these caves the speleogenetic process does not involve any liquid water but sublimation only, i.e. ice is released from the floor and deposed on the walls. The excavation of a niche to retrieve an ice sample exposed a colder portion of the wall, which acted as a cold trap for the ice molecules released by the floor. The evolution of the process is very fast and a new equilibrium condition is attained within few days.

Obviously such a process is rather peculiar and can develop in particular conditions only, as in Antarctica. It is, nevertheless, interesting to describe it for the exceptional conditions involved.

Table 7 - Heath flux in two ice caves

Cave	Date	Wall (W/m^2)	Floor (W/m^2)
Campbell 1,	Nov. 20, 2000	- 8	4
(Campbell Glacier)	Nov. 30, 2000	- 8	4
Nordbacker 1	Nov. 20, 2000	-1.7	3.7
(Backer Rocks)	Nov. 30, 2000	-4	3.7

Conclusion

In order to evaluate how much rock has dissolved according the solubilities of different kind of rock reported above, in Table 8 the densities of such rocks are listed.

Table 8 – Densities of some rocks concerned in parakarst and pseudokarst phenomena

Rock	Density
Quartz	2.65 (mg/cm^3)
Silica amorphous	2.2 (mg/cm^3)
Gypsum	2.30 to 2.37 (g/cm^3)
Anhydrite	2.98 (g/cm^3)
Halite	2.17 (g/cm^3)

The volume (in cm^3) of rock dissolved by one litre of water is evaluated by dividing the concentration in water, as reported in the previous tables, by the corresponding density from Table 8. Nevertheless it must be stressed that in most cases the factors involved in the whole process are known with a rather large approximation. Therefore a numerical value between 2 and 3 could be successfully applied to calculate the order of magnitude of the total volume of the rock dissolved, i.e. the volume of the cave.

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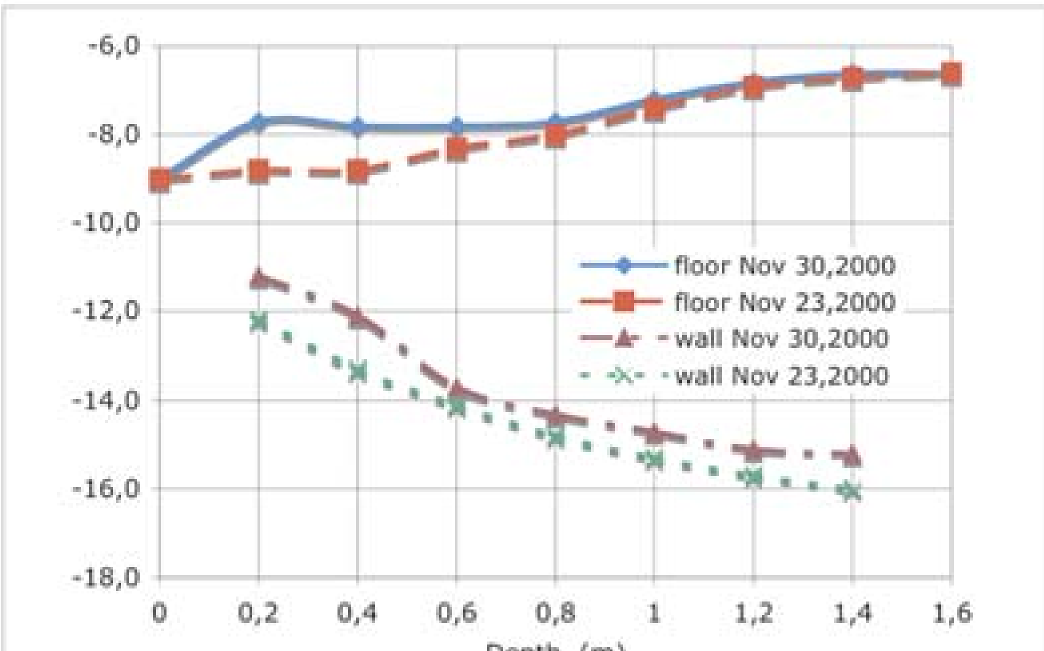

Fig. 7 - Ice temperature inside Cave 1 in the Campbell Glacier (Antarctica) (Meneghel & Badino, 1999, modified)

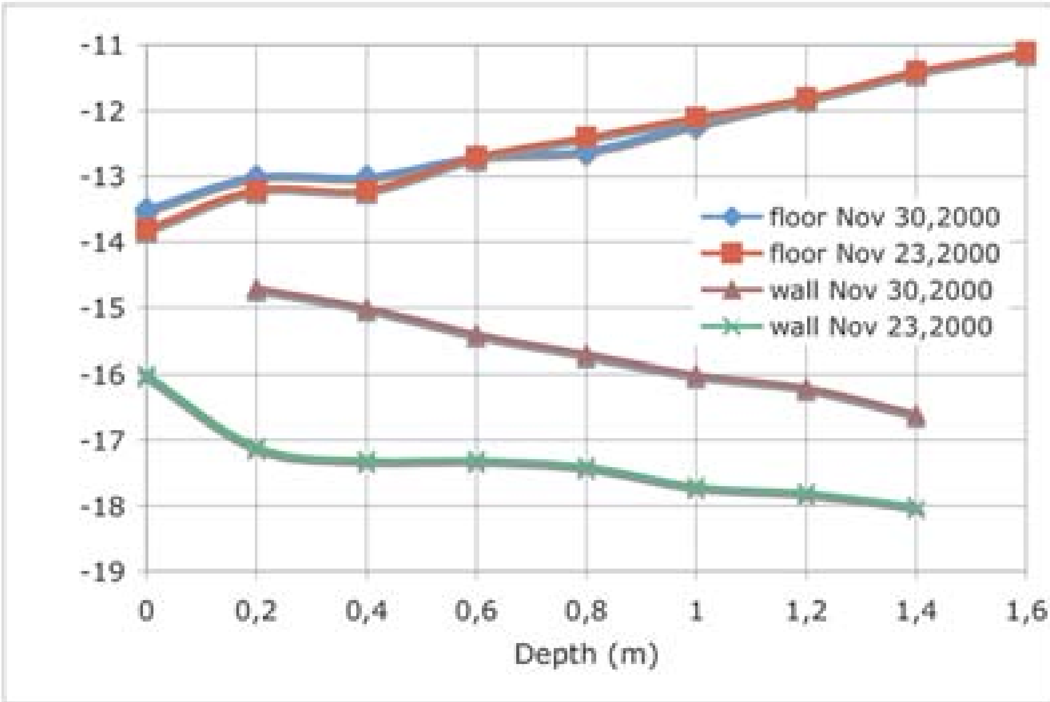

Fig. 8 - Ice temperature inside Cave 1 in the Backer Rocks Glacier (Antarctica) (Meneghel & Badino, 1999, modified)

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IL PROCESSO DISSOLUTIVO-EROSIVO NELLE ARENARIE DEL FLYSCH
(CONSIDERAZIONI GENETICO-EVOLUTIVE)

FABIO FORTI[1]

Da tempo la pratica speleologica segnala la presenza di cavità (grotte), nelle rocce torbiditiche marnoso-arenacee in facies di Flysch. Si tratta più in particolare di cavità ad un prevalente sviluppo sub-orizzontale che evidenziano l'effetto morfologico di una circolazione idrica in seno a rocce che per definizione sono state classificate come "impermeabili" e quindi non carsiche.

Da un punto di vista puramente idrologico, il Flysch nel suo complesso di alternanze di rocce arenacee e marnose, ha delle notevoli capacità per la ritenzione idrica nei vuoti che si sono formati nella massa rocciosa, in particolare in corrispondenza dei piani di stratificazione della sua parte arenacea.

La ricerca, intende analizzare le cause dell'origine di tali vuoti, il loro sviluppo ed evoluzione nel corso dei tempi geologici.

Secondo le interpretazioni date dalla pratica speleologica, le cavità presenti nel Flysch hanno un'origine carsica, spesso definita di tipo attenuato, poiché le arenarie in particolare, sono state classificate come appartenenti al gruppo delle semicarsiche, altre volte vengono attribuite al gruppo piuttosto indefinito, dei fenomeni pseudocarsici.

Negli anni più recenti, la ricerca speleologica nel Flysch ha fornito ulteriori evidenze sulla presenza di tali cavità, ma contemporaneamente sono anche aumenti i dubbi sull'attribuzione di tali fenomeni nel gruppo di quelli carsici, pur con la definizione di "attenuati", che rientrerebbero in altre categorie genetiche, ma non ancora chiaramente definite.

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Il prof. Michele Gortani, dell'Università di Bologna, iniziatore degli studi carsici, intesi su base geologica, in un suo trattato del 1948, nella categoria delle rocce permeabili per carsicità, comprende: "calcari, gessi, dolomie, talora anche conglomerati in prevalenza calcarei e arenarie a cemento calcareo". Tra i suoi allievi e continuatori, troviamo che Franco Anelli (1963), aveva sostenuto la divisione di tali fenomeni in: carsici, paracarsici e pseudocarsici, richiamandosi ai concetti espressi ancora nel 1933 dallo stesso Gortani, con la seguente precisazione:

fenomeni carsici – corrosione (attualmente è meglio e più corretto usare il termine "dissoluzione") di rocce geologicamente solubili come i calcari, i gessi, nelle acque del ciclo meteorico debolmente cariche di CO2;

fenomeni paracarsici – fenomeni carsici poco sviluppati, attenuati, nei calcari grossolani, nelle arenarie a cemento calcareo o siliceo, in alcuni casi nelle rocce dolomitiche, meno solubili dei calcari puri;

fenomeni pseudocarsici – alterazioni prodotte da azioni fisiche (disgregazione termoclastica, gelivazione ecc.) nei graniti, gneiss, scisti e lave, dove è possibile osservare

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forme analoghe a quelle dei terreni carsici, come pietraie rocciose, superfici nude, solchi, drenaggio di acque sotterranee.

Va precisato che all'Anelli interessava in particolare definire il termine di rocce semicarsiche proponendo di chiamare il relativo fenomeno "paracarsismo", riferibile ad alcune manifestazioni dell'azione solvente delle acque sui calcari grossolani, di scarsa potenza e di limitata estensione, ricoprenti i calcari compatti dei tavolati mesozoici. In questi suoi studi si collegava ad altre ricerche sulla grande piattaforma carbonatica pugliese. Va ricordato invece, che per il Gortani le rocce arenacee, appartenenti ai fenomeni paracarsici, allora non venne trattata.

In seguito l'Anelli in uno studio del 1975, citava i francesi (Renault & Geze), in merito alla presenza di cavità di dimensioni ridotte, presenti nei terreni dolomitici e nelle arenarie a cemento calcareo, che secondo questi studiosi di fenomeni carsici, apparterebbero ad un karst gréseaux e, con tale termine è stata anche così definita la specialità del fenomeno.

Ritornando ai concetti espressi da M. Gortani (1948), nello schema generale della permeabilità delle rocce, viene distinta in base alla permeabilità per: porosità, fessurazione, carsicità. Sempre nelle medesime categorie a sua volta suddivide le rocce in: permeabili, semipermeabili ed impermeabili.

Il gruppo delle rocce semipermeabili per carsicità (semicarsiche), viene distinto in: rocce calcaree o dolomitiche, rocce gessose, salgemma, aventi la caratteristica di una carsicità incipiente, ossia con fenditure ancora sottili, o con varici isolate, ovvero ingombre da residui poco solubili; condizioni che sovente sono presenti nei calcari marnosi, calcari arenacei, dolomie, marne gessifere o salifere, conglomerati ad elementi in prevalenza calcarei, arenarie a cemento calcareo, ecc..

In tali raggruppamenti di rocce, da quanto propone il Gortani, agli effetti di una classificazione per la carsicità, non sembra ci sia stata grande chiarezza. Per quanto riguarda le arenarie, non appare che abbiano avuto un particolare interesse.

La loro attribuzione ad un effetto di carsicità o semicarsicità, non venne ulteriormente indagata. Con maggiore attenzione si valutò la differenza tra carsismo e paracarsismo, inteso nel senso di carsismo ridotto, relativamente alla differenza del rapporto morfologico a causa della circolazione idrica in seno alle rocce calcaree, rispetto alle dolomitiche. Per maggiori precisazioni, si rimanda a: C. D'Ambrosi & F. Forti (1968); F. Forti (1971, 1972, 1977, 1978a, 1978b, 1979, 2002). Sono ricerche che si configurano in un rapporto differenziale geomorfologico, riguardante le misure sulla consumazione delle rocce con stazioni micrometriche, di cui a solo titolo di esempio vedi in: F. Cucchi & F. Forti (1986, 1988).

Ad una interpretazione completamente diversa sulla classificazione dei fenomeni carsici, interviene A.A. Cigna (1978, 1983), che utilizza gli stessi termini di carsismo, paracarsismo, pseudocarsismo ed aggiungendo quello di ipocarsismo, che venne riservato alle grotte presenti nei ghiacciai (?) ed a quelle che si sono formate all'interno delle colate laviche.

Il Cigna considera che la dissoluzione (con il risultato della consumazione), del calcare è dovuta (dal punto di vista chimico), dall'equilibrio delle fasi a tre componenti: carbonato di calcio, acqua, anidride carbonica.

Nel caso del gesso o del salgemma, il processo di consumazione avviene con solo due componenti (roccia + acqua). Nel primo caso assegna il termine di carsismo, nel secondo quello di paracarsismo. Ne consegue che la definizione di paracarsismo, a seconda degli

Autori può avere significati completamente diversi e fortemente contrastanti. Il termine - paracarsismo - non dovrebbe così essere utilizzato da solo, ma con l'aggiunta: secondo F. Anelli o A.A. Cigna. Dato che ci sono fin troppe incertezze ed approssimazioni negli studi carsici, non era necessario aggiungerne delle altre, portando solo ulteriori incertezze!

Va ancora osservato che A.A. Cigna (1983), a proposito del termine pseudocarsismo, applicato alla genesi delle grotte, considera l'erosione come uno degli agenti che danno origine a questi fenomeni quando esprimono delle morfologie simili a quelle carsiche. Bisogna precisare che per erosione si intende l'effetto provocato da una consumazione meccanica delle acque scorrenti su rocce insolubili, …ma perché non anche in rocce carsiche? La gran parte degli studiosi di carsismo (quasi tutti di matrice chimica e non geologica), sono fortemente legati al principio che il fenomeno sia dovuto esclusivamente a cause chimiche (soluzione) e nelle loro conclusioni ritengono che ciò costituisca una forma di assolutismo.

Per chi invece segue il pensiero geologico, in natura mai si verifica un'unica causa per spiegare qualsivoglia fenomeno naturale. Infatti, non corrisponde assolutamente alla vero che il processo carsico, in particolare quello ipogeo, se viene determinato dall'azione di consumazione in alveo dei fiumi sotterranei, sia esclusivamente chimico, anzi! E' stato ampiamente dimostrato da: F. Cucchi, F. Forti & P. Herbreteau (1997); F. Forti (1997, 1998); F. Forti & P. Herbreteau (2002); F. Forti, G Concina & R. Gerometta (2003), che il concorso dell'erosione dovuta al violento trasporto di sassi, massi e sabbie, nei momenti delle maggiori piene, supera di gran lunga qualsiasi azione dovuta alla consumazione chimica. Ciò è stato valutato sulla base di precise misure di consumazione eseguite in alveo nella Forra di Pradis (Prealpi Carniche), scavata dalle acque del Torrente Cosa nei compatti calcari a Rudiste del Cretacico superiore, ovviamente il tutto va interpretato nell'arco dei "lunghi tempi geologici", fatto questo che molto spesso viene ampiamente trascurato negli studi carsici.

* * *

In riferimento a quanto sopra esposto, si ritiene che nelle differenziazioni sui fenomeni del carsismo, sia superficiali, sia sotterranei, sono costantemente presenti delle situazioni geomorfologiche che non si possono ricondurre semplicemente in formule chimiche, legate alla circolazione ed all'aggressività delle acque sulle rocce soggette ai fenomeni di consumazione dissolutiva. Il carsismo, nelle sue variabili, non è altro che il risultato dovuto alla somma delle caratteristiche geolitologiche, petrografiche, deformative, dei complessi rocciosi per lo più carbonatici, dove ha avuto origine, si è evoluto e continua ancora a svilupparsi tale fenomenologia, che potrebbe anche essere meglio definita, della "consumazione carsica".

Ritornando al quesito proposto dal presente studio, la domanda è: per i fenomeni simili a quelli carsici che sono presenti nelle rocce torbiditiche in facies di Flysch, arenarie in particolare, qual è l'esatta definizione che può essere data?

Il Flysch è un'alternanza di argilliti, siltiti, arenarie, marne, vedi in particolare R. Calligaris et alii (1999), ma sembra che i vuoti rappresentati dalle cavità o grotte che sono state rinvenute, siano presenti soprattutto in corrispondenza delle grandi bancate di arenarie. L'arenaria è costituita da una sabbia (materiale silicoclastico) resa compatta dalla cementazione calcitica dei granuli (o cristalli) di silice, talora la cementazione è mista (argilloso - calcitica).

Le arenarie esposte agli atmosferili subiscono una degradazione meteorica di tipo selettivo. Il (cemento) calcitico passa in soluzione per l'aggressività dell'acido carbonico contenuto nelle acque piovane. Effettivamente in questo caso, si tratta di un processo carsico, però limitato alla parte cementante dell'arenaria. La massa principale della roccia, costituita dai granuli di silice ritornano così liberi e vengono asportati dall'acqua di scorrimento in sospensione mentre il cemento calcitico viene asportato in soluzione. Il trasporto in sospensione non è chimico, ma meccanico e pertanto rientra nei processi di erosione e quindi non carsici. La condizione principale del processo di consumazione delle rocce arenacee è indubbiamente fisico, però su un'impostazione di base chimica.

Rimane così evidenziato che nella consumazione per effetto delle degradazione meteorica sulle arenarie, questa avviene per dissoluzione, relativa alla sua minima parte nel volume complessivo della massa rocciosa, (la parte cementante, costituita da calcite) e si tratta quindi, di un effetto carsico, mentre l'asporto delle sabbie quarzose (massima parte in volume), rientra nella categoria legata agli effetti erosivi. Il risultato morfologico è indubbiamente classificabile quale un limitato effetto carsico, motore unico della separazione tra un solido insolubile ed un cemento solubile. Gli spazi "vuoti", come le cavità presenti nelle arenarie sono dunque il risultato, utilizzando le terminologie correnti, di un processo definibile semplicemente come semicarsico-erosivo.

Viene rilevato ancora che dalle diverse analisi che sono state fatte sulle acque presenti in seno alla masse rocciose flyschoidi è risultato che il contenuto in soluzione di carbonato di calcio è generalmente superiore ai contenuti d'acqua presenti nelle masse rocciose carbonatiche calcaree.

A questo proposito, va ricordato che la circolazione idrica nelle masse flyschoidi è lentissima, a differenza di quella largamente sviluppata nelle rocce calcaree, dove le acque scorrono molto più liberamente in vani di dimensioni maggiori e quindi con minori stagnazioni, presenti invece nel Flysch, dove è possibile la presenza di una maggiore saturazione delle acque, di bicarbonato di calcio, secondo il vecchio schema $CaCO3 + H2O + CO2 = Ca(HCO3)2$.

Concludiamo con la seguente proposta riassuntiva: premesso che i componenti delle rocce torbiditiche in facies di Flysch sono - arenarie, siltiti, argilliti e marne - la parte cementante del complesso roccioso è calcitica o argilloso-calcitica. Di conseguenza, agli effetti della degradazione meteorica, in questo caso selettiva, sono fenomeni che vanno compresi nel gruppo dei "semicarsici", con asporto idrico dei rispettivi componenti in: soluzione (CaCO3) – sospensione (SiO2). Si tratta di una fenomenologia dissolutiva-erosiva, ossia derivata da una sommatoria di conseguenze morfologiche dettate da una situazione iniziale di tipo carsico e successiva-conseguente di tipo normale o erosiva. La consumazione della roccia, dovuta alle acque di precipitazione meteorica e di quelle conseguenti di scorrimento superficiale e sotterraneo, avviene dunque per dissoluzione-erosione. Riassumendo: dissoluzione - dovuta al passaggio in soluzione della parte cementante il complesso roccioso, ossia della calcite (CaCO3), che da per risultato la graduale trasformazione dell'arenaria in sabbia silicea, della siltite in silt siliceo e dell'argillite in argilla sciolta. Conseguenza idrogeologica, è l'asporto in sospensione di detti materiali, fenomeno questo ascrivibile ad un'azione meccanica, per definizione di origine fisica e quindi di tipologia erosiva.

Tale proposta di lavoro o di studio, tende a minimizzare le classificazioni in assoluto dei vari fenomeni legati alla consumazione delle rocce calcaree e non, di sostituirle invece, con la semplice constatazione delle cause-effetto, prodotte dalla circolazione sia superficiale che sotterranea delle acque di origine meteorica, sulle masse rocciose flyschoidi.

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CAVES UNDER UPLIFTED SURFACE CRUSTS OF BASALTLAVA FLOWS

PÉTER GADÁNYI [1]

Abstract - Lava rise caves can evolve when the almost flat parts of solidified surface crusts of basaltlava flows uplift as a result of the inflation caused by the accumulating fluid lava under it and then the accumulated lava drains into the deeper parts of the lava flow. If the relatively broad uplifted lava surface crust can support itself, a flat cave remains under it. Lateral ridge caves and toe ridge caves form when the inner part of basaltlava-flows with a convex surface and solid surface crust sags because the supporting lava underneath sinks. Pressure ridge caves evolve as a result of lateral pressure in basaltlava-flows which lift up and buckle the solidified surface crust causing a shortening of it. While the surface crust arches up, a rather long and narrow cave forms under it. Lava tumulus caves evolve when fluid lava injects underneath the surface crust of the basaltlava-flow contemporaneously with the solidifying of the surface crust and arches it up forming a cupola-like form without any horizontal shortening of it. If the molten lava drains from below this lava surface-crust-cupola, there is a tumulus cave remaining. Gas blister caves evolve close to the surface of basaltlava-flows or lava lakes because of the accumulating gases which can swell up the viscoelastic parts of the cooling lava surface crust, but this lava crust does not allow the expanding gases to escape from below. If the arched surface crust solidifies before sinking back, a gas blister cave can remain below it.

Introduction

The uplifting of the solid, semisolid or viscoelastic surface crusts of basaltlava-flows of pahoehoe type can be a result of several processes within the moving and cooling lava flows, forming several types of caves under them. In case of these kinds of cave development the fluid lava does not take a considerable horizontal distance below the uplifted crusts.

The aim of this study is to present the processes which can uplift the upper hardened surface crusts of basaltlava-flows, and how the caves evolve under them.

Lava rise caves

The almost flat parts of solidified surface crusts of basaltlava flows can uplift as a result of the inflation caused by the accumulating fluid lava under it. These uplifted broad areas over the up-ponded parts of lava flows are the so called lava rises (Larson 1993).

In some cases the accumulated lava below the lava rises subsides and separates from the surface crust because of its draining into the deeper parts of the lava flow (Fig.1.). If the uplifted part of the lava surface crust can support itself, a flat cave remains under it (Pics.1, 2, 3), with a ground plan slightly elongated towards the direction of the lava draining but they can branch because of the bifurcation of the drained lava.

The disjunction surface between the surface crust and the sunken viscous lava forms the floor and the ceiling of the cave, which have a rough surface with pointed, shark-tooth

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Pic.1. Panorama view of one of the lava a rise caves below a 40 cm thick uplifted surface crust, in the Illahraun lava flow, Iceland. The entrance (shown by the white arrow), resulted from a roof collapse, is 90 cm high, and situated 10 m from where the picture was taken. The greatest height of the cave is 1.2 m.

Pic.2. An uplifted, 50 cm thick surface crust and the entrance of a cave below it in the Stropahraun lava field, Iceland. The picture was taken from the centre of the lava crust subsidence which revealed the lava rise cave (see Pic. 3.) situated below the encrusted and drained lava rise of about 20 m in diameter.

Pic.3. The lava rise cave, which developed below the lava rise in Pic.2, with a height of 50-80cm on average.

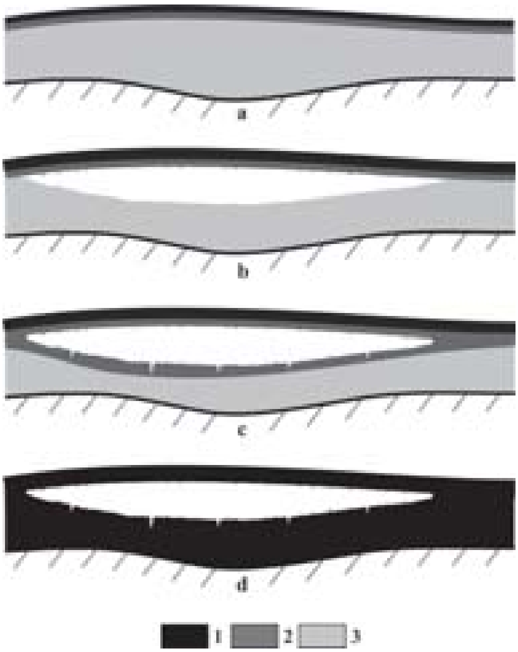

Fig.1. Schematic illustration of the main stages of lava rise cave development. Legend: 1. Solidified basaltlava, 2. Semisolid basaltlava, 3. Fluid basaltlava

projections with size generally less than 3 cm. Rough surfaces can also develop because of the mass of still-plastic lava layers which are pulled away from one another. If the viscoelastic disjunction layer beneath the surface crust is vesicular, pitted and filamented (Macdonald 1967) cave ceilings and floor surfaces can evolve.

Lava rise caves are more likely to develop over flat depressions of the original surface onto which the lava has flowed (Fig.1.).

Lateral ridge caves, toe ridge caves

Lateral ridges form when the inner part of basaltlava flows (Ollier 1988) with a convex uplifted and solidified surface crust sags because the supporting ponded lava underneath sinks (Fig. 2.).

As a result, at the edges and the toe of the lava flow, ridges of surface crust form, which are aligned parallel with the flow direction (Fig. 2/b,a).

Toe ridges form as a result of the same process but at the toe regions of the lava flows.

On the sides of these ridges the broken slabs of surface crust dip inwards and outwards forming the sidewalls and the roof of the cave, which is situated under them (Fig. 2/c).

The surface of the sunken lava forms the floor. These types of caves have an elongated shape parallel with the lava flow edge, with a triangular cross section (Fig. 2/c).

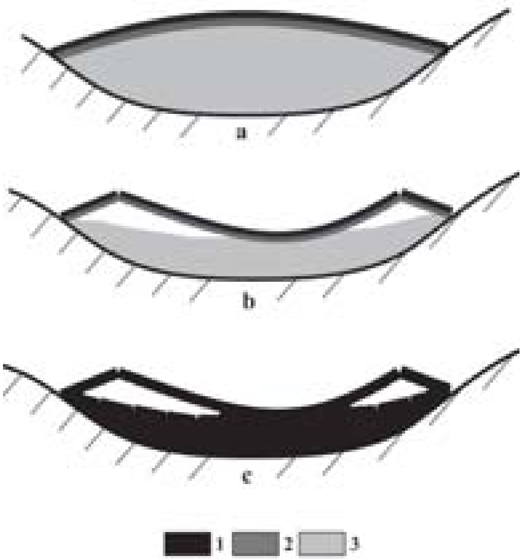

Fig.2. Schematic illustration of the main stages of lateral ridge cave development. Legend: 1. Solidified basaltlava, 2. Semisolid basaltlava, 3. Fluid basaltlava

Pressure ridge caves

The lateral compression resulting from different speed between the hardened surface crust of basaltlava flows and the fluid underlying lava lifts up and buckles the solidified surface crust causing a shortening of it (Fig. 3). It is generally caused by the pressure of the flowing fluid lava, so the pressure ridges generally align perpendicular to the direction of the lava flow. While the surface crusts arch up, a rather long and narrow cave forms under them (Fig.3/b,c, Pic. 4.).

Pressure ridge caves generally have a triangular cross section because of the upheaved flat slabs of the broken surface crust which form the roof and sidewalls of the cave (Fig.3/b,c, Pic. 4.).

Examples of pressure ridge caves are described by Russell in 1902 (Wood 1976).

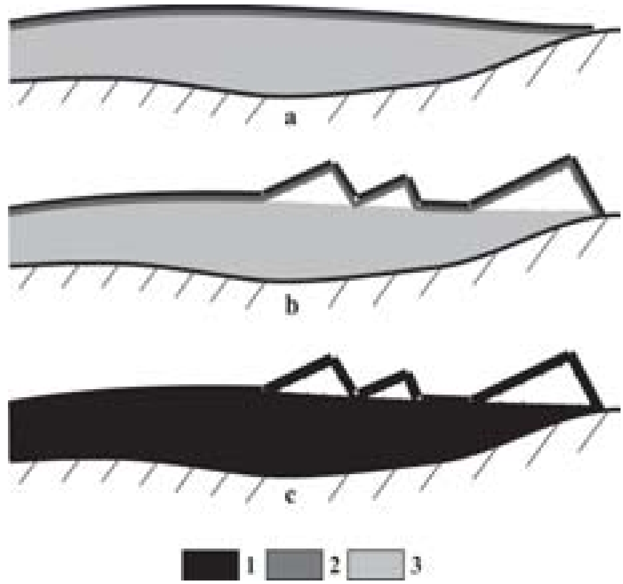

Fig. 3. Schematic illustration of the main stages of pressure ridge cave development.
Legend: 1. Solidified basaltlava,
2. Semisolid basaltlava,
3. Fluid basaltlava

Pic.4. Pressure ridge cave with a height of 1 m. Note the asymmetric triangle shape of the cave in its cross sectional view.

Lava tumulus caves

Tumuli evolve when fluid lava injects underneath the surface crust of the basaltlava-flow and the increased pressure of fluid lava below the surface crust is concentrated at a certain weak spot of the surface crust contemporaneously with the solidifying of this area (Fig. 4/a,b,c). It results that the solidifying lava surface crust arches up by the pushing up from below forming a bulging form without horizontal shortening (Walker 1991). The upper hardened parts of the swelling surface crust are usually cracked open by the excessive upward bending (Fig. 4/b) (Ollier 1962).

The fluid lava is injected into the fractures which are several centimetres or decimetres wide cutting through the surface crust, and in many cases the molten lava extrudes

Pic.5. The entrance of a tumulus cave (see Pics. 6, 7.) revealed by a roof collapse in the Illahraun lava field, Iceland. Note the lava squeeze-ups which significantly contribute to the stabilization of the arched roof.

Pic. 6. The 12. 5 m long and 5.8 m wide and 1.6 m high cave developed in the tumulus in Pic. 5. The height at the entrance is 1.3 m. The greatest height of the cave is 1.6 m. Note the broken lava slabs which indicate the vertical movement of the sunken lava caused by draining, and the absence of "tide marks" on the sidewalls and the ceiling.

Pic. 7. The gradually narrowed ending passage through which the fluid lava drained away into the deeper parts of the flow. Note the broken and tilted lava slab (shown by the white arrow) which indicates the sinking of the drained lava.

through the crack openings of the crust and spreads out onto the surface of the arching tumulus and covers it (Fig. 4/c, Pic. 5).

These outflows - also called squeeze-ups – can greatly stabilize the arched surface crust, and prevent it from collapsing when the fluid lava-support drains away from below (Fig. 4/d,e, Pic. 5).

If the molten lava which once filled the tumulus drains away from below it, there is a cave remaining (Pics. 5,6) with a rounded or elliptical ground-plan and with a lenticular form in section.

The width of lava tumulus caves usually ranges from 1-2 m up to 10-20 m, while their average height is from 0.5 m to a few meters.

The absence of "tide marks" on the sidewalls and ceilings of tumulus caves indicates that the draining out of fluid lava from below the upheaved and arched surface crust was accomplished in a single uninterrupted act (Walker 1991) (Pics. 6,7).

The withdrawal of the liquid lava which was the support for the surface crust generally causes a collapse and a skylight forms on the flank of the tumulus, which reveals the cave in it (Fig.4/e, Pic.5).

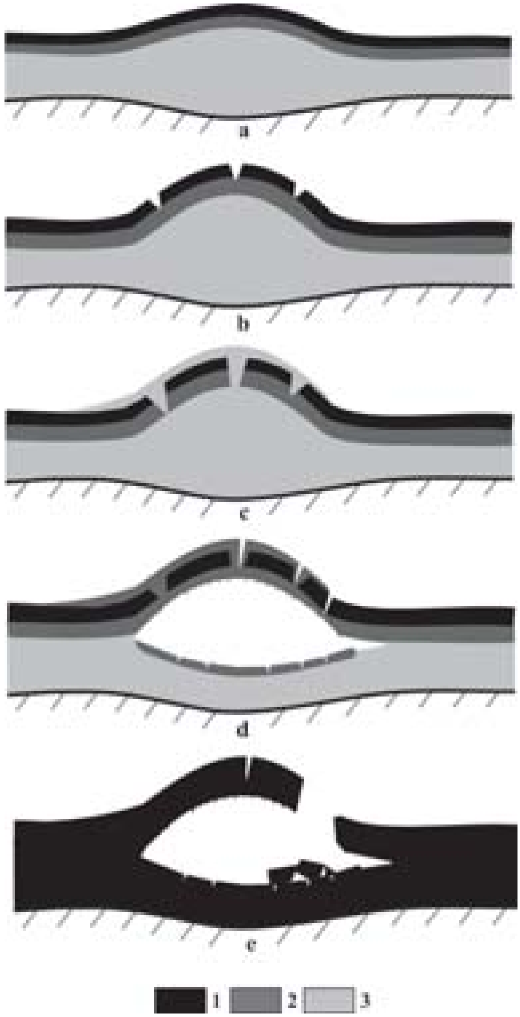

Fig.4. Schematic illustration of the main stages of tumulus cave development: a.) the lava crust begins to swell up b.) inflation clefts develop in the solidified parts of the outer crust c.) molten lava extrudes through the clefts protruding into the semisolid parts and spreads out onto the tumulus surface and covers it d.) the fluid lava drains away resulting in a tumulus cave below the arched surface covered with squeeze-ups, and contraction cracks develop because of cooling e.) a collapse takes place along the contraction cracks forming a skylight on the flank of the tumulus which reveals the cave in it. Legend: 1. Solidified basaltlava, 2. Semisolid basaltlava, 3. Fluid basaltlava

Gas blister caves

Gas blister caves do not evolve by the draining, but the expelling of the fluid lava because of the accumulating gases below viscoelastic crusts of basaltlava flows or lava lakes (Fig.5.).

In the hot molten, liquid basaltic lava, gas bubbles can migrate to join together. Under a decreasing lava static pressure the joined gas bubbles expand, and if they have sufficient time for it, they expel a considerable volume of the surrounded fluid lava. Close to the surface of basaltlava flows or lava lakes, the accumulating gases can swell up the viscoelastic parts of the cooling lava surface crust, but this lava crust does not allow the expanding gases to escape from below (Fig.5/a,b,c). If the up-swelled, arched surface crust solidifies before sinking back, a cave remains below it, with a cupola-shaped roof (Fig.5/c,d).

The expansion of the accumulating and joining gas blisters generally do not only extend upwards, but downwards to the lower molten parts of the flow and in a lateral way below the viscoelastic crust. When the surface crust is more viscous the gases can arch it only to a small extent, and the rest of the gases expand downwards to form caverns (Pic.8.).

The diameter of the gas blister caves can reach the scale of a meter due to variations in cooling rate and local gas content of the lava flow (Green-Short 1971).

The gas blister caves generally occur in small sizes. An example of an exceptionally large blister cave is the Abo Dome, in southern Idaho with 4-5 meters in diameter (Larson 1993).

The roof of gas blister caves usually collapses a short time after its formation, because it has less stable thin walls which are cracked by the contraction of cooling origin (Fig.5/d,e, Pic.8.).

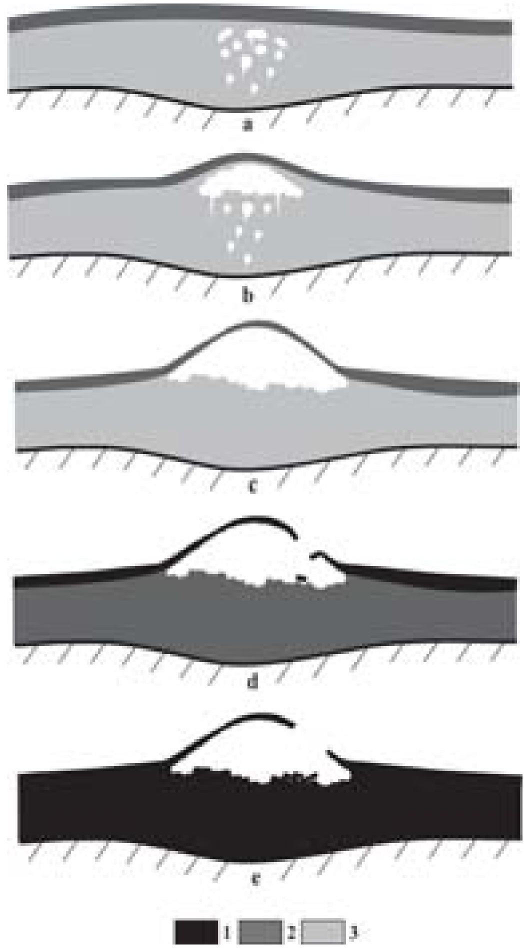

Fig.5 Schematic illustration of the main stages of gas blister cave development: a.) the accumulated gas bubbles join together and ascend to under the semisolid, viscoelastic surface crust b.) the joined gas bubbles expand below the crust and swell it up c, d.) the arched surface crust solidifies before sinking back d.) the less stable parts of the thin roof are cracked by the contraction of cooling origin and some parts of it collapse e.) the more stable part of the arched crust remains with a cave in it.
Legend: 1. Solidified basaltlava, 2. Semisolid basaltlava, 3. Fluid basaltlava

Gas blister caves originated below uplifted thin fragile surface can preserve for a longer period if they are buried with several thin subsequent lava flow layers which provide an appropriate stability for their roof.

Conclusions:

The uplifting of the solidified, semisolid surface crusts of the basaltlava flows of pahoehoe type and their disjunction from the fluid parts can be a result of several processes. Due to the different processes of these disjunctions, different types of caves develop below the uplifted surface crusts.

Pic. 8. Collapsed gas blister of 90 cm in diameter at Leirhnjúkur, in the Krafla caldera, Iceland. Its roof was 5-8 cm thick.

Lava rise caves develop when a relatively broad area of the surface crust lifts up as a result of fluid lava accumulation below it. The surface crusts of the lava rises are slightly bended. A disjunction, which causes cave development, between the fluid lava and the surface crust takes place in the middle zone of the lava flow as a result of the sinking caused by the decreasing level of the fluid lava below the uplifted crust which sinks slightly or does not sink at all.

During the development of the lateral ridge and toe ridge caves, the disjunction between the surface crust and the fluid lava is caused by the sinking of the fluid lava at the edge and behind the toe of the lava flow.

Pressure ridge caves develop by the up-tilting of the slabs of the broken surface crust as a result of lateral compression. In case of cave development of this kind it is only the lava slabs forming the roof and the sidewalls of the cave that rise up and separate from the fluid parts of the lava flow, which does not rise with the crust slabs.

During the development of the tumulus caves, the disjunction between the solid surface crust and the fluid lava is a result of the draining of the fluid lava from the extensively arched surface crust.

While gas blister caves are developing, the disjunction between the semisolid surface crust and the fluid lava is due to the accumulation of the differentiated gases below the up-heaving crust, deriving from the fluid lava.

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IMPORTANT KARST FEATURES IN ZAGROS RANGE (S.W. IRAN)

AHMAD. AFRASIBIAN[1]

Abstract

A significant presence of carbonate rocks and consequently number of well developed Karst aquifers are the main hydrogeological characteristic of Zagros – range.Due to vast exposure of karst in Zagros and increasing damand for fresh water use hasLed to new investigation on karst water in Zagros .Huge discharge from springs which are feeding the alluvium aquifer, presence of surface and subsurface karst features has made Zagros range as unique for karst – phenomena.

A cited in this paper in this region tectonic has an important role in karstification process In Zagros to addition To primary porosity of limestone the tectonic activity result in the secondary porosity which include intensive fracturing which has facilitated the flow of water. Also case study show karstification decrease with depth.

It is finally stasted thatkarst fertures in zagroswill lead to better understanding of karst in this region and so there is a great need for comparison and international scientific co – operation in recognition of karst phenomena in this area.

Introduction

Karstic terrains account for about one fifth of the Earth's surface and they have been the subject of much hydrogeological hydrogical and geotechnical research karst areas are extremely complex and produce a great variety of geological conditions. Many problems have developed in karst areas, particularly accidents and failures of large structures suchas dams, reservoirs and tunnels. For example, many man-reservoirs in karst regions could not retain water in design quantity or many wells could not to produce expected Yields. However, an increasing demand for energy and land reclamation has gradually changed the engineers attitude toward the use

Fig. 1 - Map ok karst exposure in Iran

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of karst regions.

The large part of Iran has limestone, dolomite, gypsum and salt at or near the surface.Particularly, soluble roks are distributed in south – western part of Iran along the Zagros Mountains. (Fig. 1) However, this area contains the largest water potential. Huge karst spring.Construction of large dams, development of man – made reservoirs and excavation long tunnels in this geological environment was great challenge for Iranian geologists, hydrologists and civil engineers. (Fig. 1)

In past two decades the fundamental knowledge related to the karstology, as well as geological engineering approach increased tremendously. In this period the number of high dams, huge reservoirs and long tunnels are successfully constructed in this area.

Important of karst water

Ground water in Karstic formation in Zagros mountain range (ZMR) in south of Iran has a long history. The extraction even goes to pre – Islamic period. In general the importance of Karst water resources in Iran is as follows:

The Karst water in Iran has a privilege as a country' s resources

1 - There exists a limitation on alluvium resources both from quantity and quality points of view,

2 - In many places actually Karst are feeding and recharging the alluvium resources,

3 - Since most industries and human impacts are usually located on alluvium resources and because these resources are normally in the heights & mountains, thus are generally less exposed to these damages and environmental pollution,

4 - Water supply and Karst projects are generally much cheaper than constructing dam and transfer of water and treatment for portable consumption.

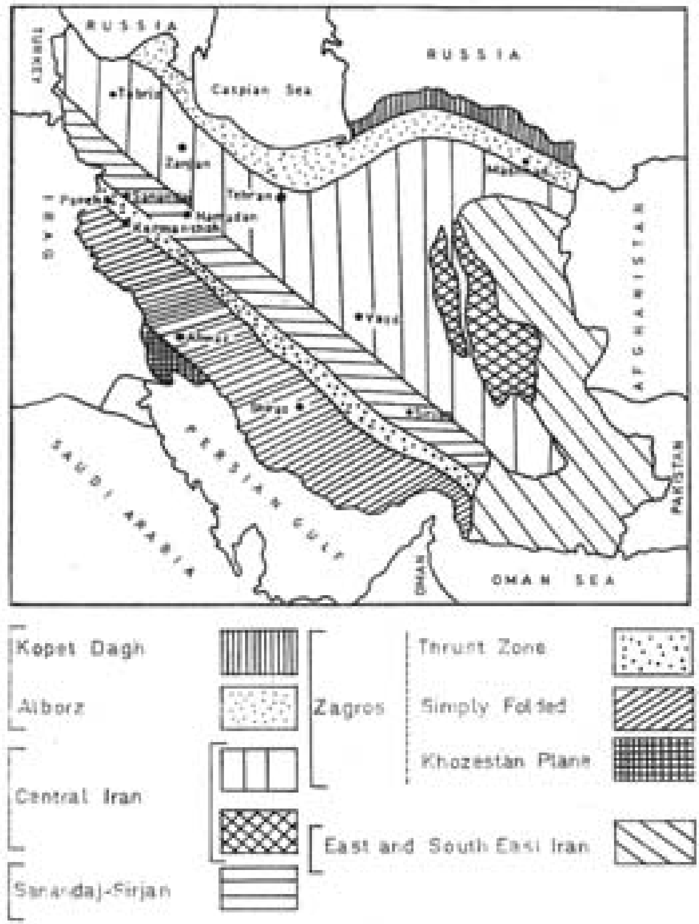


Fig. 2 - Tectonic units of Iran

Karst features in Zagros

Iran is geologically a part of the Alpine – Himalayan organic belt.Five major structural zones can be distinguished in Iran (Fig. 2). These five zones consist of a) Zagros Range, b) Sanandaj – Sirjan Range, c) Central Iran , d) East and South-East Iran, e) Alborz and Kopet – Dagh Ranges.

The Zagros is divided into the three structural zones of Khozestan plain, Simply Floded zone (ZSFZ) and Trust zone.

The ZSFZ, with width ranging from 150 to 250 km, is a sequence of late Precambrian to Pliocene shelf sediments about 12 km thick, mainly consisting of limestone, marl, gypsum, sandstone and conglomerate.

The Trust Zone is composed of crushed limestone, radiolarite and ulerabasic and metamorphic rocks. The elevation increases from the persian gulf to the boundary of Zone 1 and 2 in the northest direction. The presence of numerous salt domes,mainly of the Paleozoic Hormoz formation, indicates active tectonics of the ZMR. Although salt domes have been reported in many places of the word, e.g. to the north of the Gulf of Maxico in the USA and in the northern

Discharge of the main Karstic Springs in Zagross Range (IRAN)

Spring	Locality	Province	Formation	Discharge (lit/sec)
GhilanGharb	GhilanGharb	Kermanshah	Asmari	1393
Sarpole zahab	Sarpole Zahab	Kermanshah	Asmari	1978
Barme-Jamal	Dalon-Mirdavood	Hormozghan	Asmari	1000
Poto	Dalon-mirdavood	Hormozghan	Asmari	2287
Mal-Agha	Baghemalek	Khozestan	Asmari	1675
Pirzal	Tanghehpirzal		Bangestan	2552
Qorsa	Tanghehpirzal		Bangestan	2000
Belghais	Cheram	Fars	Asmari	1533
Haj-Ghalandar	Haje-Ghalandar	Fars	Asmari	9400
Mogharmon	Dehdasht	Kuhkiloeh	Bangestan	4000
Tanghe-Sorkh	Tanghe-Sorkh		Asmari	2000
Chahar-Tangh	Izeh-Chenarestan	Khozestan	Bangestan	1274
	Masjedsolaiman	Khozestan	Asmari	13000
Bibitarkhon	Lali	Khozestan	Asmari	3735
Cheshmeh-Sabz	Masjedsolaiman	Khozestan	Asmari	10000
Venaei	Doroud	Lorestan	Cretaceous Lst.	1736
Chamdan	Alighodarz-Azna	Lorestan	Cretaceous Lst.	1570
Darehtakht	Alighodarz-Azna	Lorestan	Cretaceous Lst.	1300
Qaleshahin	Sreghaleh-Bajghirann		Asmari	1000
Bomaj	Sahneh	Kermanshah	bistoon Lst.	2644
	Sanjabi	Kermanshah	bistoon Lst.	2586
	Harsein	Kermanshah	bistoon Lst.	1120
Kabootarlaneh	Kanghavar	Kermanshah	bistoon Lst.	1492
Sikan	Darreh shahr	Kermanshah	Cretaceous Lst.	1606
Sarabe-Motahari	Khoramabad	Lorestan	Babghestan	1190
Sarabe-Robat	Khoramabad	Lorestan	Banghestan	1207
Taghe-Bostan	Kermanshah	Lorestan	bistoon Lst.	1496
Sasan	Kazeroun	Fars	Asmari	2200
Max				13000
Min				1000

Fig. 3 - Discharge of the main Karstic in Zagross Range (IRAN)

Fig. 4 - Karst spring in Zagros basin

Fig. 5 - Karst spring with laminograph in Zagross basin

part of Germany, most of them are not outcropped and have been detected by geophysical methods. In contrast to them the salt domes in the ZMR and in the Persian Gulf are not only high elevated domes, but in many cases the salt is flowing down the flanks as salt glacier. Some of the salt domes are more than 1000 m higher than the surrounding area, e.g.Kangan salt dome. (Fig. N° 4 - 5 - 6)

Some of them have been used as open cast mines. It is more soluble than limestone and in contrast to the latter, it has plastic behavior and impedes the flow of fluids. The tertiary Gachsaran formation in ZMR, consisting mainly of salt, anhydrite and marl layers, acts as one of the best cap rocks of hydrocarbon in the Middle East.

Fig. 6 - Karst geomorphology in Zagross Range

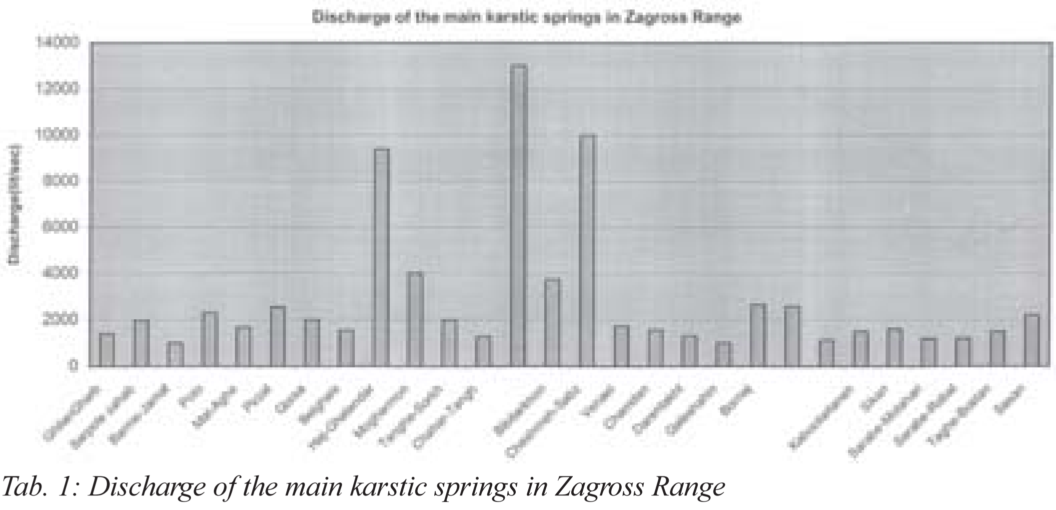
Karstic carbonateformations cover about 11% of Iran s land area. The total area of the Karstified carbonate rocks in Iran is about 185.000 square kilometer, with 55.2% in the Zagros,24.3% in central Iran, 15.2% in the Alborz, 4.7% in East and South- East Iran and less than 0.5% in the Sanandaj – Sirjan Range (Fig. 2).

Most of the outcrops of carbonate rocks are of the cretaceous and Tertiary Age.

The most important Karst features in the features in the Zagros Range are: 1) Karren, 2) grikes, to a lesser extent, 3) caves and 4) dolines.

The msin source of recharge is direct rainfall and snowmelt. Most of the springs are permanent and a high percentage of the spring waters are base flow. (Table N° 2).

Karst water in the Zagros range is usually of good quality, and it is one of the most



Tab. 1: Discharge of the main karstic springs in Zagross Range

important sources of drinking water in the area.

The most important water resources in karst at Zagros range are reserved in two stratigraphic formations: Bangestan group with Cretaceous age and Asmari formations which Oligo - Miocene age (Table N° 1). Bangestan group with forming karstic basement of Zagros is extended in the south and southwest of Zagros.

This group has formed an important water reservoir in central and northern Zagros but in the south and southwestern provinces of Zagros important water reservoir in hard formation is Asmari formation.

In general Zagros karst has its own tectonic style.

This structure style is continuous anticline / syncline forms the heights, one of the characteristics of Zagros as compared with Alborz ranges in central Iran is the type of fopIding which is rather regular and carbonate and other non – existent of igneous rock, carbonate almost make 95% of heights in Zagros. The other peculiarity of Zagros is the existence of salt - dome with rater high topography.

Limestone in zagros ranges has a high primary and secondary porosity (fracture porosity) and this is due to the tectonic and cold climate with long precipitation which has resulted in mature karst evolution in zagros and many caves such as Alisar and shahpour caves has formed as a result.

THE MAIN SEDIMENTATION CYCLES IN THE BASIN

AGE	LITHOLOGICAL UNIT	DESCRIPTION
Quaternary	Alluvium Al Colluvium	Al- pebbles, sand, silt, clay
Pliocene	Bakhtyari Fm. Bk	Bk- conglomerates, coarse clastics
		Zagros orogeny
	Agha Jari Fm. Aj	Aj- estuarine and lacustrine sediments
		regression
Miocene	Mishan Fm. Mn Razak Fm. Rz	Mn- Guri limestone, siltstone Rz- red beds, evaporites
Oligocene	Asmari Fm. As	As- limestone
	Asmari-Jahrum Fm. As-Ja	
Eocene -	Jahrum Fm. Ja	Ja- dolomite
Paleocene	Pabdeh Fm. Pd Sachun Fm. Sa	Pb- marls and shales Sa- evaporites, marls, limestone
	Tarbur Fm. Tb	Tb- reef limestone
Maestrichtian	Gurpi Fm. Gu	Gu- marls and shales
Senonian		tectonic warping
Turonian Cenomanian	Sarvak Fm. Sv	Sv- neritic limestone
	Bangestan Group Bgp	
Albian	Kazhdumi Fm. Kz	Kz- marls, bituminous shales, limestone

Tab. 2: The main sedimentation cycles in the basin

Karstification

In addition to the primary porpsity of limestone, the tectonic activity results in secondary porosity. This includes fracturing along some of them which facilitated flow of water.

In this region, the karstic area has a very huge distribution, althoughit can be divided into two northern and southern sections, but this distribution has a similarity as far as tectonic condition is concerned, which implies that the anticline forms the margin of the plain heights and syncline does the alluvial beds. In northern zagros the limestone lies over the basemsnt rocks karstic reservoir, whereas in the southern section we face a younger karst, these massive formation are followed by impermeable beds which are actually the basement rock, and hence forms a proper condition for karstic presence. The study and exploration indicate that the northern region of zagros has a wide difference over the southern zagros, there is a barrier between feeding resources and mostly all the resources came out of springs, whereas in southern zagros the situation differs and hence we have a continuous chain of karstic resources. Also based on some of exploration results indicates karstification decrease with depth as rock porosity does (Fig.7)

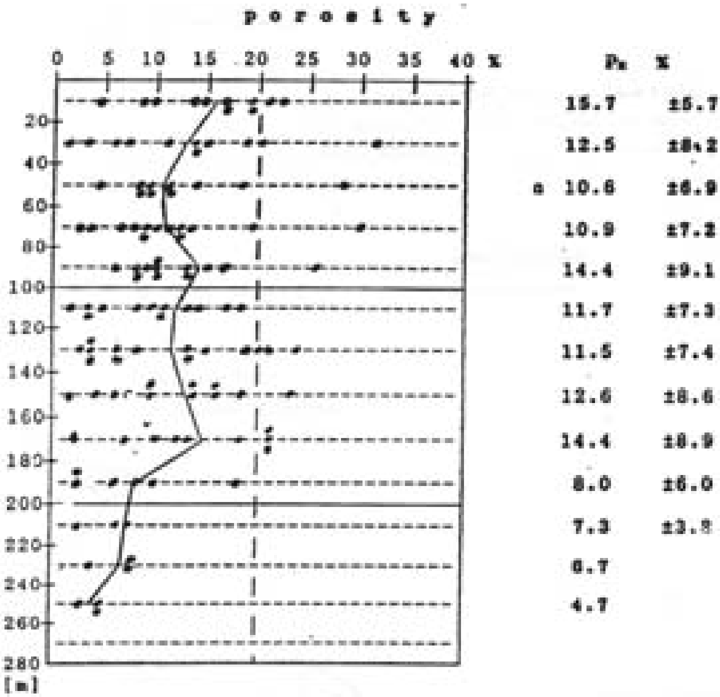


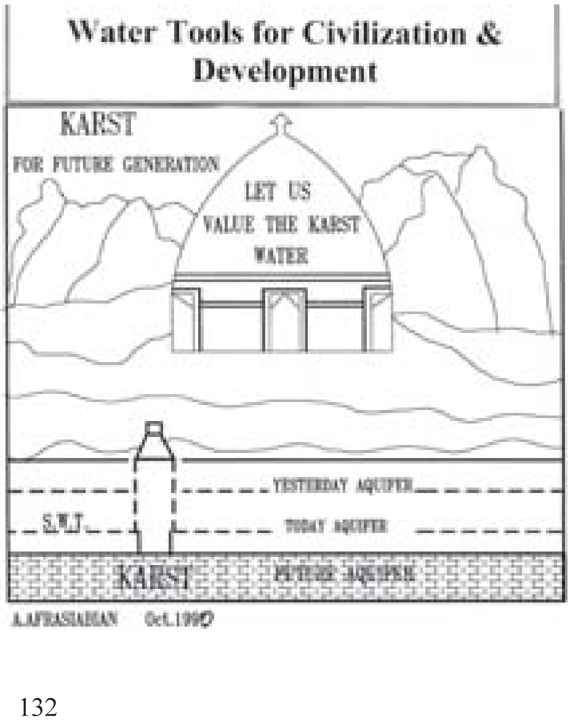
Fig. 7 - Distribution of porosity with depth

Karst water cuality in Zagros

In Zagros region generally Karstic water has a better quality than other resources of fresh water.

Carbonatic water resulting from the dissolution of limestones and dolomites represents the dominant genetic type of groundwater of carbonate aquifers of the basin. Its chemical composition is mostly of ca-Hco3 and scarcely of Mg-Hco3 types.

A basic Ca – Hco3 type is mostly related to highly elevated springs recharged by Asmari limestones. Total of dissolved solids ranges from 200 to 300 mg/1. springs and deeper boreholes located along the foot of anticlines provide water which is usually of transitional Ca-Mg-Hco3 or even basic or tran-



sitional Mg-Hco3 types where also sulfate anion can in some places or seasonally participate in the type. The above mentioned situation can be documented by hydrochemistry of exploitation wells at At many location in Maharlu basin (Fars). Total of dissolved solids varies from 300 to 800 mg/1.In respect of the drinking water quality standards the majority of groundwater of the carbonate aquifer represent high- quality resource as far as the petrogenic character is preserved i.e. without pollution and depletion by overpumping. Some sulphatogenic and all saline groundwater are unfavorable for water economy because of their high sulfate and chloride content.

It was recognized that there are springs having discharge not corresponding to their hydrological catchments therefore a possible interconnection between hydrological zones within the system was explored , hince the carbonate aquifer. So The special interest is To paid to application of tracer in the area for further research.

Conclusion

Karstic formations in ZMR have its own peculiarity and style, study show the carbonate aquifers of the area has a good stability of groundwater regime and we can say limestone represents a relatively, Homogenous, Extension aquifer with high stroge capacity and good mixing condition.

It is finally concluded with consideration to unique karst exposure in zagros and its role on water resources an international research project on similarity and differences of zagros karst phenomena through IGCP or IAH or other international fund is suggested for future research and pars Karst international compony is willing To join this research work with regional and international committe.

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PSEUDOCARSISMO NELLE SIENITI DEL MALAWI MERIDIONALE. (PSEUDOKARST IN THE SYENITES OF THE SOUTHERN MALAWI)

GILBERTO CALANDRI

Pseudokarstic morphologies are present in the southern Malawi in the siliceous rocks: not much quartzitic syenites and poor in quartz granites (Malawi Basement Complex, Precambrian-Lower Paleozoic and Jurassic-Cretaceous Syenites).

- In the Plateau of Zomba (at about 2000 mts in altitude),above the Rift Valley, a predominantly tectonic pit is located.
- In the highest sectors of the mount Mulanje (3001 mts high), with rainfalls over 2000 mm / every year, near the border with Mozambico, the pseudokarstic morphologies are extensive: as Rinnenkarren and Kamenitsa. The complex chemism of the silicates is favoured by the herbaceous and endolitic vegetation(as lichens) and by the waters of condensation.

(Presentation with slides)

PSEUDOCARSISMI DELL'AREA SAHARIANA (PSEUDOKARSTS IN THE SAHARIAN AREA)

GILBERTO CALANDRI

Several pseudokarstic morphologies in the saharian area are described, until now not indicated in bibliography: area of the Adrar (Mauritania), Acacus (Libia), Tassili (Algeria), Gelf el Kebir (Egitto), Northern Sudan, Bandiagara (Mali).

The lithologies are formed by quarzitic sandstones and quarzites, siliceous – shalky sandstones.

The morphologies are various: pseudokarren linked to the chemism of the siliceous rocks, structures(caves too) of corrasion, phreatic tubes (also with vadose deepenings) that indicate dependence of karsification on paleoclimatic conditions.

(Presentation with slides)

I FLYSCH DEL PONENTE LIGURE (ITALIA OCCIDENTALE): PSEUDOCARSISMO E CARSISMO THE FLYSCH IN THE WEST LIGURIA (WEST ITALY): PSEUDOKARST AND KARST

GILBERTO CALANDRI

The west of Liguria (western extremity of the district of Savona and a great deal of the district of Imperia) is characterized by several kinds of flysch of the upper Cretaceous and Eocene.

The typology of the lytological series (with alternations of beds of sandstones, limestones, marles or clays, with very variable facies (locally too), produces an alternation, sometimes in the same sequence, of pseudokarstic and karstic morphologies.

In the Flysch at Helminthoida where calcilutitic megastrata are present, classic caves form, phreatic and vadose too, with extensive speleothems, but the speleogenetic role of marls and clays with water flowing, trigger of clastic processes, fillings, etc. is significant.

In the Flisch at sandy beds, besides tens of prevalenty tectonic caves, pseudokarstic morphologies are present: tafoni, processes of desquamation, alveolar morphologies, grykes, pendents etc. (for porosity, termoclastic processes, lichens etc.).

(Presentation with slides)

LE PSEUDO-KAMENITZE

FRANCO CUCCHI [1]

RIASSUNTO

A ben guardare, numerose sono le forme che sulla superficie di rocce compatte si sviluppano assomigliando alle kamenitze, le tipiche forme dissolutive legate ad acqua statica che si generano sulle superfici calcaree.

Il modello genetico può essere simile a quello di dissoluzione carsica ed essere legato all'alterazione della roccia incassante per reazione chimica con l'acqua. Possono intervenire fenomeni legati alla presenza di sostanza organica che favorisce la velocità delle reazioni. Ma spesso sono anche processi termoclastici, se non crioclastici, a favorire la disgregazione e l'alterazione della roccia. Comunque sia, solitamente il fondo delle "vaschette" in rocce non calcaree è "a scodella" e non "a piatto" come nelle vaschette di dissoluzione "doc".

Forme simili alle kamenitze possono quindi essere rinvenute in rocce non carbonatiche (With, 1988). Nei graniti, ad esempio, depressioni subcircolari anche profonde, a sezione ad U più o meno aperta, dalla genesi simile a quella dei tafoni (ma non con lo stesso risultato) si possono originare per aggressione di acque piovane, non necessariamente arricchite in materia organica. Si tratta di processi di alterazione e di disgregazione che nei silicati prendono anche il nome di argillificazione: in alcuni silicati, solitamente nei feldspati, l'acqua si inserisce nel reticolo cristallino alterando i cristalli in fillosilicati tipo caolino e/o montmorillonite. Ciò porta a distacco del cristallo dalla roccia, con un processo chimico petrografico talora favorito da fito alterazione.

Al momento, suggerisco di chiamare pseudo kamenitza tutte quelle forme simili alle vaschette di dissoluzione (kamenitze, corrosion cups, ecc.) originate da processi diversi da quello carsico classico (in cui il solido è il calcare, il liquido è l'acqua, il gas è l'anidride carbonica)

Pseudo kamenitze si possono formare, a fronte di processi anche molto diversi, in brecce a forte componente silicatica, in arenarie quarzose, graniti, granodioriti, ignimbriti e vulcaniti, basalti, pirosseniti, metamorfiti (almeno per quanto io stesso ho potuto constatare).

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[2] Anche se il termine kamenitza o (plurale) kamenitze - kamenica, kamenice e anche kaminitza – deriva dall'errata ipotesi di Cvijić (1924) riportata da Gavrilović (1968) sull'origine legata allo stazionare sulla superficie di un clasto (kamen), il termine è oggi di uso comune ed internazionale. Altri termini sono validi nelle differenti località e lingue (Rose and Vincent, 1986):
Brasiliano e portoghese: marmite; Ceco e slovacco: kamenice; Inglese: solution cup o solution pan (Zotov, 1941), rock tank (Bryan, 1920), lapiés pothole, etched pothole (Udden, 1925), solution pit (Wenthworth, 1944), solution pan (Fry e Swineford, 1947), corrosion basin, clint pool (Sweeting, 1966), rock pool (Williams, 1966), corrosion cup e solution basins (Sweeting, 1972), true solution pan (Gams, 1974), solution pan (Ford and Williams, 1989); Francese: lapiés à nid de poules (Gèze, 1973); Tedesco: Napfkarren (Bögli, 1960); Italiano: vaschette di corrosione; Polacco: miseczka krasowa or kamenica; Sloveno: škavnica (ma anche kamenitza, termine croato di Cvijić, 1924); Spagnolo (e Caraibico): tinajitas (Udden, 1925).

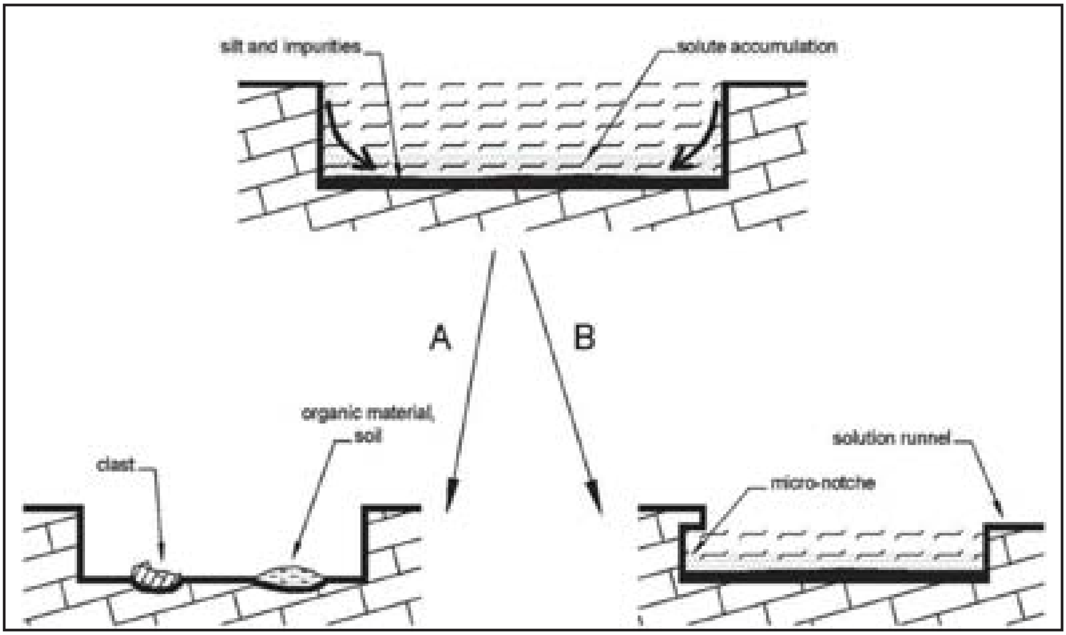

Figura 1: sviluppo di una kamenitza in rocce calcaree (tratta da Cucchi 2008, in stampa). Development of a classical kamenitza on limestones (from Cucchi, 2008 in press)

Foto 1: una articolata kamenitza con pareti aggettanti che va evolvendosi in calcari lungo la costa (Sardegna sudoccidentale, Italia). A kamenitza on limestones near the sea (Southwest Sardinia, Italy)

Le kamenitze classiche, quelle che si sviluppano in calcari (o in calcari dolomitici ma anche in gessi ed altre evaporiti), sono circolari o subcircolari (quando interagiscono con discontinuità), con i fianchi subverticali che si evolvono più rapidamente del fondo che è piatto o appena ondulato. Ciò perché l'aggressività dell'acqua è maggiore sui bordi che non sul fondo, ove spesso stazionano miscele sovrasature, impurità, depositi di vario genere.

Il materiale organico e l'attività biologica, i depositi catturati dalla depressione, i piccoli clasti, possono, preservando a lungo acqua o umidità, dare origine a corrosione sottocutanea e creare sul fondo micro-depressioni (A in figura 1).

Nel momento in cui si origina un canale emissario, si ha la progressiva trasformazione della kamenitza in una "banale" piccola depressione carsica, con la contemporanea genesi di mini-solchi lungo le pareti (dei micro "ripari sottoroccia") per diminuzione progressiva della superficie bagnata (B in figura 1).

[3] Marmitta da corrosione (Forti P. & Al., 2001), korozijski kotlici (Mihevc, 2001).
[4] Opferkassel o solution basins nei graniti (Withe, 1988).

MARMITTE DA CORROSIONE (CORROSION CUPS)

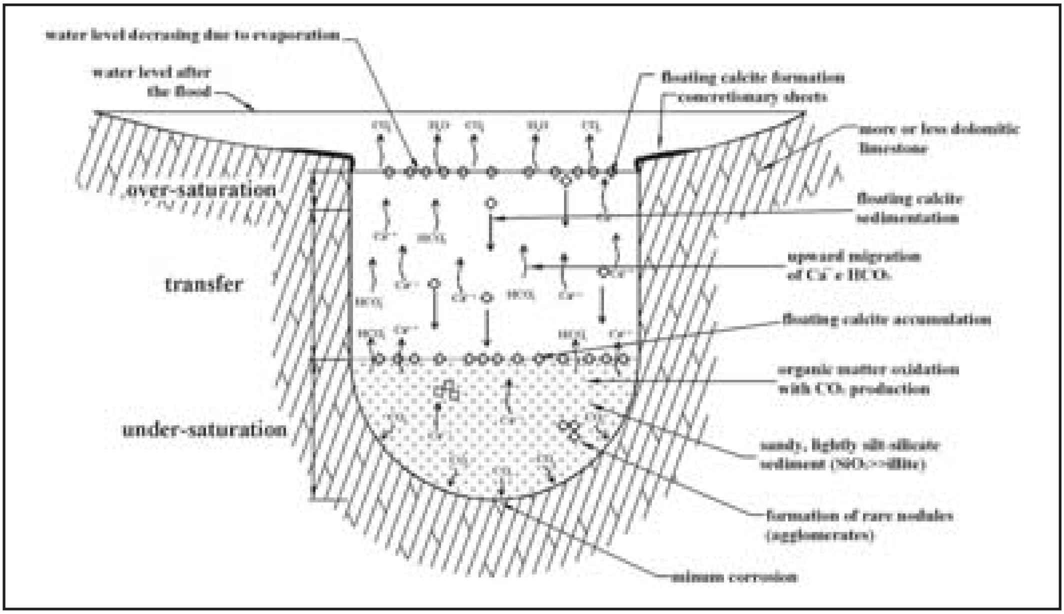

Figura 2: sviluppo di una marmitta da corrosione (tratta da Forti et al., 2001). Development of a corrosion cup (according to Forti et al., 2001)

Le marmitte da corrosione (corrosion cups) sono forme peculiari, recentemente descritte[3] in Slovenia (Mihevc, 2001) e in Brasile (Forti et al., 2001): sono del tutto simili dal punto di vista geometrico a molte altre piccole depressioni circolari a ciotola descritte in rocce non carbonatiche[4]. Merita quindi analizzarne nel dettaglio la genesi, che è molto simile a quella che in rocce silicatiche dà luogo a quelli che in letteratura sono definiti pothole-like forms e qui io interpreto come pseudo-kamenitze.

Nella depressione in calcari dolomitici microcristallini appena metamorfosati, sabbie siltose silicee o silicatiche, sature in acqua ricca in sostanza organica, favoriscono processi di corrosione statica che interessano più il fondo che le pareti della depressione. I processi di ossidazione della sostanza organica rilasciano anidride carbonica che a sua volta porta a dissoluzione della calcite e della dolomite. La calcite disciolta entra in soluzione, risale verso l'alto per diffusione e viene portata via durante le piene. Alla fine della

Foto 2: una marmitta di dissoluzione nei calcari dolomitici della Grotta Perolas (Iporanga, São Paolo, Brasile). Il diametro è di circa 30 cm e la profondità di 20 (la foto è di P. Forti). A "corrosion cup" of Perolas cave (Iporanga, São Paolo, Brazil), with diameter amounting to approximately 30 cm and depth to nearly 20 cm, developing into dolomitic limestones. (Photo by P. Forti).

piena si ha nuovamente deposito sabbioso ricco in organico nella depressione, che può aver avuto origine da un solco, da uno scallop.

Nelle marmitte da corrosione si ha una zonazione chimica dell'acqua/sedimento intrappolati: nella zona inferiore agisce la corrosione indotta dall'ossidazione, in quella intermedia si ha il trasferimento di CO_2 e di Ca^{++} verso l'alto, in quella superiore la CO_2 diffonde nell'atmosfera e l'evaporazione può portare alla precipitazione di carbonato di calcio in sottili croste, poi spazzate via insieme ai sedimenti dalla prima piena significativa (figura 2).

PSEUDO_KAMENITZE

Piccole depressioni originatesi su superfici esposte agli atmosferili per termoclastismo o altro processo possono essere riempite da materiale che concorre all'evoluzione della depressione conservando l'umidità durante la notte e favorendo l'alterazione dei carbonati e dei silicati. In linea di principio la roccia coinvolta può essere di qualsiasi tipo (foto 3).

Foto 3: una pseudo kamenitza riempita da sabbia e piccoli frammenti di roccia scavata nelle arenarie silicee della Formazione dell'Acacus (Libia).
A pseudo-kamenitza filled by sand and debris in the sandstones of the Acacus Fm. (Lybia).

Forme dall'aspetto molto simile a quello delle kamenitze classiche possono originarsi sulla superficie di colate basaltiche per effetto del raffreddamento e della successiva azione di alterazione superficiale da parte di acque, talora ad alta temperatura, fortemente mineralizzate e/o ricche in sostanza organica (foto 4 e 5).

Foto 5: pseudo kamenitze favorite da attività biologica su depressioni intra colonnari in basalto lungo la costa della Sardegna sudoccidentale (Italia).
Pseudo kamenitze into basalts interested by biological activity along the Southwest Sardinia coast (Italy.)

Foto 4: pseudo kamenitze su lava pahoehoe sulle pendici del Vulcano Roiho (Isola di Pasqua, Cile).
Pseudo kamenitze opened on pahoehoe lava (Volcano Roiho, Isla do Pascua, Chile).

Foto 6, 7 e 8: evoluzione di una pseudo kamenitza da un nodulo femico in una riolite, per alterazione differenziata e deflazione (Deserto di Atacama, Chile)

Pseudo kamenitza they develop from a femic nodule in riolite for chemical alteration and deflation (Atacama Desert, Chile).

Foto 9 e 10: forme molto simili a quelle osservabili nei calcari che si aprono nei graniti (in Sardegna nordorientale, foto 9; nell'Isola d'Elba, foto 10 di Ugo Sauro). Sono il risultato della corrosione selettiva dei differenziati femici che poi coinvolge anche i graniti incassanti e dell'alterazione da sostanze organiche.
Landforms similar to those typical of carbonate rocks observed on granites (photo 9: Sardegna nordorientale - Italy, photo 10 by Ugo Sauro: Elba island, - Italy). They are the result of a selective corrosion in femic differentiates (involving the contact with the host granites). Furthermore, by bio- and phyto- alteration.

Foto 11: depressioni (pseudo kamenitze?) legate all'asportazione di clasti basaltici grossolani da una breccia calcarea poi elaborate da acque fortemente aggressive lungo la costa sud orientale della Sardegna (Italy).
Pseudokamenitzas on a calcareous breccia.

SUMMARY

PSEUDO_KAMENITZE

Kamenitze are depressed landforms that develop on karstifiable surfaces exposed to atmospheric agents, due to the presence of static water that produces small round closed pans, larger than deeper.

They form on flat or slightly inclined and undulating surfaces, where water does not flow but collects into the smallest depressions: usually, their genesis is more conditioned by micro-relief patterns rather than by discontinuity surfaces. Their genesis has been widely discussed: according to different theories, it could be either essentially chemical (Gavrilovic, 1968; Forti F., 1972) or essentially biochemical, thus linked to the action of endolithic algae (Perna & Sauro, 1978); some researchers are rather in favour of an exclusively corrosive origin and therefore take into consideration increases in growth or changes in shape, linked to phytokarst phenomena (Belloni, 1969) or to the presence of dissolved deposits (Boegli, 1960).

Corrosion cups are peculiar formations, similar to kamenitze, recently described in Slovenian (Mihevc, 2001) and Brazilian (Forti P. & Al., 2001) cavities; they are, in turn, similar in geometry to some peculiar pothole-like forms, described in non-carbonatic rocks. Sand deposits containing a little percentage of silt and essentially composed of quartz, saturated with water rich in organic substances and located in depressions formed on microcrystalline lightly dolomite limestone, favour "static" corrosion processes that affect the rocks present on the bottom, and outward diffusion of dissolved calcite.

Landforms similar to kamenitze (solution basins) can be found also on non-carbonate rocks (Withe, 1988). On granites, for instance, flat-bottomed sub-circular depressions similar in genesis - but not in shape - to the so-called "tafoni" can originate owing to attack by solution weathering, due to alteration and disgregation phenomena linked to silicate feldspar argillification, and to phyto-alteration. Gustavson & Al. (1995), recognize tens of thousands playa basins (small, roughly circular to oval, internally drained depressions), whose genesis is conditioned by a concurrence of geomorphic, pedogenic, hydro-chemical and biological processes, state that they are economically "important because they collect runoff and recharge the aquifer".

For the present, I suggest to call pseudo_kamenitze all the forms similar to corrosion cups or to kamenitze not due to H_2O + limestone/dolostone + CO_2 but having several different genesis.

I describe several pseudo_kamenitzas, founded around the world and excavate into non carbonatic rocks: breccias, quarzitic sandstones, granites, granodiorites, ignimbrites and vulcanites, basalts, pirossenites. I analyze shortly the genesis and I remind the convergence of forms, due to similar results of different processes

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TMEM SURVEYING ON SANDSTONES

STEFANO FURLANI, FRANCO CUCCHI

ABSTRACT

Sandstone bare surfaces have been investigated using a traversing micro erosion meter (TMEM). Three rock samples have been exposed for more than one year and measurements have been collected at different time scales (seasonally and daily). While seasonal data have been always collected at 14:00, daily surveying resulted in repeated cycles of measures, four or six times a day.

This surveying highlighted different patterns of rock variations for long-term and short-term measurements. Long-term rock surface changes range from 0.054 mm/y to -0.043 mm/yr, but significant daily variations have been recorded. Previous observations about the phenomenon of diurnal swelling on colonised rocks is confirmed also for inland bare sandstones.

The pattern of daily variations is similar for all samples and it seems mainly related to physical factors, such as diurnal variation in temperature and humidity. TMEM data together with meteorological data seem to indicate that bedrock surface rises due to water absorption (evening), while it lowers because of water evaporation (morning).

Key words: traversing micro erosion meter; sandstones; surface weathering; Trieste; Italy

INTRODUCTION

Rock breakdown is the result of weathering and erosion processes. Turkington and Paradise (2005) suggested that weathering research is constrained by slow rates of stone decay and rock weathering, and linear extrapolation of short-term or intermittent information could be inappropriate. However, few field observations have been made on the rate at which weathering and erosion proceed on natural rocks. Recently, some feedbacks have been obtained using TMEM. Short-term surface changes have been reported by Stephenson et al. (2004) and Gomez-Pujol et al. (2007) on coasts and Furlani & Cucchi (2007) on inland. These studies suggested that rock surface oscillate according to daily cycle. They focused on the agents and environmental parameters causing diurnal surface changes without considering the comparison between different time intervals. Long-term (seasonal, annual or decadal) lowering rates are more commonly reported (Trudgill, 1970, 1976a,b; Robinson, 1977a,b; Kirk, 1977; Torunski, 1979; Forti, 1980; Spencer, 1981, 1985; Gill and Lang, 1983; Viles and Trudgill, 1984; Cucchi et al., 1987, 1995; Mottershead, 1989; Smith et al., 1985; Moses et al., 1995; Spate et al., 1995; Stephenson and Kirk, 1998; Cucchi et al., 2006; Furlani et al., 2008).

Surface change rates have been collected both seasonally and during two periods of daily measurements on four bare rock samples, in order to minimize the biological processes. Two samples consist of laboratory-cut surfaces (exposed) and two of natural bare surfaces

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(one sample is exposed and one is located inside the laboratory).

This paper aims at quantify and compare the differences between long-term (seasonal) and short-term (diurnal) sandstone surface changes through the analysis of TMEM data, identify the environmental factors and the agents that cause rock surface change and study short-term surface change to determine the role played in long-term weathering and erosion processes.

PHYSICAL SETTING

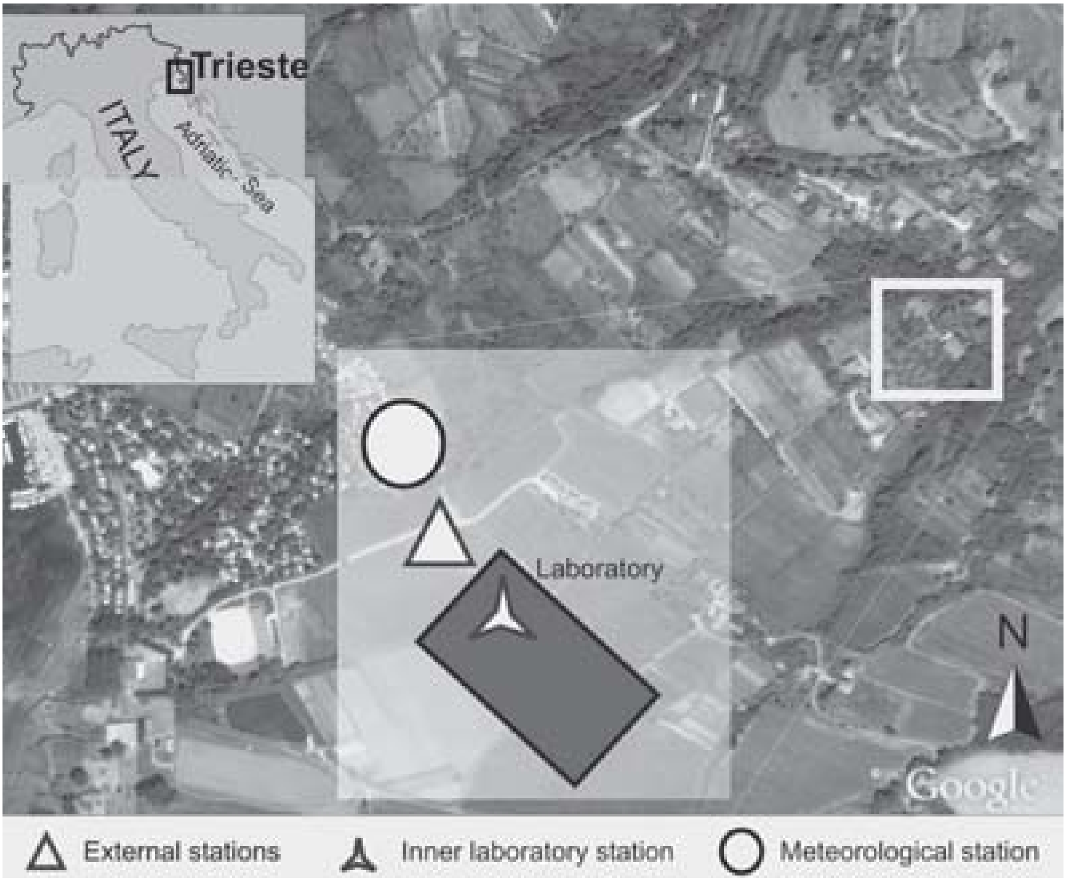

Fig. 1. Geographical location of the studied site and the relative position of the stations.

The study site is located in Trieste, in the northeastern part of the Adriatic Sea, Italy (Fig. 1), at +85 m a.s.l and it contains 3 stations on sandstones.

The climate in the study's area is characterised by equally distributed rainfall throughout the year, lightly rainier periods in autumn (mean rainfall 290 mm) and less rainfalls in summer (213 mm). Mean annual rainfall measured in the 1931-1960 period in San Bartolomeo (80 m a.s.l.) is 887 mm/yr (Stravisi, 1980). The minimum mean value was recorded in March (57 mm), while the maximum in October (109 mm). Storms are more frequent at the end of the summer and in autumn. The mean temperature is 14.2 °C, and the hottest month is July (23.7 °C) whereas the coldest one is January (4.8 °C).The relative humidity is 68%, while the evaporation is 794 mm (Stravisi, 1980).

The sandstones in the studied area have been analyzed by Vierthaler (1873), Malaroda (1947) and Wiesender (1960). The light brown sandstone can be classified as a greywacke, characterized by a relatively high hardness and poorly-sorted, angular grains of quartz 0.1 mm in diameter, feldspar and small rock fragments set in a compact, clay-fine matrix and carbonatic cement. On average they are composed by quartz (43-53%), flint (6-11%), feldspar (18-26%) as plagioclase, mica (4-6%), carbonates (16-20% as cement or rock fragments, less abundant in Trieste than in Muggia) and other residual components (iron oxides, glauconite, tourmaline, garnet, zircon and rutil for less than 1-3%). They lack of fossils apart from very rare rehandled Globigerinae and locally Medusas. The larger grains can be sand-to-gravel sized, and matrix materials generally constitute more than 15% of the rock by volume. The linear thermal expansion coefficient for the studied sandstones is 0.0019 mm/ml/°C (~10 a/10-6 K-1 at 293 K).

MATERIALS AND METHODS

Rock surface changes was surveyed using a digital traversing micro erosion meter (Fig. 2), following the specifications of Trudgill et al. (1981) and Stephenson (1997).

Fig. 2. The traversing micro erosion meter (TMEM)

TMEM data have been collected 4 times, from December 2006 to May 2008: between the 11th - 12th December 2006, 26th - 27th February 2007, 25th - 28th May 2007, 13th - 14th August 2007, 11th - 12th 2008, 11s - 14th May 2008, while additional data have been collected at 14:30 of 30th September 2007, 16th December 2007, 16th February 2008 and 2st March 2008. The relative heights of 22 coordinates within 10 cm2 have been obtained. In order to assess the rock surface movement directions, we used the algorithm designed by Gomez-Pujol et al. (2007). The algorithm defines stable, rising and falling points. Negative values indicate a rising while positive values indicate lowering.

Probe erosion and instrumental error have been estimated (Spate et al., 1985). The electronic dial gauge has a resolution of 0.001 mm, while the error, confirmed by the builder (Mitutoyo), is ±0.003 mm. A calibration steel base was constructed to check the instrument periodically and to define analytical errors. Probe erosion was estimated using two different methodologies: (1) by repeated readings on a test block, which revealed a probe erosion of ±0.004 mm after 300 measures and (2) through observation via microscope of 34 touched rock samples (70 times) and untouched ones (pers. Comm. Tretiach and Crisafulli, Dept. of Geobotany, University of Trieste). Field experiments show that the total error (probe erosion and instrument error) ranges between 0.003 mm and 0.005 mm. Readings between -0.005 and 0.005 mm are therefore considered stable. The influence of a thin film of water on the rocky surface compared to a completely dry surface was tested in laboratory on the steel calibration block. A total amount of 144 measurements on dry surface and 88 measurements on wet surface was performed. Differences among them are lower than the estimated error of the instrument (±0.004 mm).

Sandstone samples are located near the laboratory where the instrument is stored. Measurements have been collected in very short time, so temperature-related error, pointed out by a lot of researchers (Spate et al., 1985, Stephenson et al., 2004) is reduced to a minimum. The comparison between measurements collected before and after field surveying show, in fact, that temperature or insolation slightly influenced on the instrument.

Air Temperature, humidity and rainfall have been collected during the surveying together with surface rock temperature. Rock samples of the studied rock have been collected for thin-section analysis.

RESULTS

Data have been collected during different meteorological settings: stable weather, rainfall and hailstorms. The period between December 2006 and May 2008 highlights a total amount of 1191 mm of rainfall.

During meteorologically stable days (e.g. May 2008), the temperature usually increased during morning and decreased during evening, with maximum values at 13:00-14:00 and minimum values at 2:00-3:00. The relative humidity followed an inverse trend.

During unstable weather days diurnal variations of physical parameters are affected by the occurence of cloudy and rainy time intervals, as for example in January 2008, when temperature increases from 8°C (11th Jan) to 14.5°C (12th Jan) and 11th Jan was rainy day. Also the 27th May 2007 was rainy and an hailstorm occured between 15:00 and 18:00.

The maximum duration of the measurement record was 520 days, corresponding to the S1 station, whereas the S2 and S3 measuring stations have been surveyed for 355 days.

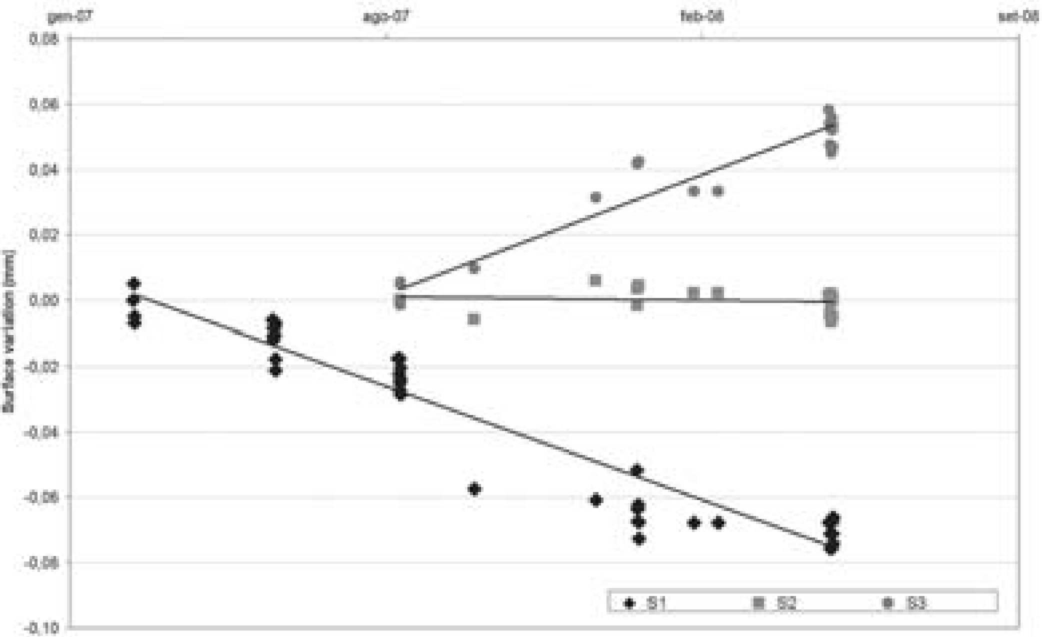

Fig. 3. Long-term surface changes of the studied sandstone samples.

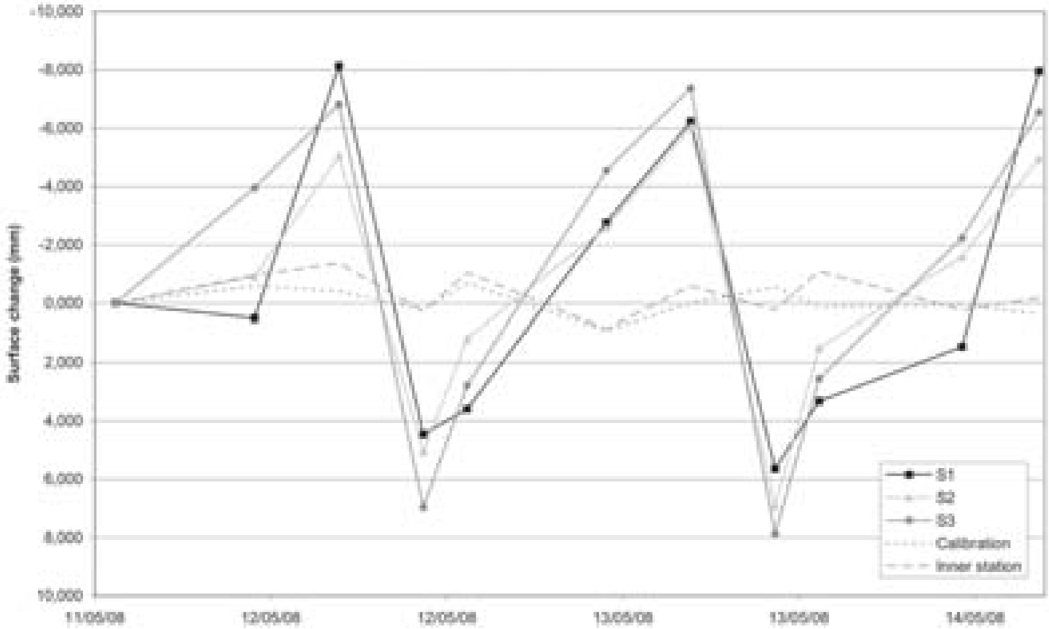

Fig. 4. Sandstone surface changes on May 2008. The inner laboratory station and the steel block remain stable, while the exposed stations (S1, S2, S3) are subjected to cyclic daily rock height variations.

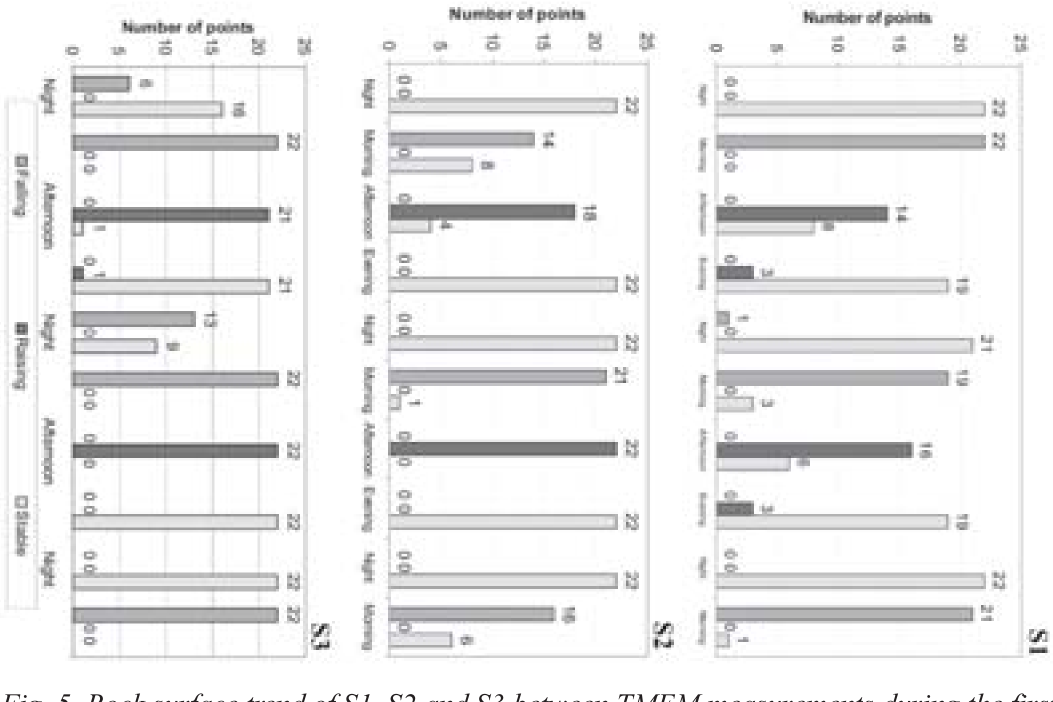

Fig. 5. Rock surface trend of S1, S2 and S3 between TMEM measurements during the first surveying period (12-15 May 2008).

During the surveying period (Fig. 3), S1 lowered (0.054 mm/yr), S2 remained stable (-0.002 mm/yr) while S3 raised (-0.043 mm/yr).

During the May 2007 surveying period, the maximum range between extreme relative height measurements was 0.248 mm and the minimum was 0.005, while the maximum positive movement was 0.244 mm and the negative 0.231 mm. The maximum variation occured during the hailstorm event, May 2007 (0.248 mm).

During the May 2008 surveying period (Fig. 4), the maximum range between extreme relative height measurements was 0.012 mm (S1), and the minimum was 0.001 mm (S2), while the maximum positive movement was 0.012 mm and the negative 0.009 mm (S2, S3).

Rock surface seems to be stable mainly during the night (23:00 and 9:00), but low temperatures or unstable meteorologic settings can cause strong variances.

Most of the points are stable during the whole day, but in the morning a number of points lower while in the afternoon a number of points rise (Fig. 5). The occurence of this cyclic events was measured particularly during stable weather day.

Most of the variations have been founded during the first and the last hours of the day. During May 2007 surveying period, most of the points remained stable, 187 points, while 22 points raised and 11 points lowered. During May 2008 surveying period, most of the points remained stable usually during evening and night (91 on S1, 129 on S2 and 121 on S3), others falling, usually in the morning hours (85 on S1, 51 on S2 and 63 on S3) and others raise, usually in the afternoon (45 on S1, 40 on S2 and 36 on S3). In the morning rock surface lowers while in the afternoon it raises. Most points are independent of each other. There are significative variations of micro-topography (÷2=46.88; p=0.000), apart for the inner laboratory station (÷2=6.24; p=0.000).

DISCUSSION

Relative changes of rock surface can be classified as rising, falling or stable. There are significant variations in microtopography and rock behaviour both at the same scale (daily and seasonal) and at different scales (daily vs seasonal). Moreover, these values can be affected by the occurence of meteoric events that divert the daily surface trend and it lower the rock surface.

The annual pattern is different for the three considered stations: S2 is stable, S3 is rising while S1 is lowering. Considering that we studied bare surfaces and that they are all exposed to similar environmental conditions, the surveyed long-term differences could be attributed to differences in lithological compositions or to the occurence of local events (e.g. haildrops, accumulation of small residual particles, etc).

While long-term variation pattern is different for every studied stations, daily pattern is very similar. If stable meteorological conditions occur, the surface seems to fall in the morning, as air and rock temperature increases and humidity decreases. On contrary, the surface seems to rise during evening, as air and rock temperature decreases and humidity increases. Micro-topographic stability seems to prevail during the night (without solar heating and maximum relative humidity) or during the maximum solar heating (maximum temperature and minimum relative humidity). Although daily variations are lower, the pattern is similar to the one observed by Gomez-Pujol et al. (2007). In this case, endolithic lichens cannot be the cause of the reported variations as we considered fresh laboratory-cut rock surfaces.

Measurements collected on the steel calibration block showed that water did not influence directly the surface variations. Probably wetting and drying, as demonstrated by Stephenson et al. (2004) and Mottershead (1989), are the most important factors on fresh rock surfaces. On the subject, Blend and Rolls (1998) stated that wetting and drying is closely related to hydration shattering and could be related to unsatisfied electrostatic bounds in the surface minerals. The polar water molecules will be attracted by minerals in the small cracks of the surface and it will make up a layer of adsorbed water. The addition of further water may cause a swelling pressure which may create strain. When water disappear, the sides of the crack may be pulled together as attractive force. Cycles of wetting and drying could trigger daily expansion and contraction of the sandstone surface.

TMEM surveying on sandstone bare surfaces highlight different behaviour at different time-scale. Significative microtopographic variations, both long-term, that is annual (from 0.002 to 0.107 mm/yr), and short-term, that is four times a day (from -0.018 to 0.009 mm), have been measured. Annual rates highlights different trends on the studied samples, that is rising, stable and lowering, while diurnal trends are similar. Moreover, diurnal trends seem to be driven by wetting and drying processes.

Further studies to elucidate the mechanisms of surface change, to investigate the internal properties of the sandstones and to compare sandstones changes to other rocks are needed.

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Grotta di Villanova.

TMEM MEASUREMENTS ON DOLOMITES COLONIZED BY ENDOLITHIC LICHENS

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RIASSUNTO

Vengono riportati i primi risultati dello studio degli effetti delle colonizzazioni di licheni endolitici sulle dolomie con il "micro erosion meter" (MEM) e il "traversing-micro erosion meter" (TMEM) e vengono confrontati con i dati disponibili da circa vent'anni su stazioni non colonizzate. Le stazioni fanno parte di un network di oltre 120 stazioni posizionate lungo due transetti altimetrici, da 0 a 2500 m, il primo sulle Alpi orientali (Carso Classico-Monte Canin), il secondo nell'Appennino centrale (Massiccio della Maiella) con il quale vengono studiati gli effetti dei licheni endolitici sulle rocce carbonatiche.

Il sito considerato comprende 6 stazioni, di cui 5 posizionate su superfici orizzontali colonizzate ed 1 su superficie ricavata in laboratorio per fratturazione di un blocco della medesima litologia.

Le misure sono state raccolte in media due volte all'anno. Per ogni stazione è stato raccolto anche un campione, usato per allestire una sezione sottile ed identificare il lichene. Le prime misure sembrano indicare valori di accrescimento nelle dolomie colonizzate e valori di abbassamento per le superfici non colonizzate.

Ciò sembra imputabile all'effetto protettivo della superficie esterna ("lithocortex") dei licheni, che protegge il substrato dall'aggressività dell'acqua meteorica. Vengono infine discussi criticamente i problemi legati a questo tipo di misure quando esse sono condotte su superfici colonizzate da licheni.

1. INTRODUZIONE

In Europa, circa il 60% delle superfici carbonatiche esposte sono colonizzate da organismi vegetali, i più comuni dei quali sono i licheni endolitici, che vivono immersi nel substrato che viene dissolto mediante meccanismi non ancora del tutto chiariti. Rimane anche da stabilire se l'alterazione superficiale che ne deriva incrementi o rallenti il rateo di abbassamento delle superfici colonizzate rispetto a quelle non colonizzate.

I tassi di consumazione dei calcari sono stati studiati con diversi metodi, sia in campagna che in laboratorio: con pesate, ripetute nel tempo, di campioni esposti agli agenti atmosferici (Forti et al., 1975; Gams, 1979; Forti & Stefanini, 1981; Stefanini et al., 1985, Plan, 2005), con misure di abbassamento della superficie rocciosa mediante il micro erosion meter (MEM) o il traversing-micro erosion meter (t-MEM) o con il Rock Erosion Meter (REM) (Forti, 1980; Cucchi & Forti, 1986, 1988, 1989; Cucchi et al., 1987a, b, 1995, 1998). Numerosi sono anche i lavori nel settore costiero, con misure dei tassi di consumazione sia nel lungo termine (Trudgill, 1976; Kirk, 1977; Robinson, 1977; Spencer, 1981, 1985; Trudgill

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et al., 1981; Gill & Lang. 1983; Stephenson & Kirk, 1996) che nel breve termine (Stephenson, et al., 2004; Gomez-Pujol et al., 2007; Furlani & Cucchi, 2007). Alcuni hanno proposto metodi per la quantificazione dei tassi di dissoluzione mediante esperimenti di laboratorio (Martinez & White, 1999) o mediante modellizzazione numerica (Kaufmann & Braun, 2001).

Alcuni dati MEM specifici sulle dolomie sono riportati in Cucchi & Forti (1988) e riguardano una serie di stazioni posizionate a Borgo Grotta Gigante (Trieste, Italy) su blocchi di dolomia provenienti da varie parti d'Italia.

La presente ricerca è stata eseguita nell'ambito di un progetto PRIN2004, "Licheni endolitici e dissoluzione delle rocce carbonatiche: meccanismi, ratei e impatto sul bilancio globale della CO2".

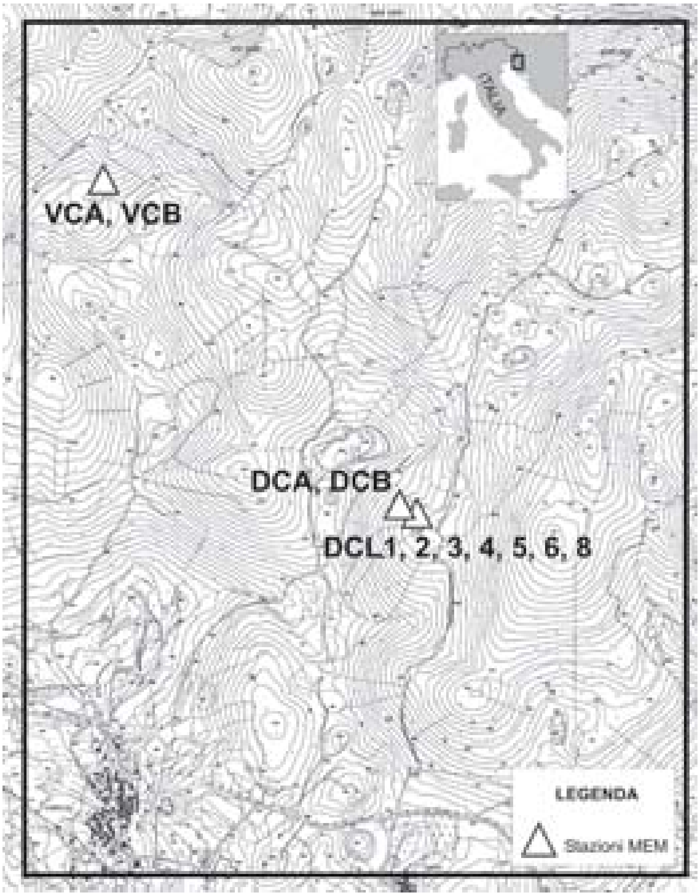

Fig. 1: Posizione delle stazioni sulle dolomie indagate con il MEM ed il t-MEM sul Monte Lanaro, Trieste.

In questa sede vengono descritti i siti, le stazioni oggetto d'indagine e vengono presentati i primi risultati delle campagne di misura sulle stazioni posizionate sulle dolomie (Fig. 1) del Monte Lanaro (Carso Classico, Trieste, Italia).

2. MATERIALI E METODI

2.1 Area di studio

Il sito d'indagine si trova sul Carso, un plateau calcareo che si sviluppa alle spalle del Golfo di Trieste, fra il livello del mare e i 500 metri di quota. E' caratterizzato da una potente successione carbonatica che va dal Cretacico inferiore all'Eocene inferiore p.p. Ad essa segue una spessa sequenza clastica riferibile all'Eocene inferiore, definita da alternanze quarzoso-feldspatiche e marne in facies torbiditica (Flysch eocenico Auct.). Le stazioni qui considerate sono state posizionate su dolomie di età Cretacico inferiore, in corrispondenza delle pendici meridionali del Monte Lanaro.

Il clima nell'area di studio è di transizione tra il tipo prealpino e quello sub-mediterraneo (Righini et al., 2002). Le precipitazioni sono piuttosto elevate, con 1340 mm/a (stazione di Padriciano, 300 m s.l.m., periodo 1961-1990: vedi Stravisi, 2003), e sono distribuite abbastanza omogeneamente tra primavera, autunno ed inverno, con massimi ad ottobre e giugno, mentre sono sporadiche in estate. La temperatura media annua è di circa 12°C. Il mese più caldo è agosto (24°C) mentre il più freddo è gennaio, con temperature medie inferiori a 6°C.

2.2. Strumentazione di misura

Le misure sui tassi di consumazione in campagna sono state eseguite con il micro erosion meter, MEM (High & Hanna, 1970) e con il traversing micro erosion meter, TMEM (Trudgill et al., 1981).

Lo strumento è equipaggiato con tre supporti di forma apposita, che aderiscono a tre chiodi in titanio, due semisferici e uno piatto, inseriti nella roccia. Il micrometro è fermamente fissato ai supporti, grazie alla particolare combinazione supporti-chiodi. I supporti in titanio vengono inseriti in tre fori opportunamente disposti nella roccia e fissati con cemento a presa rapida. Il TMEM, a differenza del MEM, è in grado di acquisire più dati su ogni singola stazione. Lo strumento è equipaggiato con un comparatore elettronico millesimale direttamente interfacciato al computer portatile (Stephenson, 1997). La configurazione utilizzata permette di ottenere un data set corrispondente ad un massimo di 238 misure per stazione.

Considerato l'elevato numero di stazioni posizionate ed il tempo necessario all'acquisizione dei dati, si è deciso di limitare le letture ad un massimo di 20-25 punti per stazione.

Nella presente ricerca si è fatto uso di uno strumento equipaggiato con un comparatore digitale (risoluzione 0,01 mm). Per ridurre l'errore legato alle variazioni di temperatura, lo strumento, prima dell'utilizzo, viene messo in equilibrio con la temperatura esterna.

L'eventuale errore dovuto ad un possibile danneggiamento della superficie rocciosa, causato dalla punta del micrometro, è stato stimato con due metodologie: (1) attraverso misure ripetute su un campione di prova, che ha evidenziato, dopo 100 misure, differenze massime pari alla precisione dello strumento e (2) attraverso osservazioni al microscopio elettronico a scansione (SEM) di 25 campioni colonizzati e non colonizzati, toccati dalla punta del micrometro e altri 25 campioni non toccati. Considerando l'estrema precisione richiesta in questo tipo di misure, non va dimenticato che le letture al di sotto dei 0.010 mm devono comunque essere valutate con molta cautela, come suggerito da Spate et al. (1985) e Stephenson et al. (2004). Inoltre, è consigliabile ripetere la taratura dello strumento su una piastra in acciaio ad ogni ciclo di misure.

I valori negativi indicano che la superficie si solleva, mentre i valori positivi indicano che la superficie si consuma.

2.3. Localizzazione dei siti e delle stazioni di misura

Per quanto riguarda la scelta del posizionamento delle singole stazioni, sono state privilegiate superfici orizzontali colonizzate da numerosi talli endolitici e su cui fosse agevole il posizionamento e la lettura dello strumento.

Il sito d'indagine considerato, denominato DCL, contiene 5 stazioni su superfici colonizzate da licheni endolitici (Fig. 2) ed 1 stazione su superficie non colonizzata, ottenuta per rottura meccanica di un blocco di dolomia esposto orizzontalmente, per un totale di 6 stazioni.

Sono state inoltre considerate anche altre 4 stazioni sulle dolomie (VCA, VCB, DCA, DCB) posizionate a partire dal 1979 su superfici non colonizzate.

Le misure sono state acquisite generalmente due volte all'anno, in maggio-giugno ed in ottobre-novembre, in modo da studiare la variabilità stagionale dei tassi di consumazione.

Fig. 2: Sezione sottile di dolomia colonizzata da Bagliettoa parmigerella. Nella parte superiore dell'immagine si possono notare in sezione trasversale i corpi fruttiferi del lichene e lo spesso strato algale di colore verde.

2.4 Caratterizzazione delle singole stazioni di misura

Ognuna delle stazioni del progetto sono state fotografate a scale diverse: una foto relativa al sito d'indagine, una foto della singola stazione e una foto con l'ingrandimento dell'area centrale indagata con il TMEM. Ogni stazione colonizzata inoltre è stata identificata mediante incisione di un numero romano progressivo, in quanto più resistente e duraturo dell'utilizzo di pennarelli indelebili.

Per ogni stazione è stato effettuato un prelievo di roccia colonizzata da un tallo della stessa specie della stazione di misura, in genere ad una distanza molto contenuta (10-30 cm).

Il campione è stato inserito in una busta numerata, e trasportato al laboratorio per la successiva identificazione del lichene, e l'allestimento di una sezione sottile, ottenuta tagliando la roccia perpendicolarmente alla superficie esterna del tallo, in modo da poter caratterizzare tanto l'interfaccia lichene-substrato, quanto la litologia.

L'identificazione delle specie è stata effettuata allestendo preparati montati in acqua dei corpi fruttiferi, che sono stati esaminati al miscroscopio a luce trasmessa. Sono state utilizzate le chiavi di identificazione di Clauzade & Roux (1985) e Purvis et al. (1992). Il materiale è stato inoltre confrontato con campioni di riferimento dell'erbario lichenologico del Dipartimento di Biologia di Trieste (TSB), dove sono stati anche depositati tutti i licheni raccolti nello svolgimento del lavoro di campo.

RISULTATI E CONCLUSIONI

In Tab. 1 sono riportati per ciascuna delle 5 stazioni colonizzate: il lichene indagato, i valori di consumazioni risultanti (i valori positivi indicano un abbassamento della superficie topografica, i valori negativi indicano un accrescimento), ed eventuali note relative ad ogni stazione. Le specie di licheni endolitici indagate appartengono al genere Bagliettoa [B. parmigera (J.Steiner) Vìzda & Poelt e B. parmigerella (Zahlbr.) Vìzda & Poelt]. Si tratta di specie che producono come corpi fruttiferi dei periteci quasi completamente immersi nel tallo, che protrudono verso l'esterno solo attraverso una porzione molta ridotta, con l'ostiolo attraverso cui verngono scaricate le spore nell'ambiente circostante.

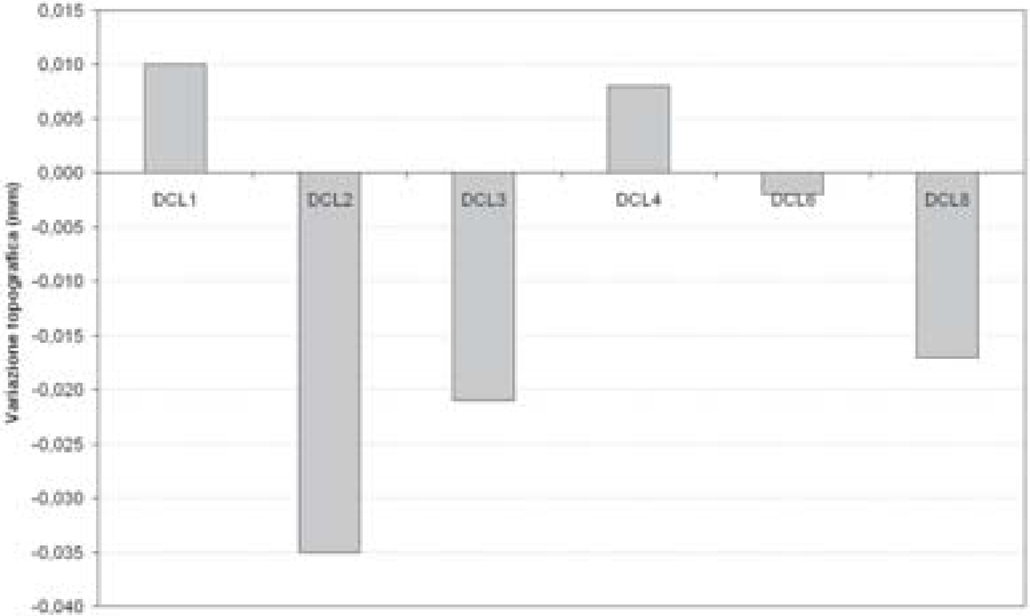

Fig. 3: Variazione topografica delle stazioni sul Monte Lanaro (Progetto PRIN 2004).

Stazione	Quota	Litologia	Tipo di lichene indagato	Tasso medio di consumazione (mm/a)	Giorni di osservazione	Note
DCL1	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	*Bagliettoa parmigera*	0.010	647	Stazione progetto PRIN
DCL2	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	*Bagliettoa parmigerella*	-0.035	647	Stazione progetto PRIN
DCL3	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	*Bagliettoa parmigera*	-0.021	647	Stazione progetto PRIN
DCL4	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	*Bagliettoa parmigera*	0.008	647	Stazione progetto PRIN
DCL6	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	*Bagliettoa parmigerella*	-0.002	647	Stazione progetto PRIN
DCL8	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	Superficie fratturata	-0.017	647	Stazione progetto PRIN
DCA	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	\	0.011	2904	
DCB	420	dolomite (85.6%), calcite (10.1%), residuo insolubile (4.3%)	\	0.009	2904	
VCA	390	dolomite (85.65%), calcite (10.13%), residuo insolubile (4.22%)	\	0.022	9846	
VCB	390	dolomite (85.65%), calcite (10.13%), residuo insolubile (4.22%)	\	0.008	8593	

Tab. 1 - Dati descrittivi delle stazioni di misura: acronimo della stazione (A); specie di lichene indagato (B); periodo di misura (giorni) (C); tasso medio di variazione microtopografica (mm/anno; valori negativi: accrescimen-to; valori positivi: abbassamento) (D); eventuali note aggiuntive (E).

I dati mostrano che la superficie superficie esterna dei licheni varia tra -0.039 mm/anno nella stazione DCL2 (B. parmigerella) a 0.012 mm/anno nella stazione DCL4 (B. parmigera). Le misure ottenute indicano che le superfici delle dolomie colonizzate si sono generalmente accresciute nel corso del periodo di osservazione, così come anche la superficie non colonizzata (Tab. 1, Fig. 3). Unica eccezione la stazione DCL 4 (0.012 mm/anno) che inve-

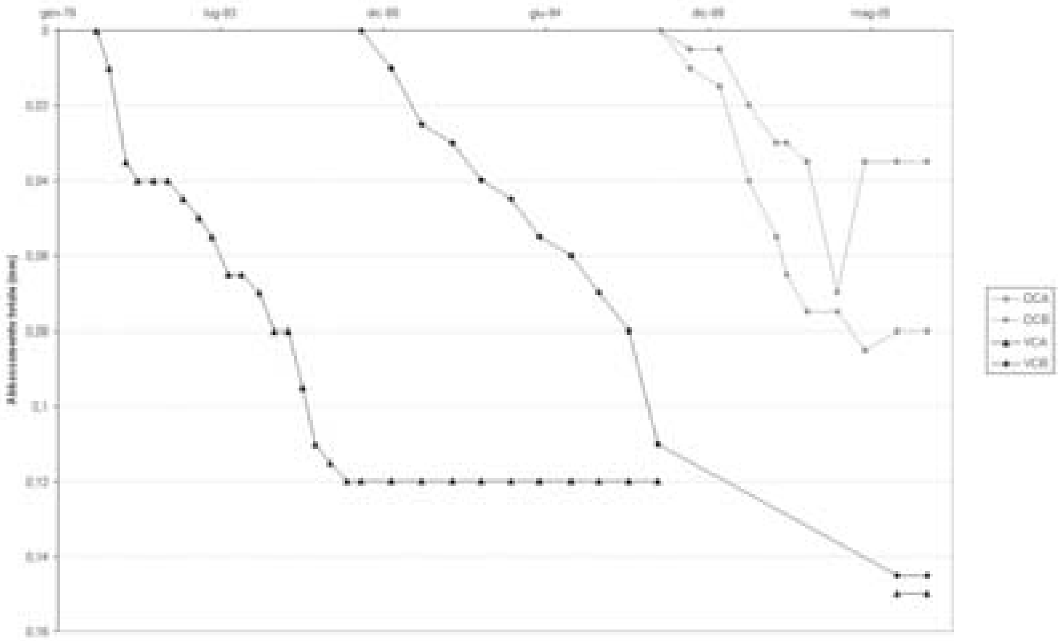

Fig. 4: Variazione topografica media nelle stazioni posizionate precedentemente sul Monte Lanaro.

ce ha evidenziato un modesto abbassamento. Le stazioni posizionate in precedenza su superfici non colonizzate si abbassano con valori che variano da 0.008 a 0.022 mm/anno (Tab. 1, Fig. 4).

I valori in accrescimento potrebbero anche essere legati alle variazioni giornaliere legate all'espansione ed alla contrazione dei talli lichenici, come proposto da Gomez Pujol et al. (2007), o al semplice assorbimento di umidità da parte della superficie rocciosa (Furlani e Cucchi, 2007). Va osservato comunque che questre misure vanno considerate con cautela, dal momento che il TMEM misura le variazioni topografiche della superficie esterna del lichene, mentre non è misurabile direttamente quanto avviene in corrispondenza della roccia al di sotto del tallo. E' evidente in ogni caso che è necessario un periodo di tempo molto più lungo per evidenziare variazioni significative causate dalla crescita lichenica, e i dati qui presentati hanno valore puramente indicativo.

RINGRAZIAMENTI

Si ringraziano Anna Rossi per l'aiuto nelle misure di campagna e Lorenzo Furlan (Dipartimento di Scienze della Terra, Trieste) per l'allestimento delle sezioni sottili.

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CAVES IN THE YOUNGEST VOLCANIC STRUCTURE OF SLOVAKIA

LUDOVÍT GAÁL & IGOR BALCIAR [1]

Abstract: The youngest volcanic structure of Slovakia occurs in Middle Slovakia, in the Štiavnické vrchy Mts. It consists of scoria cone named Putikov vršok and the extensive basalt lava covers deposited in 3 levels. The youngest cover lies on the Quaternary terrace of the Hron River. Its age was determined by OSL method to 102,000 ± 10,000 years (younger Riss). Caves are developed both in the scoria cone and the lava cover. A volcanic exhalation cave named Sezam is known in the scoria cone with small underground spaces and exhalation chimney. A small crevice-type cave is known in the upper part of lava cover which originated by the deflection of the basalt column of jointing on the edge of cover. The most interesting is a lava-tube cave in the lower part of the lava cover. Unfortunately this cave was covered by bulldozer during agricultural terrain modifications shortly after its discovery.

Key words: alkali basalt, scoria cone, lava cover, basalt cave

Fig. 1. Basalt lava cover near Nová Baňa in Southern Slovakia.

The alkali basalts are the youngest volcanic rocks in Slovakia. They occur in Cerová vrchovina Mts. (South Slovakia, Cerová Basalt Formation, 5.5-0.4 MA), in the Luèenec Basin (South Slovakia, Podreèany Basalt Formation, 8-6.4 MA) and in the Štiavnické vrchy Mts. (Middle Slovakia, 102,000 years). These basalts originated by the subduction of SE part of the oceanic lithosphere of External Carpathians during the Tertiary.

The youngest basalt volcanic structure is discovered in Štiavnické vrchy Mts. near Nová Baòa town. It consists of scoria cone named Putikov vršok and of lava cover in 3 levels. The youngest cover lies on the Quaternary terrace of the Hron River. Its age was determined by OSL method to 102,000 ± 10,000 years, e. g. younger Riss (Šimon & Král' 2001).

The 1st cave is known in the SW slope of scoria cone Putikov vršok (Gaál 1999). It is a typical syngenetic volcanic exhalation cave with underground space and exhalation chimney with the depth of 12 m. The length of the cave is 26.4 m. Some nice volcanic bombs and lava scraps were discovered on the cave wall.

The other little cave named Malá bazanitová is situated in the upper part of the lava cover.

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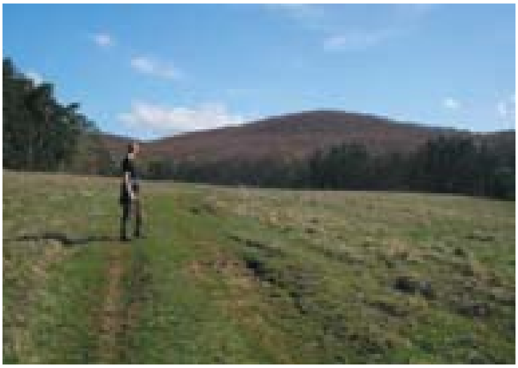

Fig. 2. Scoria cone Putikov vršok and the lava cover. Photo: L. Gaál

Fig. 3. The entrance of the Sezam cave. Photo: I. Balciar

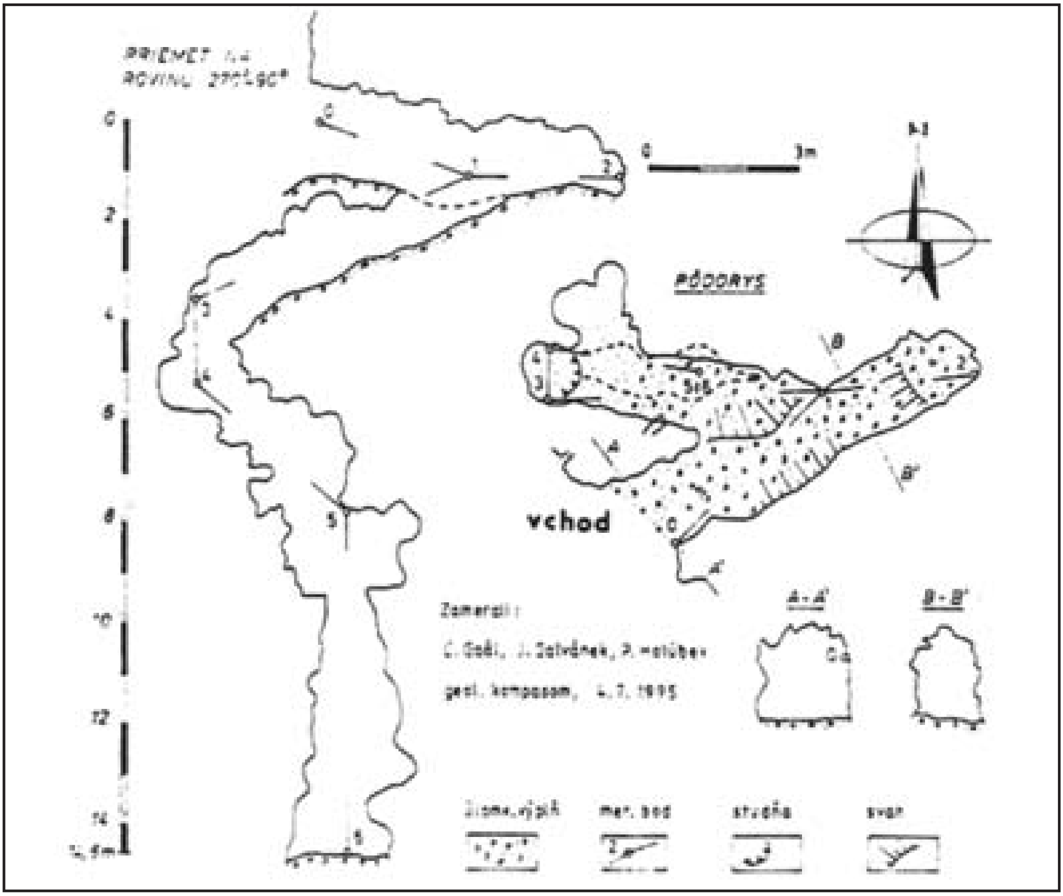

Fig. 4. The Sezam cave.

It is a small crevice cave with the length of 11 m originated by the deflection of the basalt column of jointing on the edge of the lava cover.

The entrance of the last cave was discovered during agricultural terrain modifications in summer 2003 in the lower part of the lava cover. But shortly after the discovery, it was covered by bulldozer. Meantime, two geologists of Dionýz Štúr Geologic Institute in Bratislava (L. Šimon and J. Maglay), who also mapped this area, took some pictures of the cave. After them the tube-shape cavity has a lateral ledge after lava setting. The depth of cavity was about 3 m, but speleological and geological research in continuation of underground space wasn't realized.

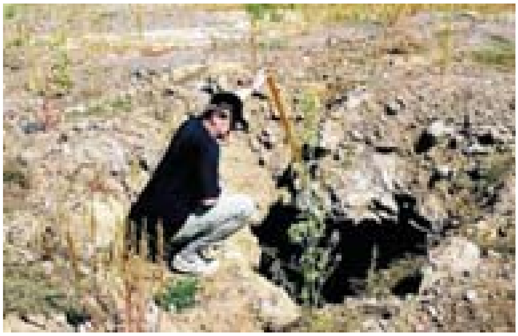

Fig. 5. The entrance of the lava cave in 2003. Photo: L. Šimon

We have tried finding it again by geophysical researches but without result until now. Two methods were used in spring of 2008: gravimetric and georadar. The linear underground space was not identified by either of these methods. Therefore we suppose that this underground space represents a lava rise cave originated by uplifting of solidified surface crust of lava cover. The uplifting of lava crust could happen as a result of the fluid lava inflation after the lava flow on the water-soaked alluvial sediments of Hron River. The similar caves were researched by P. Gadányi (2008) in Island.

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SIGNIFICANCE OF THE TOPOGRAPHICAL MEASUREMENTS PERFORMED BETWEEN 2006 AND 2007 FOR ANALYSING THE MORPHOLOGY OF THE COLLAPSE SINKHOLE ESTABLISHED ON THE ANTHROPIC SALT KARST FROM OCNELE MARI, ROMANIA

MAGDALENA NĂPĂRUŞ[1] - MARIUS MOCUȚA[2]

The Field No. 2 from Ocnele Mari region, in the Vâlcea County, Romania, was an important salt exploitation from 1970 to 1991, using dissolution to produce brine. The brine was send by pipelines to adjoining chemical works. By means of echo measurements taken in 1993 and 1995 by SOCON (Sonar Control Kavernenvermessung, Germany), disproportional large voids were detected. The improper management resulted in a gigantic cavern of 4 million m^3, filled with brine, with a diameter of approximately 350 m - one of the largest caverns in the world. This cavern was linked with the acceleration of karst processes by human impact.

In 2001, the cavern collapsed and it formed a very large sinkhole, with a diameter of 300 m on E - W direction and 260 m on N - S direction. The brine evacuated on this collapse has caused the contamination of the river that crosses the Ocnele Mari region. In 2004 and 2005, similar events have enlarged the sinkhole. Since the cavern extent is still larger than the sinkhole dimensions, the morphology of the collapse sinkhole is currently very dynamic. The latest topographical measurements, made outside and inside the collapse sinkhole, gave us its new outline and the impact of this extinction on the residential area.

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CAVES IN NON-SOLID AND POORLY CONSOLIDATED ROCKS OF AUSTRIA

RUDOLF PAVUZA[1] & LUKAS PLAN

Summary

Some Austrian Pseudokarst-Caves in miocene sandstones and pleistocene gravels, conglomerates and moraines as well as in loess are presented.

Lateral stream erosion lead to sometimes extended caves which have been artificially altered by locals. In contrast to this genesis loess-caves have have been formed by infiltrating local waters mobilizing the unconsolidated fine-grained sediments. Finally a “cave” in poorly consolidated gravels is presented where the genesis remains rather unclear.

1. Introduction

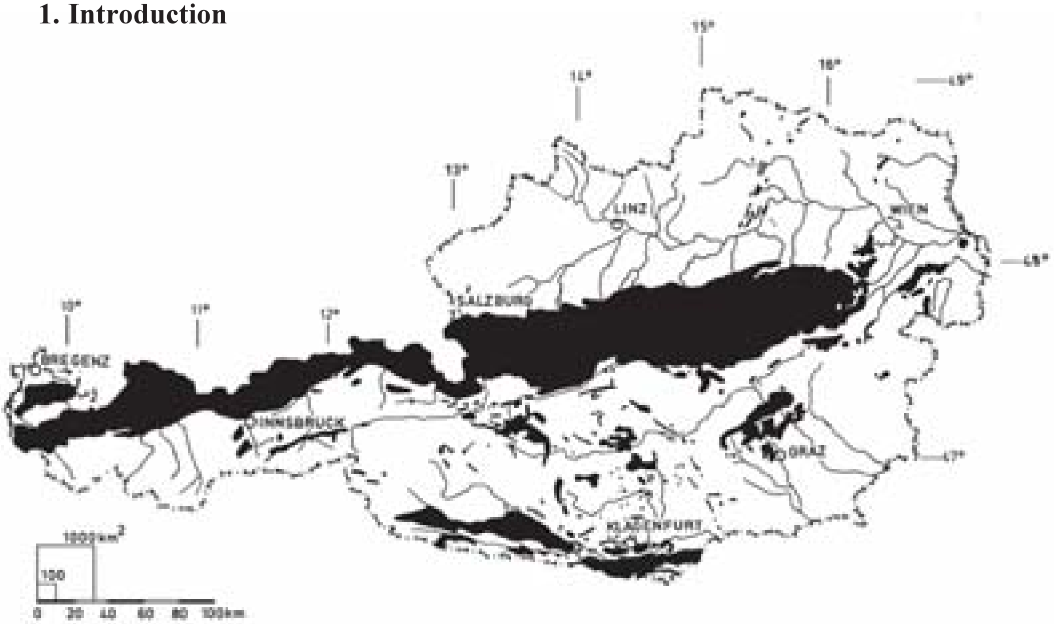

Fig. 1: Karst- and non-Karst areas of Austria (black= Karst)

Some 20 % of Austria is dominated by karst rocks (Fig. 1) The remaining 80 % consist of crystalline rocks of the Central Alps and the Southern Bohemian Massif - mostly non karstic -, Flysch and Molasse and some extended basins and valleys. In the former some isolated karst phenomena can be found. Pseudokarst features are abundant, but not well investigated yet. In the past Pseudokarst Symposia we presented some overviews (Mais & Pavuza, 1988, Pavuza & Mais, 1988, Pavuza et al. 2003, Pavuza 2006)

In this paper examples from different geological settings are presented, showing again the wide variety of non karstic - “pseudokarst” - caves.

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2. Miocene calcitic sandstones

In the „Leithakalk“ (Leitha-Limestone, Miocene) of the Southern Vienna Basin a variety caves have been mapped, where - despite the fact, that the host rock would be karstifiable - the speleogenesis is dominated by non-karstic processes. Dominating factors are river erosion and tectonics as well. In the example from Steinberg (NE of Vienna) 8 caves have been investigated where a severe overforming by man could be documented, but the initial phases of these objects turned out to be of natural origin by lateral stream erosion (Fig. 2). It has to be mentioned that the current stream would not be able to produce caves of this remarkable size (Fig. 3), implicating a period with significantly increased runoff - probably Interglacial periods - for their genesis.

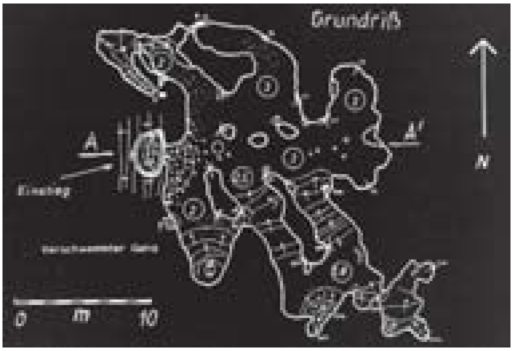

Fig.3: Map of Steinberghöhle I (6847/13); from MAYER et al.(1989)

Fig 4: Surrounding of the Steinberg-Caves, Lower Austria; from MAYER et al.(1989)

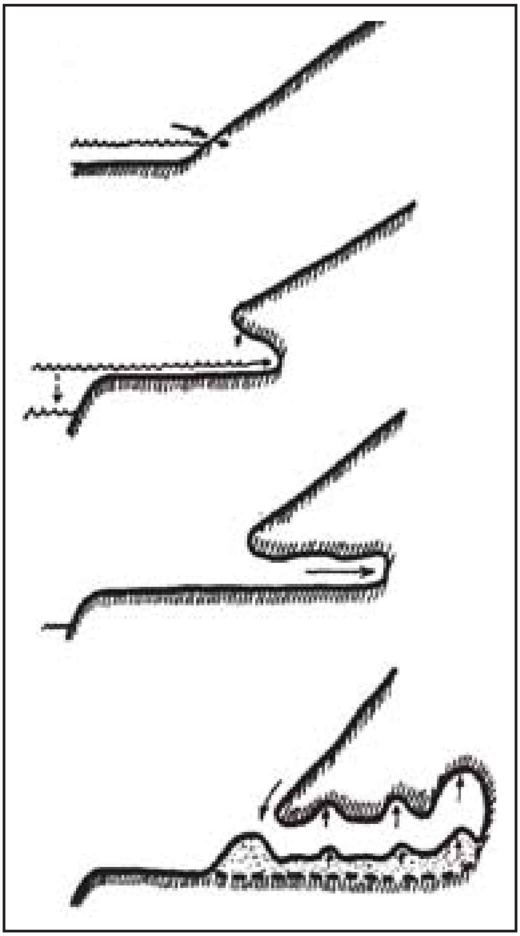

Fig 2: Modell of cave development in the Steinberg Caves, Lower Austria; from MAYER et al., 1989)

3. Pleistocene conglomerates and moraines

In the Ybbs-Valley in western Lower Austria one can find extensive outcrops of consolidated Pleistocene conglomerates up to 20 m high. Due to lateral erosion of the Ybbs-River

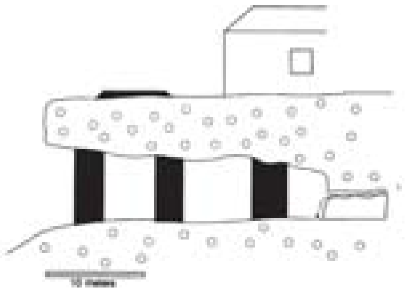

Fig. 5: Cross section of the Höchtlhöhle (1873/5) near Waidhofen, Lower Austria (right hand side: passage of Fig. 6)

Fig 6: Remote passage in the Höchtlhöhle

several caves, mostly shallow, but sometimes of notable depth can be observed (Fig.5) . Their genesis is - again - related predominantly to this erosional process, as the dissolution of the partly calcitic matrix is too slow to compete but might be of some significance for subsequent overforming. In the back of the largest cave, the 40-m long "Höchtlhöhle" there is a narrow continuation of a different character. Almost entirely barred by fine grained sediments and showing remarkable tiny straw-stalactites this passage can be followed some 10 m before it becomes to small (Fig. 6). A distinct airflow into the cave could be detected at that time. Some 10 m above the cave there are houses and gardens with no signs of any cave entrance. We believe that this passage - probably formed by corrosional processes - is older than the cave formed by the river and their coincidence is rather accidental.

4. Loess

In the lowlands between the Southern Bohemian Massif and the Alps loess is abundant and several caves have been described in the past. Recent investigations proved severe alterations of these caves due to the instability of the loess during periods of heavy precipitation.

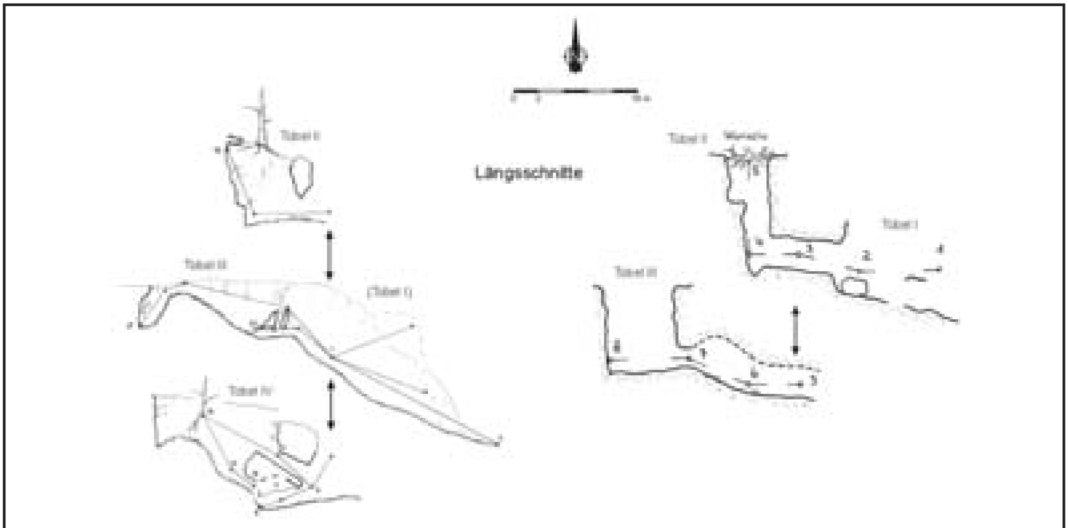

Fig. 7: Cross Section of "Wasserschloss" (6846/12), Engelmannsbrunn, Lower Austria (mapped 9/2005)

An example from the village of Engelmannsbrunn NW of Vienna documents this process (Fig. 7 and Fig. 8) and the ephemerality of these objects.

5. Pleistocene gravels

In a extensive gravel pit in the southernmost Vienna Basis a „cave passage“ some ten meters long appeared during diggings for a garbage dump (Fig 9). No signs of artificial overforming or other traces of human influence could be detected. On the other hand the Pleistocene gravels are poorly consolidated, so that former traces could have been altered entirely. No further investigations were possible because this object has been destroyed after the preliminary studies. We assume that this might have been be an old "Erdstall" from the middle ages - or a natual phenomenon with a genesis perhaps similar to the caves in the loess to some extent.

6. Key questions and goals for future research

* Identification and quantification of manmade and/or overformed cave passages

* Identification of "Consequence Caves"

* Quantification of dissolution of calcitic components

* Coverage of research (still poor)

Fig. 8: Entrance of Wasserschloss (6846/12), Sept. 2005

Fig. 9: Cave passage in the "Fischer quarry", Southern Vienna Basin

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ENVIRONMENTAL MONITORING OF KARST AQUIFERS AND ASSESSMENT OF PHYSIO-CHEMICAL PROPERTIES OF KARST WATER

VINOD KUMAR JENA[1]

Abstract - Karst areas are regions where layers of water soluble rock, such as Limestone, Dolomite, or Gypsum are found. These rocks are dissolved by groundwater and typically have caves and sinkholes. The karst water contains inorganic components such as NO3 -, PO4 3-, Cl- and SO4 2- including organic matters. Karst aquifers are important sources of drinking water. It is polluted through the human activities, which includes waste water directly drain into the Karst. Water generally moves very fast by infiltration processes but far more by concentrated flows through fissures and openings in Karst. In our Investigation it is found that anions such NO3 -, PO4 3-, Cl- and SO4 2- ranged from 212-852, 442 - 962, 300-785, and 142-756 mg l-1. In addition this some metals such as Na, K, Mg, Ca, and Fe are found in Karst water. In the present study environmental components affecting the Karst aquifers and includes assessment of physical parameters of Karst water at different period of time. The study contributes a better preservation of cave environment of Karst region.

Keywords: Karst aquifers, Metals, Anions, Environnemental components, Cave, Preservation.

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