International Workshop
September 27 - October 2, 1996
Postojna, Slovenia

THE ROLE OF IMPACT PROCESSES IN THE GEOLOGICAL AND BIOLOGICAL EVOLUTION OF PLANET EARTH

ABSTRACTS

GEOLOGY OF WEST SLOVENIA FIELD GUIDE

Ljubljana 1996

Edited by Katica Drobne, Špela Goričan, Barbara Kotnik

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FOREWORD

Impact cratering on earth has traditionally not been accentuated as a geological process in classical geological studies. Only recently have earth and planetary scientists realized that impact cratering is either the most important, or one of the most important processes that affects the shaping of the surfaces of the terrestrial planets - including the Earth. In January 1993, the ESF initiated a Scientific Network on "Impact Cratering and Evolution of Planet Earth", as an interdisciplinary effort of scientists representing the geoscience, astronomy, and material science communities. The Network led to the development of a highly interactive scientific community with clear perspectives for future research. A very important aspect of impact cratering is the influence of impacts on the geological and biological evolution of our own planet. Only recently do we now begin to appreciate that impacts played a larger role in the evolution of the earth than was realized before. A specific example is the discussion about the causes for major biological extinctions. Thus, a reassessment of the role of catastrophic events in geoscience is needed. This exceedingly important aspect has been widely neglected by the conventional geoscience community, especially in Europe. Even after the ending of the ESF Network at the end of 1995, a continuation of the current efforts on a European level is mandatory to prevent Europe from falling short of the international standards in this important field of innovative research. The European impact community is very grateful to the organizers of the present workshop for providing a forum for impact researchers in an attempt to keep the ball rolling.

Christian Koeberl
Institute of Geochemistry
University of Vienna, Austria

A WORD FROM THE SLOVENIAN MEMBER OF THE EUROPEAN SCIENCE FOUNDATION

We in the Slovenian Science Foundation are very pleased to learn that the Ivan Rakovec Institute of Palaeontology, operating under the aegis of the Scientific Research Centre of the Slovenian Academy of Sciences and Arts has accepted the responsibility of organising the international scientific workshop entitled "The Role of Impact Processes in the Geological and Biological Evolution of Planet Earth". This is by all means a recognition of the quality of scientific and research work by Slovenian palaeontologists and a mark of trust in the organisational capabilities of Slovenian researchers.

I am pleased that Slovenian palaeontologists and geologists have now achieved through their characteristic perseverance and zealousness, within the framework of the ALPE-ADRIA Community and further afield, exceptional results in their scientific and research work and have cooperated in transnational projects. After the acceptance of the Slovenian Science Foundation into the European Science Foundation, our establishment is also striving to ensure moral and financial support for the further cooperation of Slovenian researchers in transnational research projects, in coordinating activities, in creating and spreading scientific and research networks and for their participation in international scientific meetings. Through the latter, we are monitoring with special concern the development of new research personnel and are assisting them to join the flow of scientific information in the international scientific community, especially within the framework of the European Science Foundation.

We expect that the science workshop, which will take place from 27 September to 2 October 1996 in Postojna, will not only be the right environment for presentations and discussions on the results thus far of scientific and research work but also an opportunity to reach agreement on further activities, especially on transnational projects which will be open to researchers from various countries.

I wish the participants at this international workshop in Postojna successful and fruitful work.

Dr Edvard Kobal
Director of the Slovenian Science Foundation

PREAMBLE

This conference has been organised on the sunny side of the Alps, in a small but beautiful country. Here, we live a dynamic life in the social, commercial and political fields. All this is like our geology, which is among the most complicated on this side of the Alps. Large tectonic units, with rocks from the Devonian to the Pleistocene, lie in a triangle between Italy, Austria and Slovenia. Many years of geological research have been done here. Many researchers have strolled over this region, ever since the first printed maps in the middle of the last century were published. Today's international meeting was stimulated on the one hand by the enthusiastic work of a group of domestic and foreign researchers of the Cretaceous-Tertiary bundary and, on the other, on the request of our zealous colleague, Sandro Montanari, expressed at the last ESF meeting in Ancona in 1995. We all held the desire to keep our collegial contacts, to present our results and to hold professional discussions each year.

Now in Slovenia we have the honour and pleasure to greet our colleagues from 27 countries of Europe, Asia and America. We shall present a part of the geological peculiarities of the western part of Slovenia and Friuli, along with their inherited natural scientific and cultural monuments.

With your help we have also prepared the Conference Proceedings for later use. It contains printed abstracts and papers on the geology of western Slovenia, and particularly on the Karst written for this occasion. These proceedings have been enriched with a review of geological periodicals and geological maps from Slovenia, articles on the geology of the Trieste Karst region (1987-1966) and a 570 page long Bibliography (1973-1992) for Croatia.

With the accompanying events - excursions, plus exhibitions of geological literature and maps and ex libris collections with geological contents, as well as a concert of vocal and instrumental folk music, we would like to leave a deep impression with all participants of the work, life and culture here on the sunny side of the Alps.

Katica Drobne
Editor-in-Chief (MC)

PROGRAM

Friday, September 27 afternoon

Arrival of participants and hotel registration. Dinner.

Saturday, September 28

9:00 *Welcome addresses*
9:45 ***Coffee break***

GENERAL SESSION — Chairman A. Deutsch

10:30 D. Stöffler: *Concepts, goals, and achievements of the 1993-1995 ESF Scientific Network "Impact Cratering and Evolution of Planet Earth".*
11:00 A. Deutsch and V.L. Masaitis: *Geological aspects of terrestrial impact cratering.*
11:30 L.J. Pesonen: *The geophysical signatures of terrestrial impact craters.*
12:00 F. Langenhorst: *Shock metamorphic effects in minerals: correlation of optical and electronoptical observations.*

12:30 ***Lunch***

Chairman J. Smit

14:30 C. Koeberl: *Impact structures in Africa: a case study.*
15:00 D. Stöffler and R.A.F. Grieve: *IUGS classification and nomenclature of impact metamorphic rocks: towards a final proposal.*

15:30 ***Coffee break***

16:00 J. Smit: *The K/T boundary Chicxulub Impact event: A Review.*
16:30 L. Hottinger: *The fossil record of the foraminifera, a succession of global community maturation (GCM) cycles, or: how to survive global disruptive events in Earth History.*

INTRODUCTION TO EXCURSIONS — Chairwoman K. Drobne

17:00
- Geology of west Slovenia, Karst of Trieste and Gorizia
- Tectonic structure of southwest Slovenia
- Carbonate-platform sections:
  1. *Dolenja Vas (K/T boundary)* - K. Drobne, B. Ogorelec, T. Dolenec, E. Marton and L. Palinkaš
  2. *Škrbina (Cenomanian-Turonian)* - B. Ogorelec and B. Jurkovšek
  3. *Padriciano (K/T, Paleocene)* - T. Brazzatti, M. Caffau, A. Cozzi, F. Cucchi, K. Drobne and N. Pugliese
- Basin sections:
  4. *Lijak (K/T boundary, Paleocene)* - J. Pavšič
  5. *Lig (K/T boundary)* - J. Pavšič, T. Dolenec and A. Horvat
  6. *Doblar (Upper Cretaceous)* - B. Ogorelec, S. Buser and L. Šribar

20:30 ***Dinner***

Concert of Slovenian ethnic musicians:

- vocal group "Katice"
- instrumental group "Kurja koža"

Sunday, September 29

FIELD TRIP TO DOLENJA VAS, ŠKRBINA, PADRICIANO
- carbonate platform (p. 163-196, 215)

8:30	*Departure*
9:00	***Stop 1: Dolenja Vas*** - K. Drobne, B. Ogorelec, T. Dolenec, E. Marton, L. Palinkaš, H.J. Hansen
10:45	***Stop 2: Škrbina*** - B. Ogorelec and B. Jurkovšek
12:00	***Lunch*** at Kobjeglava
	Slovenian-Italian border
14:00	***Stop 3: Padriciano*** - T. Brazzatti, M. Caffau, A. Cozzi, F. Cucchi, K. Drobne and N. Pugliese
16:00	Grotta Gigante, ***coffee break***
	Lipica, stud farm
18:20	Lokev: tower ("tabor") and church
19:10	arrival in Postojna

Monday, September 30

IMPACTS AND BOUNDARIES — Chairman C. Koeberl

8:30	I. Gilmour: *Impact diamonds from Tunguska*
9:00	C. Schrand and A. Deutsch: *Formation of impact melt glasses in experimentally shocked granite.*
9:20	V.L. Masaitis and A. Deutsch: *On the distribution of the meteoritic component in shock-melted material at impact structures.*
9:40	Th. Hölker and A. Deutsch: *Geochemistry of impact melt rocks from the Lappajärvi (Finland) and Boltysh (Ukraine) impact structures.*
10:00	M. Ostermann, A. Deutsch and V.L. Masaitis: *New geochemical constraints on Urengoite, South Ural and Zhamanshin-Irghizit impact glasses.*
10:20	***Coffee break***
10:50	A. Preisinger, S. Aslanian, F. Brandstätter and F. Grass: *Distribution of KT-spinels in the Mediterranean area.*
11:10	E. Robin, R. Rocchia and O. Pierrard: *The K/T spinel: composition, origin and formation.*
11:30	P. Claeys: *Impact and global perturbation of the Earth system. A philosophical view and future research.*
11:50	Z. Sawlowicz: *Geochemical evidence for euxinic conditions in a water column during deposition of the Cenomanian-Turonian boundary sediments at Cismon (Venetian Alps - Italy).*

12:10 H.J. Hansen and P. Toft: *Dolenja Vas and its carbon isotopes.*

12:30 ***Lunch***

14:30 V. Puura, J. Plado, K. Kirsimäe, J. Kivisilla, M. Niin, and K. Suuroja: *Impact-induced metasomatism of granitic target rocks? Kardla Crater, Estonia.*

14:50 E.P. Gurov: *The Boltysh impact crater: lake basin with heated bottom.*

15:10 A.S. Vishnevsky, I.A. Balagansky and S.A. Vishnevsky: *Computer simulation of the Popigai impact event (compression and initial excavation stages) and some consequences on global dispersion of projectile and tektite glasses.*

POSTER SESSION

15:30 - 18:00

Impacts

- P. Solt: *Investigation of spherules in the Kaba CV3 chondrite fall area.*
- G. Don: *Study of extraterrestrial spherules in Hungary.*
- O. Pierrad, E. Robin, R. Rocchia and A. Montanari: *Discovery of extraterrestrial spinel in upper Eocene sediments.*
- B. Abate and C. Koeberl: *Search for impact craters in Ethiopia.*
- S. Zvonarić: *Gorski Kotar - Astroblema - Multiring basin - K/T boundary?*
- S. Zvonarić: *Shatter cone - Köfels (Tirol, Austria).*
- S. Zvonarić: *Hollow central uplift of the crater - submarine impact indicator?*
- A.L. Palinkaš, K. Drobne, G. Durn, G and S. Miko: *Mercury anomaly at the Cretaceous-Tertiary boundary; Dolenja Vas, Slovenia.*
- T. Dolenec, S. Buser and M. Dolenec: *Isotopic changes at the P/Tr boundary in the Southern Karavanke Mountains.*

Paleobiology — Asia

- M. Akyazi and N. Özgen: *An example of determination of Jurassic/Cretaceous boundary with calpionellids from Turkey: Ilgaz Mountains (Çankiri).*
- N. Inan and E. Meriç: *An abnormal growth in* Orbitoides apiculatus *Schlumberger individuals at the K/T boundary in Yeleme (SW Antalya - Turkey).*
- N. Özgen and M. Akyazi: *Foraminifers of the K/T boundary from the Kastamonu region (NW Turkey).*
- E. Sirel: *Revision on the species of* Pseudolacazina *Caus 1979 (Foraminiferida) from the different localities of Turkey.*
- E. Sirel: *Occurrence of the genus* Sistanites *Rahaghi, 1983 (Foraminiferida) in two localities of Turkey.*
- Ş. Acar: *A new grouping for subgenus* Alveolina (Alveolina) *Hottinger 1960 species and subspecies.*
- S.J. Sameeni and A.A. Butt: *Use of Alveolinids for the recognition of the Paleocene-Eocene boundary in the Salt Range, Northern Pakistan.*
- A.K. Jauhri: *Recovery of the larger benthic foraminifera after the terminal Cretaceous event in the south Shillong region, NE India.*

- T. Kolar-Jurkovšek, B. Jurkovšek and H. Summesberger: *Reflection of the two pelagic episodes in the macrofossil associations of the Komen and Tomaj limestones in the Trieste-Komen Plateau, Slovenia.*
- J. Bulić, D. Babac and Z. Dmitrović: *Cretaceous/Paleocene boundary of stratigraphic section "Gvozd (Vrginmost - Tukleč wood)".*
- V. Veseli, Z. Dmitrović, D. Stanković and R. Slavković: *The Upper Cretaceous-Paleogene carbonate sediments in well Istra More-5 (Northern Adriatic, Croatia).*
- V. Premec Fuček: *Planktonic foraminiferal turnover near the Middle/Late Eocene boundary (Northern Adriatic, Croatia).*
- R. Calligaris: *Bone specimens of Dinosaurs of the karst of Trieste.*
- Gruppo Grotte "Carlo Debeljak": *Fossiliferous subterranean levels in Carso Triestino.*
- D. Miletić and B. Lugović: *Pliocene volcaniclastic sediments in the Croatian Adriatic off-shore region (Drill-hole Kruna-1).*

Africa, Pyrenees (coordinator Y. Tambareau)

- Y. Tambareau, J.-F. Babinot and J.P. Colin: *Non marine ostracod assemblages around the Cretaceous/Tertiary boundary in southern France and northern Spain.*
- M. Feist, L. Hottinger, Y. Tambareau and J. Villate: *Continental and brackish-water fossil assemblages around the Cretaceous-Tertiary boundary in the Pyrenees.*
- J.P. Colin, L. Hottinger, Y. Tambareau and V. Krasheninnikov: *Ostracods and shallow benthic foraminifera assemblages around the Cretaceous/Tertiary boundary in Mali, Western Africa.*

INTRODUCTION TO THE KARST OF POSTOJNA

18:00 M. Knez: *The karst of Postojna and surroundings. Its geological and speleological properties.*

19:00 ***Dinner***

20:30 Visit to Postojna Cave

Tuesday, October 1

IMPACT/PALEOBIOLOGY — Chairman H.J. Hansen

8:30 E. Pierazzo, H.J. Melosh and D.A. Kring: *Accurate modeling of the Chicxulub impact event using hydrocodes.*

9:00 H.B. Vonhof and J. Smit: *Late Eocene impact ejecta at DSDP site 689B (Maud Rise Antarctica): stretching up the strewn fields of the Late Eocene impacts.*

9:30 E. Buffetaut: *Birds at the Cretaceous-Tertiary boundary: a hidden mass extinction?*

10:00 D. Lučić: *Sequence stratigraphy and lithofacies of the Upper Cretaceous to Eocene carbonate deposits in the Kate-1 and Koraljka-1 off-shore wells (mid-Adriatic, Croatia).*

10:20	***Coffee break***
10:50	E. Luperto Sinni and A. Reina: *The Cretaceous-Tertiary transition in the southern part of the Apulian Platform.*
11:10	E. Luperto Sinni: *New data on the carbonate breccia deposits of south-oriental area of Murges (Puglia, southern Italy).*
11:30	F. Kulbrok: *K/T boundary and subsequent Tertiary facies and sedimentary patterns at the nothern Gulf of Suez (Egypt).*
11:50	R. Gietl: *Evolutionary events in the genus Alveolina from the Galala-Heights (NE Egypt).*
12:10	V.V. Shuvalov and N.A. Artem'eva: *Ejection of plumes created due to impacts against the Earth.*
12:30	V.V. Svettsov: *The erosion of the atmosphere caused by the impacts: numerical simulations.*
12:50	***Lunch***
14:30	*Information and discussion about IGCP projects 386, 384, and 393*
15:30	*Closure (D. Stöffler and C. Koeberl)*
16:00	***Coffee break***

Wednesday, October 2

FIELD TRIP TO LIJAK, LIG, DOBLAR
- basin (p. 199-213)

8:30	*Departure*
9:45	***Stop 4:*** *Lijak (Maastrichtian to Eocene)* - J. Pavšič
12:15	***Stop 5:*** *Kanal-Lig (K/T boundary)* - J. Pavšič, T. Dolenec and A. Horvat
14:15	***Stop 6:*** *Doblar (Upper Cretaceous)* - B. Ogorelec and S. Buser
	Lunch in Kobarid
16:40	*Tonovcov grad - archeological site, Late Antiquity*
17:40	*Museum of First World War*
19:45	arrival in Postojna

NOTES:

ABSTRACTS

CONTENTS

SEARCH FOR IMPACT CRATERS IN ETHIOPIA

B. ABATE AND C. KOEBERL

Institute of Geochemistry, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria

Currently, 17 impact craters are known in Africa (Koeberl, 1994, see also companion abstract by Koeberl, this volume). Considering the size of the African continent and the fact that worldwide about 150 impact craters are known at present, this is a small number. Many impact craters are known from cratonic areas in Northern Europe, Asia, and Canada, reflecting not only better preservation of impact structures in such stable areas, but also intense geological fieldwork. Thus, Africa is far from a similar share of established impact craters - young or old, even though, considering cratering rate estimates (e.g., Grieve 1987), there must be numerous craters in Africa still waiting to be discovered. Considering the substantial importance of impact craters for geology in general, but also for a possible economic interest (e.g., Grieve and Masaitis, 1994), and influence on the evolution of life on our planet, impact craters in general (and in Africa, in particular) deserve more extensive study.

No impact structures are so far known in Ethiopia. Ethiopia is one of the larger countries in Africa, with an area of about 1.13 million km^2 (slightly less than twice the size of Texas). Topographically, the country comprises about 50% of highland areas, divided by the Rift Valley, with some low-lying desert areas near Djibuti and Somalia. Due to political instability, relatively little international geological studies were done in Ethiopia over the past decades. In January and February 1996, we performed field studies in Ethiopia in an attempt to identify possible impact structures. In addition, satellite images of selected areas were studied as well. Field work was done in north central Ethiopia (in the area around Lake Tana), and in south central Ethiopia (around Shakisso, Sidamo province).

Lake Tana is the largest lake in Ethiopia and the source of the Blue Nile. It has an average diameter of about 60-70 km, but is very shallow, with an average depth of only 9 m. Lake Tana occupies the center of a large circular basin of at least 100-120 km in diameter, which is apparent on topographical maps. The area is covered with Quaternary alkaline olivine basalts (Merla, 1973), which may have a thickness of up to 1300 m (Mohr, 1971). Around Lake Tana, pumice and scoria are found at several locations. The origin of Lake Tana has been ascribed to rifting (Lake Tana Rift; Kazmin, 1972), but this hypothesis is largely untested. We collected a number of rocks from outcrops around Lake Tana and from Daq Island in the south-central part of the lake for petrographical and geochemical studies. Preliminary investigations confirm that the rocks are young basalts. Several drill cores, which were drilled to depth of < 100 m for water resource reasons, were studied as well, but none of the cores reached basement. While it is clear that the Lake Tana area is presently covered by several basalt flows, the basin must be more than just a geologically recent structure. However, presently available data do not allow any conclusions regarding an impact origin of this basin.

In addition, two small 350 m wide circular crater structures, Lake Zengena and Lake Tirba (at 10° 49' N and 36° 51' E), were also studied. Each of these lakes is filled by a lake, and both are apparently of volcanic origin. Abundant basalt outcrops were encountered, and no structures similar to those of impact craters were found.

Another attempt to check on a possible impact structure was made in the area around the town of Shakisso (at 5° 46' N and 38° 54' E), in the Sidamo Province. Two unpublished reports (Evdokimov, 1987; Evdokimov and Abebe, 1987) suggested the presence of a ring structure of 1.2 to 5 km diameter, shatter cones, Fe-Ni pellets, and other geological anomalies, which led these authors to suggest the presence of an impact structure. Our own field work failed to confirm the presence of any of these geological features. However, samples were taken for more detailed petrological and geochemical analyses, to rule out that any microscopic shock effects have been overlooked.

While we have so far been unable to confirm the presence of any impact structures in Ethiopia from geological field work, detailed petrographical and geochemical studies (by XRF, INAA, AAS, DCP-AES) of the samples from Lake Tana and Shakisso are in progress to obtain finn conclusions.

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A NEW GROUPING METHOD FOR SUBGENUS *ALVEOLINA (ALVEOLINA)* HOTTINGER 1960 SPECIES AND SUBSPECIES

Ş. ACAR

General Directorate of Mineral Research and Exploration of Turkey (MTA, 06520 Ankara)

In the previous work on subgenus *Alveolina (Alveolina)* Hottinger of genus *Alveolina* d'Orbigny related with grouping method of the species of subgenus have not been examined yet. In this study, 149 specimens of species and subspecies belonging to subgenus *Alveolina (Alveolina)* found in the Ilerdian to Lutetian sediments have been studied in detail and their grouping has been made. This new grouping method is based mainly on flosculinization. The basal layer of the adult chambers which follow two or more chambers cycles of the juvenile stage are thickened in the flosculinization. These 3 growing periods are namely juvenile, adult and senile stages.

1- Group of flosculinized *Alveolina (Alveolina)*: The juvenile stage with tightly coiled two or more whorls at least is followed by flosculinized chambers of adult stage of *Alveolina (Alveolina)* species and subspecies. For example *Alveolina (Alveolina) montanarii* Drobne (1977).

2- Group of pseudoflosculinized *Alveolina (Alveolina)*: There are no chambers of juvenile stage following the proloculus. Flosculinated whorls (chambers) of the adult stage in this group start from the proloculus to the last whorl of *Alveolina (Alveolina)* species and subspecies (Acar, 1995). For example *Alveolina (Alveolina) bayburtensis* Sirel (1976).

3- Group of unflosculinized *Alveolina (Alveolina)*: The chambers of the growth stages (juvenile, adult and senile) which follow the proloculus are coiled tightly or loosely and regular in the species and subspecies of this *Alveolina (Alveolina)* group. For example *Alveolina (Alveolina) lehneri* Hottinger (1960).

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AN EXAMPLE OF DETERMINATION OF JURASSIC/ CRETACEOUS BOUNDARY WITH CALPIONELLIDS FROM TURKEY: ILGAZ MOUNTAINS (ÇANKIRI)

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Jurassic/Cretaceous boundary could not easily be lithologically distinguished in Turkey because of continuous sedimentation as is the case in many regions of the world. However, this boundary in Calpionellids containing units could easily be determined either by means of detailed investigations of phylogenetic evolution in Calpionellid units, or Calpionellid Zone boundaries.

The study was carried out in vicinity of Sarialan village in the south of Ilgaz Mountains (Çankiri) of North-West Turkey which is located within Tethys province.

Calpionellids containing units are represented by clayey limestones, micritic limestones and least sandy clayey limestones which were thin-medium layer structured.

As a result of detailed investigations on Calpionellids found within this unit, 5 Calpionellid biozones were determined and phylogenetic evolution of Calpionellid assembly was also investigated.

In this detailed investigation a conspicious phylogenetic evolution of *Calpionella alpina* Lorenz and *Tintinnopsella carpathica* Murgeanui & Flipescu species in Jurassic/Cretaceous boundary were observed which is located in a nearby *Crassicollaria intermedia* and *Calpionelia alpina* Biozone boundary.

At the Jurassic/Cretaceous boundary, *Calpionella alpina* Lorenz was very small, whereas *Tintinnopsella carpathica* Murgeanui & Flipescu was bigger.

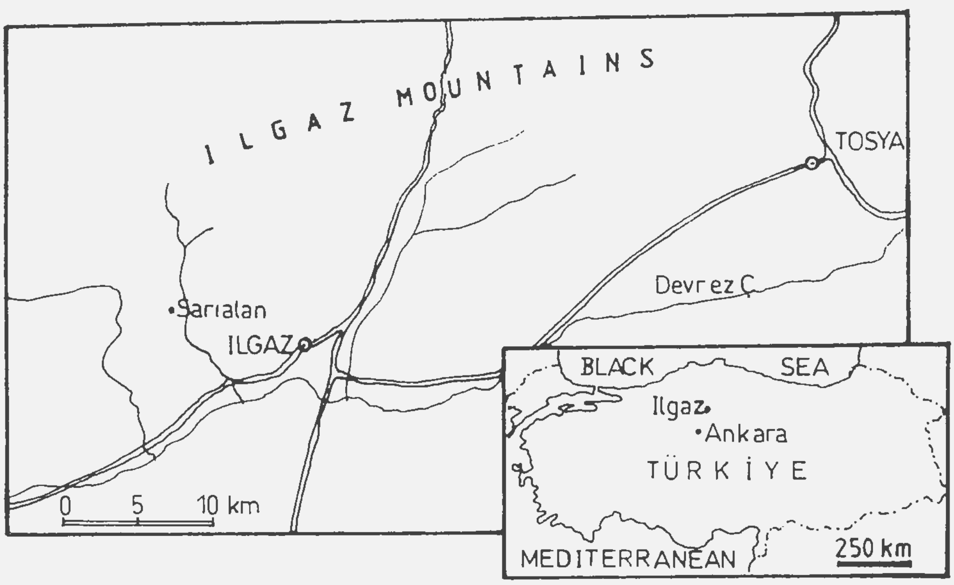

Figure 1. The location map of investigated area

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BIRDS AT THE CRETACEOUS-TERTIARY BOUNDARY: A HIDDEN MASS EXTINCTION ?

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Contrary to the so-called "non-avian" dinosaurs, the "avian" dinosaurs (i.e., birds) survived the events of the Cretaceous-Tertiary. Because the fossil record of birds is supposedly very poor, however, they are seldom mentioned in studies on K-T extinctions and survivals. In recent years, our knowledge of Cretaceous birds has increased considerably (Chiappe, 1995), and speculations about what happened to birds at the K-T boundary have appeared (Feduccia, 1995). There is clearly no consensus among specialists about the extent and significance of bird extinctions at the K-T boundary, but a few facts having a bearing on the question may be mentioned.

There is now good evidence for a previously unsuspected radiation of Cretaceous birds different from the modern groups (Feduccia, 1995; Chiappe, 1995). Besides forms which have been known since the last century, such as the Hesperornithiformes and Ichthyornithiformes, the Enantiornithes now appear to have diversified considerably during the Cretaceous, on a world-wide scale. In addition, flightless forms such as *Patagopteryx* also occur in the Cretaceous. A recent unexpected addition to the Cretaceous avifauna is the discovery of very large, probably flightless birds, in the Upper Cretaceous of Europe (Buffetaut et al., 1995). The relationships between the various groups of Cretaceous birds are still disputed, but it remains that the diversity of these birds was much greater than what had previously been suspected.

Many of the above-mentioned Cretaceous bird groups (including the Enantiornithes) are unknown in the Tertiary. Some modern bird groups appeared during the Cretaceous, but their main diversification appears to have taken place during the Tertiary. This pattern has been interpreted in various ways. According to Feduccia (1995), there was a mass extinction of birds at the K-T boundary, which resulted in the disappearance of most of the Cretaceous groups, and the modern diversity of birds is the result of explosive evolution after the end of the Cretaceous, from a group of "transitional shorebirds" which escaped extinction. This interpretation has been challenged by Chiappe (1995), who claims that the diversification of modern birds began before the end of the Cretaceous, and remarks that the last record of several lineages of Cretaceous birds is before the Maastrichtian.

Considering the importance of birds in both Cretaceous and Cenozoic ecosystems, their fate at the K-T boundary is of obvious interest for the study of the biological effects of the K-T catastrophe. One of the main problems in this respect is the paucity of Maastrichtian (and especially late Maastrichtian) bird remains. The fact that some lineages of modern birds were already present in the Cretaceous is not in real contradiction with Feduccia's hypothesis, since the Tertiary radiation of birds had to have roots in the Cretaceous. The idea that the radiation of modern birds during the Tertiary was made possible by a mass extinction of the Cretaceous types of birds which had been dominant before the K-T boundary is definitely interesting, even though it may be difficult to test it on the basis of the available fossil record. There is an obvious need for more remains of terminal Cretaceous (and Palaeocene) birds, in order to get a better picture of K-T boundary events among this group.

The bone microstructure of some Cretaceous birds (notably Enantiornithes) suggests that they had a less advanced physiology than modern birds (Chinsamy et al, 1995), and this may help to explain why they disappeared at the K-T boundary while other birds survived.

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CRETACEOUS / PALEOCENE BOUNDARY OF STRATIGRAPHIC SECTION "GVOZD (VRGINMOST) - TUKLEČ WOOD"

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Investigated area is located between two rivers, Kupa and Glina, close to the town Gvozd (Vrginmost), 30 km south of Zagreb. Stratigraphic section "Gvozd (Vrginmost) - Tukleč wood" shows continuous deposition across the Upper Cretaceous - Paleocene boundary.

Upper Cretaceous deposits

"Scaglia" limestones were identified accross 30 m from the beginning of the section. They are unclearly stratified and faulted. The mud-supported limestones are red, partly greyish green. Abundant *Globotruncana* species make possible to determine the Santonian - *Globotruncana lapparenti, Dicarinella concavata* etc.

"Transitional layers" are hemi-pelagic marls followed by thin-bedded sandstones with higher content of terrigenous components. Their colour is grey and greyish green. Thickness of deposits is approximately 170 m. The age is Campanian - Maastrichtian and it is defined on the basis of pelagic foraminifera: *Rugoglobigerina rugosa* and *Dicarinella citae*. "Transitional layers" in this area of Banovina are a stratigraphic equivalent of Maastrichtian flysch in northern Bosnia.

Paleocene deposits

The deposition of "Transitional layers" started in the Maastrichtian and it continued until the Paleocene. Although the lowermost zone "*Parvularugoglobigerina eugubina*" was not documented, we suppose on the basis of very clear superpositional relationship that there was no interruption in sedimentation between the Senonian and the Paleocene. Thickness of deposits is approximately 30 m. The Lower Paleocene was determined with the following fossils: *Parasubbotina pseudobulloides, Praemurica trinidadensis, Planorotalites compressa* - (P1 zone) (Berggren & Miller, 1988).

Hemi-pelagic marls assigned to the Senonian and a part of the Lower Paleocene are conformably overlain by Paleocene flysch. Thickness of flysch deposits is approximately 110 m. The marls, fine-grained sandstones and calcitic clays are mainly grey coloured and show characteristics of turbidite sedimentation. The lower part of the flysch was deposited in the environs of middle - outer fan and the upper part is turbidite facies of outer fan. The Upper Paleocene fauna consists of *Morozovella angulata* (P3) and *Planorotalites pusilla pusilla* (P3) zones. *Subbotina triloculinoides, Planorotalites compressa, Praemurica trinidadensis,* and *Planorotalites ehrenbergii* were determined.

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BONE SPECIMENS OF DINOSAURS OF THE KARST OF TRIESTE

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The limestones outcropping near the "Villagio del Pescatore" belong to the member of Borgo Grotta Gigante and can be related to the lower Turonian p.p. - Senonian p.p.

A tectonic phase in the lower Senonian caused the heteropic deposition of facies of rough breccias and of black laminated limestones belonging to a lagoonal environment.

A ministerial concession of excavation granted to the Civic Museum of Natural History of Trieste allowed to discover some samples of dinosaurs, some fishes and only some vegetal samples.

Specimens which have been recovered:

- pubic bone (28 cm) and placed side by side a rib fragment (16 cm). This bone is supposed to belong to the Ornitischia order, Hadrosauridae family.
- Coracoid (19 cm) and placed side by side a rib fragment (9 cm)
- 4 vertebrae very crushed (total length 30 cm)
- vertebral body, isolated (width 16 cm)
- bones of the lower arm (25 cm) and two manus of the same individual (18 cm)
- bones of two arms (30 cm) and two manus, the phalanges of one, coracoid part of scapula, perhaps part of sternum of another individual
- probable metatarsus (8.5 cm)
- a vertebral series, 60 cm long

Certainly there are other samples in the rocks, in places different from those of the small lagoon.

These findings demonstrate the existence of lands above the sea level in the environment of deposition of the member of Borgo Grotta Gigante. They also remind of the previous existence of the reptile families of Dolochosauridae and Aigialosauridae in the member of Monte Coste.

GEOLOGICAL ASPECTS OF TERRESTRIAL IMPACT CRATERING

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General acknowledgment of the importance of terrestrial cratering for the evolution of Planet Earth as well as for evolution of life only started in 1980, when the impact of an extraterrestrial projectile was proposed as cause for the long-known mass extinction at the Cretaceous-Tertiary (K/T) boundary (Alvarez et al., 1980). Although research on all aspects of cratering started to bloom, a comprehensive textbook on terrestrial cratering is not available so far. For introduction to several aspects of impact processes, we refer to Deutsch and Schärer (1994), Grieve & Shoemaker (1994), Grieve et al. (1996), Masaitis et al. (1980), Melosh (1989).

Hypervelocity impact of extraterrestrial projectiles yields impact structures, which are either bowl-shaped or display complex morphologies with a central uplift and/or structural ring(s). Impact results in characteristic deformation and transformation of minerals (Langenhorst, 1996, this volume), formation of rock bodies, and development of particular geological formations. Among the rocks, (par-)authochthonous, allochthonous (allogenic), and dike breccias are most important. They carry mineral and rock fragments with various degrees of shock metamorphic overprint, and display either clastic or melt matrix. Breccias devoid of impact melt are "fragmental", and "suevitic" (or simply Suevite) if the content of melt particles exceeds 5 (10) vol. %. Impact melt rocks (tagamites) characterize impact structures in crystalline targets. Based on their regular distribution, up to four different geological formations can be distinguished in and around an impact crater: (i) crater basement, (ii) allochthonous breccia deposits, (iii) the coherent impact melt layer, whose relative volume increase with crater size, and (iv) distant ejecta. In addition, post-impact sediments, containing rewashed breccias and melt rocks, are commonly observed.

Consensus over a nomenclature for geological formations in terrestrial impact structures, and impactites - the rocks generated by the impact process - has not been reached to date. A consistent rock classification system should be, in principle, also applicable to shocked lunar and meteoritic samples. For phases, occurring in the context of impact structures, and their specific features, definitions relay in part on microscopic, and in part on TEM observations (Langenhorst, 1996, this volume).

Several features are diagnostic for the impact origin of a geological structure: (i) residual shock effects in minerals, including certain high pressure polymorphs, (ii) shatter cones, and (iii) projectile remnants close to small, so-called meteorite craters. Second order evidence is established by (iv) breccia sequences and dikes, including impact melt bodies, and pseudotachylites, (v) circular geophysical anomalies, (vi) topographic features, and (vii) geochemical signatures, such as enhancement of certain siderophile elements (e.g., Ni, Co, Cr, and PGEs), and isotope ratios (e.g., low $^{187}Os/^{188}Os$). (viii) Exotic chemical compounds (e.g., fullerenes) with, so far, unconstrained diagnostic value, have only been reported from the Sudbury impact structure (Canada), and K/T ejecta deposits. None of the features listed under (iv) to (viii), however, provide ALONE ultimate proof for an impact origin of a geological structure. Criteria for recognizing deeply eroded, and very ancient impact structures have yet to be developed.

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For evaluating the importance of hypervelocity collisions to the evolution of life it is critical to detect traces of impact in the sedimentary record. The K/T boundary represents the, so far, only known global occurrence of distant ejecta (Smit, 1994). This may be due to the fact, that the knife-sharp extinction horizon, and the well-known fern-spore peak facilitate to locate the occasionally very thin ejecta layer (< μm) in marine or continental sections, respectively. Mineralogical, sedimentological, and geochemical anomalies characterize the K/T ejecta layer. Convincing evidence for the impact origin of a distinct sedimentary layer is provided by the presence of material with a shock history (e.g., tektosilikates or zircon with planar microstructures, diamond, tektite-like objects). In certain cases, sharp excursions in the stable isotope record may represent long term consequences of an impact process, but we are lacking arguments to prove the cause-effect relationship. Compared to the about 150 proven impact craters and structures, impact debris is very scarce in the stratigraphic column, and unambiguously relation of distant ejecta material to its source crater is restricted to even fewer cases (Grieve, 1996). To detect more of these ejecta layers is a major challenge in geology.

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ISOTOPIC CHANGES AT THE P/TR BOUNDARY IN THE SOUTHERN KARAVANKE MOUNTAINS

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The aim of the presented study was to assess the possible systematic changes in $\delta^{13}C$ and $\delta^{18}O$ across the P/Tr boundary in carbonate rocks of the Košutnik Creek and Brsnina section in the southern Karavanke Mountains in Slovenia.

In the southern Karavanke Mountains sedimentation proceeded concordantly across the P/Tr boundary. The biostratigraphic and lithostratigraphic boundary between the Lower Triassic (Scythian) beds and the underlying Upper Permian beds is transitional and, no exact line can be drawn between them.

The Middle Permian Val Gardena Formation of mostly fluvial origin is overlain by a 270 m thick Upper Permian carbonate sequence that was named the Karavanke Formation (Buser et al., 1986). The Karavanke Formation is exclusively in the dolomite development. The basal unit of this sequence is represented by an up to 70 m thick evaporitic facies composed of cellular dolomite which alternates with rare black bituminous shales and grey vuggy dolomites. The boundary between the Middle Permian and the Upper Permian is also transitional and is characterized by thin sandy red coloured dolomite layers alternating with the topmost Val Gardena shales and sandstones. The evaporitic sequence is overlain by an up to 200 m thick succession of fossiliferous biomicritic dolomites probably deposited in an open lagoon and/or shallow shelf environment. The Upper Permian age of these beds is indicated by calcareous algal assemblages (*Mizzia cornuta, Permocalculus* sp., *Conexia* sp.), as well as by very common small foraminifers (Ramovš, 1986).

The P/Tr boundary is placed at the end of the sedimentation of the well bedded grey dolomicrite. It is followed by a red coloured more or less terrigenous sequence predominantly composed of well bedded siltstones, mudstones and sandstones alternating with micritic dolomites which contain no characteristic fossils. The thickness of this sedimentary sequence is up to 25m. The beds were deposited in a very shallow evaporitic part of the basin into which abundant terrigenous material was transported. In the investigated area these beds are overlain mostly by dark grey and brown micritic and sparitic limestones intercalated with oolitic limestone, marls and shales.

The transition from Permian to Triassic is characterized by an abrupt shift of $\delta^{13}C$ and $\delta^{18}O$ toward lower values (Fig. 1). In terms of amplitude, the $\delta^{13}C$ and $\delta^{18}O$ depletion straddling the P/Tr boundary is of about 4 ‰ for $\delta^{13}C$ and 7 ‰ for $\delta^{18}O$. The $\delta^{13}C$ and $\delta^{18}O$ anomalies are not confined strictly to the lithostratigraphically and/or biostratigraphically proposed boundary. A major global drop of $\delta^{13}C$ and $\delta^{18}O$ begins at about 30 m below the boundary.

The $\delta^{13}C$ curve reaches the peak values of -1.86 ‰ about 8 m below the boundary and after that suffers a succession of additional drop at the end of Permian and two similar drops in the lowermost Scythian. These shifts may be related to the eustatic oscillations of the Tethys Sea level, as well as to the local fluxes of isotopically light organic derived carbon in a depositional environment. The observed general decrease of $\delta^{13}C$ values at the P/Tr transition is interpreted as reflecting an increased terminal Permian regression which resulted in a ^{13}C depleted CO_2 flux into the atmosphere. This CO_2 then equilibrated with the ocean waters, ultimately resulting in ^{13}C depleted carbonates.

The variations in $\delta^{18}O$ across the P/Tr boundary show slightly different trends with respect to those in $\delta^{13}C$ and cannot be interpreted only in terms of water temperature. They may have also been related to changes in $\delta^{18}O$ of the sea water, decrease of salinity, as well as to the post depositional alteration or some combination of the mentioned possibilities. They could also suggest a climatic instability at and across the boundary.

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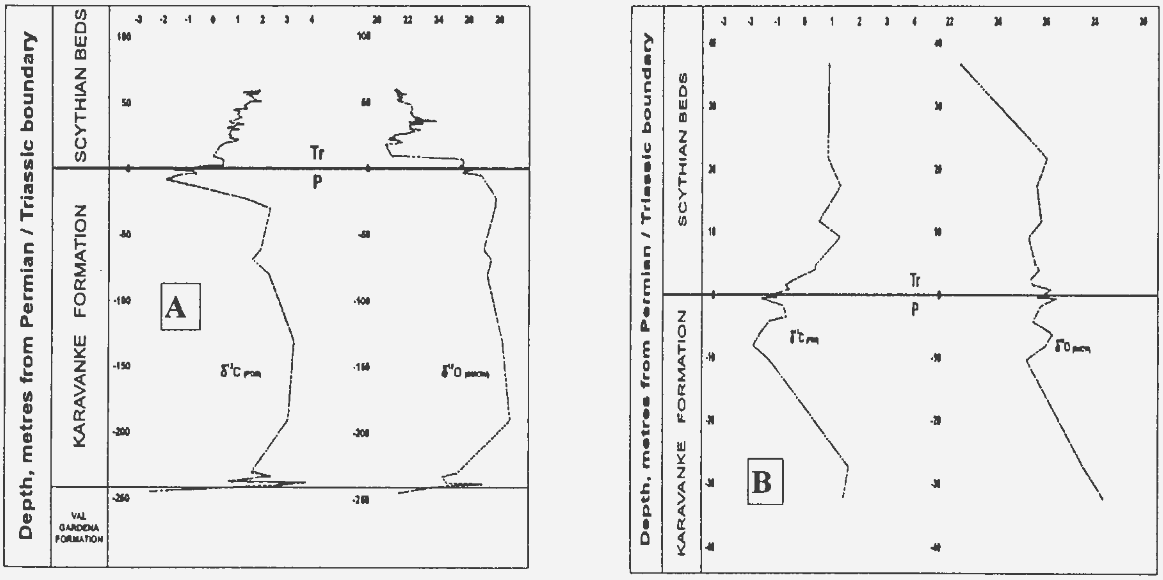
Fig. 1. $\delta^{18}O$ and $\delta^{13}C$ data of the Košutnik Creek (A) and Brsnina section (B).



STUDY OF EXTRATERRESTRIAL SPHERULES IN HUNGARY

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In Hungary it was first in Triassic (Anisian) rocks in 1994 that glassy micro-spherules were discovered. Since then we have succeeded in identifying magnetic and glassy microspherules in quite a number of geological formations of the following ages: Holocene, Lower Pleistocene, Miocene (Pannonian, Badenian, Carpathian), Oligocene/Eocene boundary, Eocene (Lattorfian, Lower Eocene), Cretaceous (Senonian, Gosau), Jurassic (Oxfordian, Callovian, Hettangian), Triassic (Rhaetian, Norian, Carnian, Anisian, Middle- and Lower Triassic), Permian/Triassic boundary, Permian, Carboniferous.

Spherules have been revealed altogether in 41 sites including exposures and deep bore holes alike. In most cases they occur sporadically but in some sequences they are present in larger number. Their size ranges between 2 and 500 microns with the average value of 100 microns. Samples taken from geological formations by binocular microscope are submitted to SEM EDAX, MicroPIXE and INAA tests as well as to analyses by laser-ray mass spectrometer. These procedures allow us to acquire precise data concerning their chemical and mineral composition, while fission track studies help us assuming the absolute age of their fusion.

The geological age of spherule-bearing sequences was determined upon biostratigraphic levels and palaeomagnetic investigations.

Relying on the results of the afore-mentioned tests and studies we succeeded in separating micro-spherules of terrestrial (volcanic) and extraterrestrial origin and in some superficial samples those deriving from industrial production. Further division of extraterrestrial spherules provides answer to the question whether they formed of terrestrial rocks fused under the effect of impact or they originate directly from the impact body.

Our primary objective is to assess the reliability of the use of spherule levels occurring in geological sequences for regional and global correlation. Additional issues we try to address include the identification of eventual impact structures in geological formations along with specifying the genetics of spherules in detail.

This program is supported by the Hungarian Scientific Research Fund (OTKA) and the Hungarian Space Office (Grant T014958). In 1996 our program was approved by the IGCP Scientific Board as global project N^{0}384 entitled "Impact and Extraterrestrial Spherules: New Tools for Global Correlation". The project proposal was submitted by eight co-proposers as follows: Alex Bevan (Australia), Csaba H. Detre (Hungary), Billy P. Glass (USA), Katarina Jakabská (Slovakia), Ziyugan Ouyang (China), Éva Papp (Australia), Anto Raukas (Estonia), Gheorghe Udubasa (Romania). We have organised three international conferences in Hungary so far concerning this issue.

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EVOLUTIONARY EVENTS IN THE GENUS *ALVEOLINA* FROM THE GALALA-HEIGHTS (NE-EGYPT)

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Area: Within the Eastern Desert of Egypt the North- and Southgalala expose a Paleogene series of limestones and limestone-marl interstratifications. Most of them are interpreted to be of shallow-marine, subtidal origin. Debris flows, slumpings and sandstones are intercalated of various amounts. The sedimentary geometries are due to a southward dipping distally steepened ramp (Paloecene) and a homoclinal ramp in the lower Eocene respectively .

Biostratigraphic frame: The biostratigraphic subdivision of this series is based on the genus *Alveolina*. Former investigations have proved a time range from the Thanetian (*A(G)levis*-Zone/ *A(G)primaeva*-Zone) to the Ypresian (A. violae-Zone) with a diastem within the *A. corbarica*-Zone.

Variations - Introduction: The morphologies of variations within the single *Alveolina* species are interpreted as being due to ecological factors, the adaption being limited by the evolutionary height and velocity of the single species. Height and velocity of evolution are also influenced by ecological factors and by the velocity of which these factors change. This leads to the statement that morphological variations in the foraminiferal test reflect changes of ecological factors, limited by evolutionary trends. The sedimentary environments are defined with the aid of microfacies studies, forming the base of ecological interpretations. Based on the well-known lines of evolution (Hottinger, 1960), it is possible to determine the influence of ecological factors on the range of variation. Furthermore, it will be possible with the aim of the range of variation to redetermine the ecological factors. At least, detailed statements can be made about the influence of evolutionary development on the range of variations .

Results: Former investigations have shown that there is no evidence of disconnected changes in the development of the individual species. Oceanic events, which have a major influence on the planktonic fauna, seem to have only a minor influence on the shallow-marine, benthonic fauna.

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FOSSILIFEROUS SUBTERRANEAN LEVELS IN CARSO TRIESTINO

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Museo Civico di Storia Naturale di Trieste

Gruppo Grotte "Carlo Debeljak" (Trieste) discovered (May 1996) a new cave in Carso Triestino. Attending exploration and survey, fossiliferous sediments at different levels of depth were observed. These are, in short, the results of first stage studies:

The cave is developed in limestones of "Borgo Grotta Gigante Member". At present the depth is 180m; exploration is going on.

The fossiliferous outcrops in question concern generally Gastropoda, the shells of which, after death, were amassed and concentrated by sea-waves. These deposits form "pockets" in rocky mass; thickness and expanse are very variable.

At 60 m in depth in the cave there is the first "pocket" formed mostly of gastropod genera *Plesioptygmatis* and *Trochactaeon*. This association Plesioptygmatis-Trochactaeon is typical of Upper Cretaceous, often with Rudista intrusion. Age of deposit should be between Cenomanian and lower Turonian.

At 120 m depth in the cave there is a second "pocket" formed by little sea-urchins, genus *Cidaris*. This genus is still living in Mediterranean sea, except in the Adriatic sea; it is often found in the Aegean sea. Age of this "pocket" (older than upper deposit) should be Cenomanian.

Whole fossils are standing out in relief made by selective dissolution.

We think that this discover is of remarkable scientific interest because it is a concrete contribution to a wider and better palaeontological knowledge of Mediterranean area (Albania, Greece, Lebanon).

THE BOLTYSH IMPACT CRATER: LAKE BASIN WITH HEATED BOTTOM

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The Boltysh impact crater just after its formation 90 ± 10 Ma ago, was the circular depression about 24 km in diameter and to 580 m depth in its central part. The crater was surrounded with an uplifted rim to about 330 m height. The floor of depression was formed by the lake of impact melt (12 km in diameter) surrounding the central uplift, 4 km in diameter, surface of which was elevated on about 80 m above the melt surface [1].

From the very beginning filling of the crater with sediments occured by creeping and collapse of unconsolidated material from the crater walls and partly from the central uplift. The atmospheric precipitation contributed to the process, but water was completely evaporated on the early stage of sedimentation. Formation of the crater lake started after cooling of the impactites surface to 100° C and lower. The heated water of the lake interacted with impactites and caused replace of the glass by montmorillonite and zeolite, oxidation, etc. High temperatures of water contributed to dissolution of the silicates in it. Sediments of that stage are presented by sands, sandstones, aleurites and breccia to 120 m thick. Organic remains are absent in the sediments. Cooling of water in the crater lake to some tens of degrees produced fall of solubility of components dissoluted and precipitation of the chemogenic sediments interlayered with clastic material in the deposits. Those chemogenic sediments are presented by clinoptilolite layer [2] and layers of carbonates enriched with P_2O_5.

The second stage of sedimentation was characterized by deposition of shales, clays and pyroschists in isolated freshwater basin. Remains of various organisms including fishes, gastropods, ostracoda and phytogene detritus are abundant in clays and shales. Thickness of this series is about 300 m in the crater cetral part [3]. Age of the sediments was determined by paleofloristic investigations as Paleocene [4].

The Boltysh impact crater and surrounding area were flooded in the time of Eocene transgression to the northern slope of the Ukrainian Shield. Accumulation of sands, aleurites and marls had formed the sedimentary deposits to 80-100 m thick. The sedimentation in the Boltysh crater was completed by Neogene sands series about 80 m thick.

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DOLENJA VAS AND ITS CARBON ISOTOPES

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The limestone sequence at Dolenja Vas spanning the Cretaceous-Tertiary boundary was assigned to magnetochron 29 R by Marton et al. (1995). Various fossils indicate the presence of the Cretaceous-Tertiary boundary (i.a. Pugliese et al. 1995). Stable isotopes from carbonates of the section were reported by Ogorelec et al. (1995) and Dolenec et al. (1995). They found a negative C-13 excursion of 6 delta values around the K/T boundary and a return to previous values in the lowermost Danian part of the section. This pattern is different from that reported by Keller & Lindinger (1989) from the boundary stratotype at El Kef, Tunisia.

We made a study of isotopes of non-carbonate carbon and found the direct opposite trend (fig. 1). The observed pattern corresponds well with the non-carbonate carbon-isotopic pattern at the marine boundary stratotype section at El Kef (Hansen et al. 1996) and the terrestrial boundaries in the North Horn Formation, Utah, USA, and different terrestrial K/T boundaries in India (fig.2).

The isotopic pattern supports the identification in the Dolenja Vas section of the presence of a K/T boundary. This is equally well supported by the pattern of magnetic susceptibility of the sediments earlier reported by Hansen et al. (1995).

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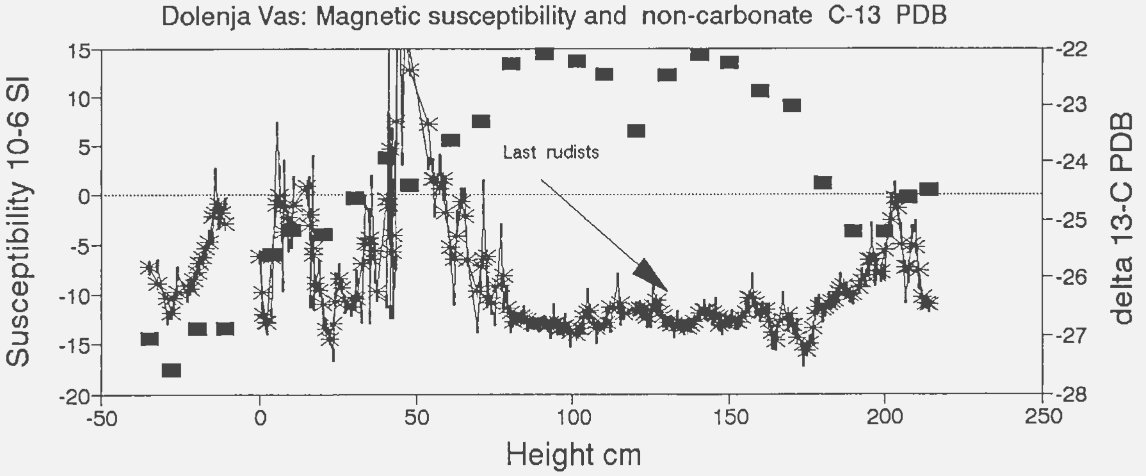

Fig. 1. Plot of magnetic susceptibility of sediments from Dolenja Vas (vertical signature: actual measured values; asterisks: 3-point moving average). Non-carbonate delta 13-C values (square signature). Position of the last rudists from Pleničar et al. (1992).

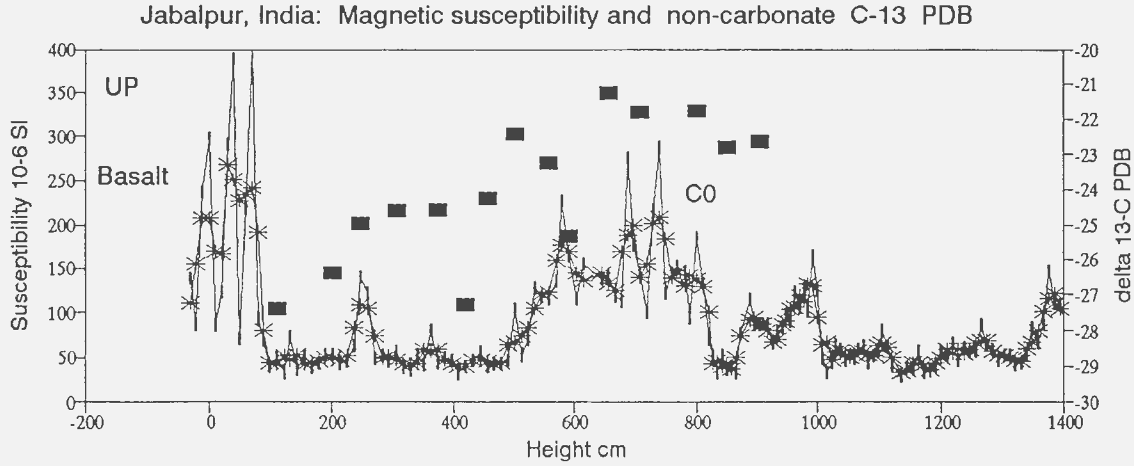

Fig. 2. Plot of magnetic susceptibility and non-carbonate carbon-isotopes of Lameta sediments from Jabalpur. Signatures like fig. 1.

GEOCHEMISTRY OF IMPACT MELT ROCKS FROM THE LAPPAJÄRVI (FINLAND) AND BOLTYSH (UKRAINE) IMPACT STRUCTURES

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To test whether impact melt layers are indeed an extremely well homogenised mix of local target materials, major, minor and trace elements, including rare earth's (REE), as well as Sr and Nd isotopic compositions are analysed systematically in drill core samples from the impact structures, Lappajärvi (Ø=23 km; 77.3 ± 0.4 Ma; impact melt layer ~145 m thick; total volume ~10 km^3), and Boltysh (Ø= 25 km; 85 to 118 Ma; impact melt layer ~200 m thick, total volume ~10 km^3). The 11 drill core samples from Lappajärvi drill core DH 301 cover 23 m of the nearly clast-free central part of the melt sheet and they are texturally homogeneous [1]. The 11 samples of the Boltysh cores B-50 and B-11475, located 3.5 and 2.25 km off the crater center, sample 150 m of the melt layer, which has widely varying textures and a clast content up to 10 vol % [2].

The coherent impact melt layers of both craters show a high degree of geochemical homogenisation; the 1δ deviation to the mean is for major, minor and trace elements close to or even below the analytical error [3-5]. Exceptions are (i) the alkali-elements at Boltysh, and (ii) Ni at Lappajärvi. (i) The variation in Rb and K is not directly related to the cratering process but explained by hydrothermal activity: At Boltysh, the K_2O/Na_2O ratio ranges from 0.6 to 1.3; in contrast, at Lappajärvi, this ratio varies only between 1.18 and 1.38. (ii) The variable Ni-concentrations reflect different contributions of the projectile to the Lappajärvi melt sheet.

Both impact melt layers show high absolute REE contents (Lappajärvi: 178.7 to 190.3 ppm; Boltysh: 165.2 to 217.4 ppm) with only minor variations between the distribution patterns for the individual samples. The rocks of both melt sheets display a significant negative Eu anomaly (Eu_{cn}/Eu_{cn}* range from 0.54 to 0.62 at Lappajärvi, and 0.44 to 0.50 at Boltysh) and LREE enrichment [3-5].

Time-corrected Sr, Nd isotope compositions cluster in relatively narrow fields; complete rehomogenisation at the scale of the cm^3 sized whole rock samples is only observed for Nd at Lappajärvi. There ΣNd^T lies between -21.4 and -21.9 (i.e., slightly below the analytical error), and $(^{87}Sr/^{86}Sr)^T$ is 0.7355 to 0.7362. At Boltysh, ΣNd^T ranges from -24.4 to -27.1; and $(^{87}Sr/^{86}Sr)^T$ from 0.7677 to 0.7753 [3-5]. The somewhat larger spread in the isotope parameters for the Boltysh material indicates variations inherited from the precursor materials. The Rb-Sr and Sm-Nd data do not allow dating of the cratering event using the whole rock isochron technique. Dating via mineral isochrons is in work and preliminary results will be presented at the meeting.

The data substantiate that superheating and turbulent movement of the melt in a growing crater produce a three-dimensionally, geochemically homogeneous melt pool. Superheating and temperature decay, however, are not sufficient to yield Sr and Nd isotope re-equilibration on the m^3 scale.

F. Pipping, GSF, and R. A. F. Grieve, GSC, are gratefully acknowledged for providing the samples.

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THE FOSSIL RECORD OF THE FORAMINIFERA, A SUCCESSION OF GLOBAL COMMUNITY MATURATION (GCM) CYCLES, OR: HOW TO SURVIVE GLOBAL DISRUPTIVE EVENTS IN EARTH HISTORY

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A plastic bottle submerged in the sea provides a new, i. e. empty habitat for marine organisms and is exposed to colonisation. We observe short-lived communities of pioneering organisms relaying each other through time until an equilibrium is reached corresponding to the carrying capacity of the respective environment under conditions of long term stability. This is called a community maturation process which is governed by the laws of interspecific competition for limited resources, in this case for space on hard substrate, involving processes of immigration of specimens from populations living elsewhere and of specific, respective growth and reproduction rates.

On a much larger scale in space and time, during Earth History, global boundary events take over the role of sweeping at least some ecological niches, rewinding so-to-say the maturation clock and putting its hands at zero hours. The subsequent maturation is governed by evolutionary processes starting from surviving genomes which will have to match the new ecological conditions. This large scale community maturation is called global because usually, at first, the communities are limited only by climatic gradients from equator to pole around the earth. The fossil record of shallow benthic and planktonic foraminifera closely reflects global community maturation and sheds some light on the common properties of major boundary events. Do we find similar properties in the history of mankind?

AN ABNORMAL GROWTH IN *ORBITOIDES APICULATUS* SCHLUMBERGER INDIVIDUALS AT THE K/T BOUNDARY IN YELEME (SW ANTALYA, TURKEY)

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An abnormal grow phase within *Orbitoides apiculatus* Schlumberger individuals observed in the uppermost Maastrichtian "Yeleme Formation" (Poisson, 1968), exposed around the Yeleme village (Figure 1), NW of Antalya (SW Turkey) is determined and described.

The Yeleme Formation has a wildflysch character and consists of detritic sediments of Maastrichtian and Paleocene age and crops out in a tectonic window.

Orbitoides apiculatus Schlumberger individuals in sandstone levels of uppermost Maastrichtian in Yeleme Formation are determined. They are curly grown. These individuals are arc-shape curled and show approximately (a) 55-110° external and (b) 80-115° internal degree and external (A) 1.2 - 2.95 mm and internal (B) and their thickness ranges between 0.675 - 2.35 mm (Plate 1, Figs. 1-6). In this level, 19% of total individuals are normal, 19% of abnormal grown as curled, and 4% are regarded as terratological, and 4% are fossilized in increase phase as *Orbitoides apiculatus* Schlumberger individuals. These individuals are accompanied with 42% of *Orbitoides gruenbachensis* Papp and 14% of *Orbitoides medius* (d'Archiac).

The curled shape of some *Orbitoides apiculatus* individuals is not secondary since normal and abnormal individuals were found together and display no breaking and crushing in test section. In addition, the tests are well-preserved in other genera. In this case, some *Orbitoides apiculatus* individuals should have been formed as curled. This abnormal growth must have occurred due to ecological stresses in the shallow water environment caused by change in temperature at the K/T boundary.

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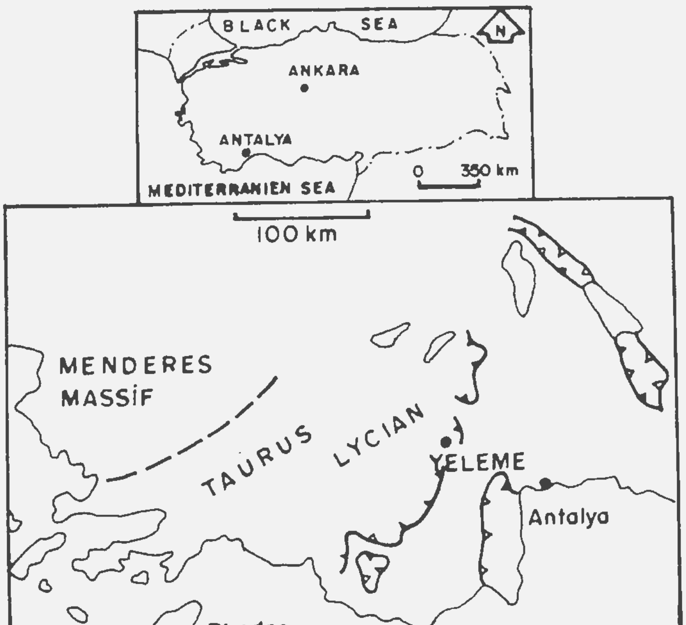

Figure 1. Location map of the investigated area.

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Plate 1
Curly grown abnormal *Orbitoides apiculatus* Schlumberger individuals

Figures 1-5. Axial sections, 1: (119), x 28; 2: (106), x 24; 3: (118), x 18; 4: (104), x22; 5: (108), x 19.
Figure 6. Tangential section, (118), x20.

RECOVERY OF THE LARGER BENTHIC FORAMINIFERA AFTER THE TERMINAL CRETACEOUS EVENT IN THE SOUTH SHILLONG REGION, NE INDIA

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Recent biochronostratigraphic studies on planktic microfossils (foraminifera and nannoplankton) by Pandey (1990) and Garg and Jain (1995) precisely establish the K/T boundary interval and the associated terminal event slightly above the larger benthic (*Siderolites - Orbitoides*) horizon (Nagappa, 1959) in the Shillong area. The stratigraphic distribution shows that the larger foraminifera disappear in the sequence earlier than the terminal event. This disappearance seems to be due to loss of carbonate environment (inhabited by the larger benthics) in response to environmental changes considered precursor to the devastating global event of the Late Cretaceous. This is borne out by the extensive development of clastic facies that overlies the calcareous facies of *Siderolites* in the area of study. The carbonate facies with which the larger foraminifera are intimately associated, reappears stratigraphically much higher in the Palaeocene succession.

The first appearance of larger foraminifera in many Tethyan sections is seen in the Late Palaeocene when the carbonate habitats were re-established (Hottinger, 1987; Hallock et al., 1991). This interval is marked by the characteristic monotypic foraminiferal assemblage dominated by operculines, miscellaneids, etc. and is considered equivalent of the zone Late P3 (=SB2). It is followed by an interval of extensive carbonate deposition (referred to as the period of "expanded oligotrophy" by Hallock et al., 1991) when the foraminiferal assemblage began to become highly diversified and widely distributed on global basis. In the Shillong area, the assemblage of the zone P3 is, however, missing, and the appearance of larger foraminifera, on the other hand, is slightly delayed. The latter reappear in full diversity during the progradational cycle of a widespread marine transgression dated as the late Early Thanetian (=SB3 i.e. Late P4) by the presence of *Glomalveolina primaeva*. It seems that it was during the "expanded oligotrophy" that the event of recovery of the larger foraminifera may have occurred in the Shillong area.

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IMPACT STRUCTURES IN AFRICA: A CASE STUDY

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Over the last 15 years, renewed interest in the events that led to the extinction of the majority of all life on earth at the end of the Cretaceous period, 65 Ma ago, implicated a large-scale asteroid or comet impact as the cause of this catastrophe. Earlier, impact cratering as a geological process has been rather unappreciated by the general geological community, despite the fact that impact cratering is one of the most important surface-altering processes on terrestrial planets and planetary satellites. Detailed studies, mainly since the 1960s, have led to the recognition of about 150 impact structures on earth. Currently, about 2-5 new impact craters are being described every year.

In 1994, only 15 confirmed impact structures were known in Africa (Koeberl, 1994). Considering the size of the African continent, this is a small number. For a long time, the discovery rate of impact craters in Africa lagged behind that of most of the rest of the world. Dietz (1965) listed 8 structures as probable young impact craters, all of which are now confirmed. Four of those were in Africa. The situation remained unchanged until in the mid 1970s several U.S. and French expedition to the Sahara regions identified several mostly small impact structures in Mauritania, Algeria, and Libya (see Koeberl, 1994, for details). Then nothing changed until during the last few years, another attempt was made to improve the African record, this time in southern Africa. The currently known impact craters in Africa are listed in Table 1. However, today Africa is still far from its share of known established impact craters compared to those known elsewhere in the world, even though, considering cratering rate calculations indicate that numerous, so far undiscovered, craters must exist in Africa. Considering the substantial importance of impact craters for geology in general, but also for a possible economic interest, impact craters deserve more extensive study. It should be noted, though, that it is necessary to use unambiguous criteria for the identification of impact structures. The formation conditions of impact craters lead to pressure and temperature conditions in the target rocks that are significantly different from those reached during any internal terrestrial processes. Among the most characteristic changes induced by the impact-generated shock waves are irreversible changes in the crystal structure of rock-forming minerals such as quartz and feldspar. These shock metamorphic effects are characteristic of impact and do not occur in natural materials formed by any other process. It is with such mineralogical evidence, together with several independent chemical, isotopic, dating, and geophysical studies, that impact structures are confirmed.

Since the late 1980s, several impact structures were confirmed in southern Africa. These were Roter Kamm (Namibia), Pretoria Saltpan (South Africa), Kalkkop (South Africa), and Highbury (Zimbabwe) (see Koeberl, 1994, for details). These discoveries were the result of work done by a very small, but highly motivated group of scientists from South Africa and Europe. Since the publication of the review by Koeberl (1994), three new African impact structures have been identified: the small 220 m diameter Sinamwenda crater in Zimbabwe (Master et al., 1996), the 14 km diameter Gweni-Fada complex crater in Chad (Vincent and Beauvilain, 1996), and the large (70-

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340 km diameter) Proterozoic Morokweng impact structure in South Africa, near the border to Botswana (Corner et al., 1996; Reimold et al., 1996). The discoveries of impact craters in Africa provide a case study for impact crater research.

Acknowledgements: The role of the former ESF Network on "Impact Cratering and Evolution of Planet Earth" in promoting these studies is gratefully acknowledged. I am also grateful to the Austrian Science Foundation (FWF) for support (project P8794GEO).

Table 1. The Known African Meteorite Impact Craters

Name	Country	Latitude	Longitude	Diameter	Age (Ma)
Amguid	Algeria	26°05' N	04°23' E	0.45	<0.1
Aorounga	Chad	19°06' N	19°15' E	12.6	>0.01
Aouelloul	Mauritania	20°15' N	12°41' W	0.36	3.1±0.3
B.P. Structure	Libya	25°19' N	24°20' E	2.8	<120
Bosumtwi	Ghana	06°32' N	01°25' W	10.5	1.1±0.2
Gweni-Fada	Chad	17°25' N	21°45' E	14	<300
Highbury	Zimbabwe	17°05' S	30°09' E	20	1000-1800
Kalkkop	South Africa	32°43' S	24°26' E	0.64	<5
Morokweng	South Africa	26°31' S	23°32' E	70-340	1400-2200
Oasis	Libya	24°35' N	24°24' E	11.5	<120
Ouarkziz	Algeria	29°00' N	07°33' W	3.5	<70
Pretoria Saltpan	South Africa	25°24' S	28°05' E	1.13	0.2
Roter Kamm	Namibia	27°46' S	16°18' E	2.5	3.7±0.3
Sinamwenda	Zimbabwe	17°12' S	27°47' E	0.22	<10
Talemzane	Algeria	33°19' N	04°02' E	1.75	<3
Tenoumer	Mauritania	22°55' N	10°24' W	1.9	2.5±0.5
Tin Bider	Algeria	27°36' N	05°07' E	6	<70
Vredefort	South Africa	27°00' S	27°30' E	180-300	2024±5

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REFLECTION OF THE TWO PELAGIC EPISODES IN THE MACROFOSSIL ASSOCIATIONS OF THE KOMEN AND TOMAJ LIMESTONES OF THE TRIESTE-KOMEN PLATEAU, SLOVENIA

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The platy and laminated limestone with chert of the Trieste-Komen plateau occurs as a specific facial development within the Senonian, Turonian, Cenomanian, and in the north also the Lower Cretaceous platform sediments (Fig. 1). The limestone is bituminous dark grey or black biomicrite or intrabiomicrite, varying from mudstone to wackestone. Benthic organisms are scarce. At certain levels pelagic microfossils, fragments of redeposited echinoderms, ostracods and "nonskeletal algae" are abundant. The later two groups generally occur also under conditions of increased salinity and reducing conditions. Reducing conditions are also indicated by the presence of dispersed organic matter and pyrite. Chert occurs in nodules and thin sheets.

In present geological investigations these beds are discussed within two members of different formations. In future study of the Komen and Tomaj limestones, regardless to their separate or united definitions, the differences between these levels due to different modes and areas of their origin, will have to be taken into consideration.

The Komen limestone has been lately mentioned as the evidence of the second anoxic event (OAE 2) (Jenkyns, 1991). Complete study of its genesis in a wider area has not been worked out yet. Some attempts to interpret depositional environment and elements of microfacial characteristics have been made (Buser, 1973; Ogorelec et al., 1987).

Recent geological studies (Šribar, 1995; Jurkovšek et al., 1996) ascertain that the Cenomanian-Turonian part of the Komen limestone and the Cenomanian-Turonian Repen Formation can be correlated to the second Cretaceous anoxic event (OAE 2) and to the global Cenomanian-Turonian eustatic sea level rise (Haq et al., 1987). Pelagic event is demonstrated by numerous pelagic microfossils (mainly pithonellas, calcispheres and globotruncanas) and rare ammonites and saccocomas.

The following stronger pelagic influence is documented by a rich ammonite fauna in the Tomaj limestone of the Lipica Formation. Beside ammonites with aptychi still preserved in the body chambers, also ammonites with roll marks, and scarce disintegrated saccocomas, fishes and plant remains are frequent (Jurkovšek & Kolar-Jurkovšek, 1995; Summesberger et al., 1996a,b). Horizon of fossiliferous black platy limestone, few metres thick, is underlain by bedded rudist limestone with abundant foraminifera *Murgella lata* (Luperto Sinni) and overlain by the limestone with *Calveziconus lecalvezae* Claus & Cornella. Based on these two species the horizon with ammonites can be dated as Upper Santonian to Lower Campanian and this stratigraphic position corresponds to the second pelagic episode on the Dinaric Carbonate Platform (Gušić & Jelaska, 1990).

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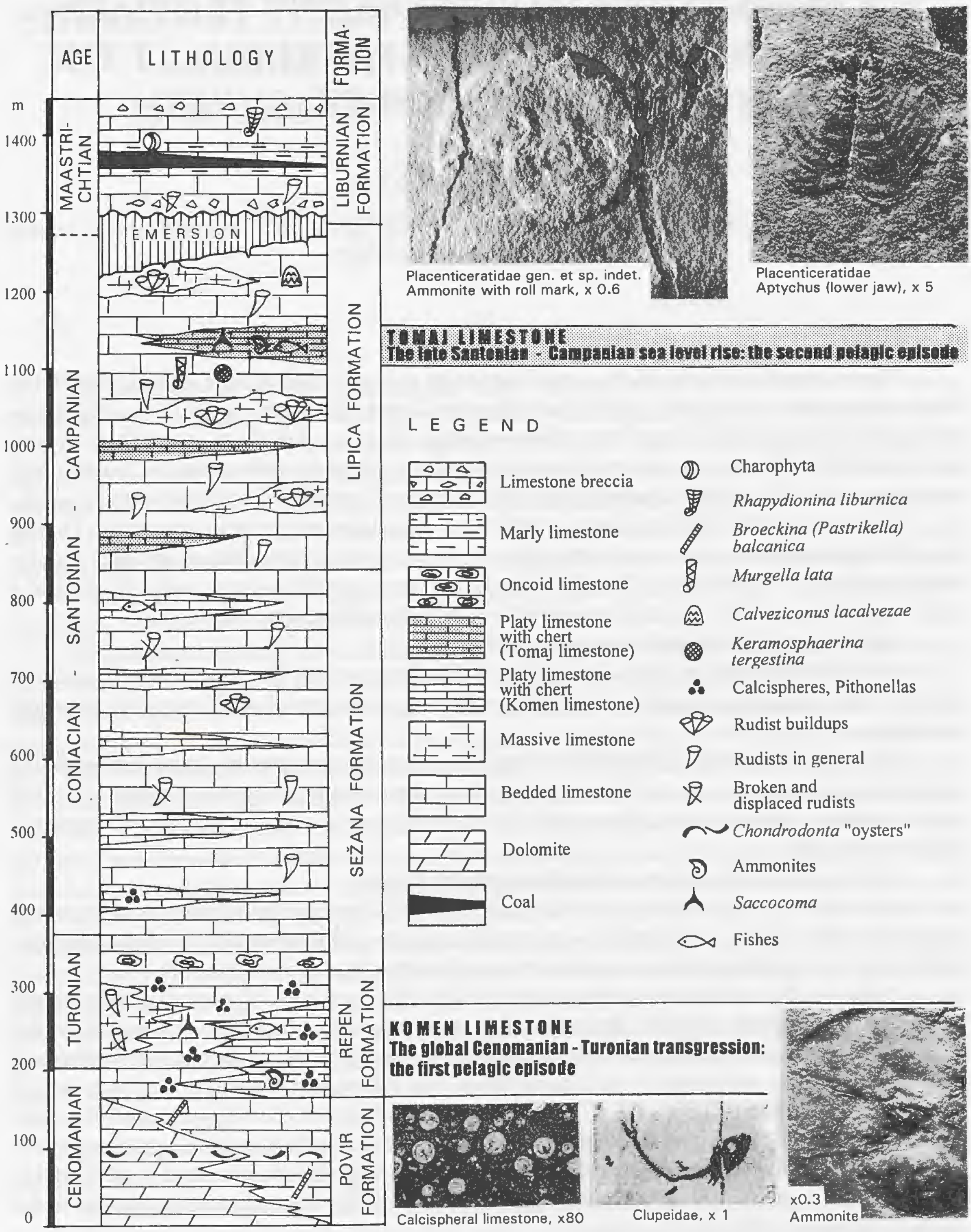

Fig. 1. Stratigraphic column of the Cretaceous sediments of the Trieste-Komen plateau with the position of two horizons of the Komen and Tomaj limestones that correspond to two pelagic episodes (magnification reduced to 82%).

K/T BOUNDARY AND SUBSEQUENT TERTIARY FACIES AND SEDIMENTARY PATTERNS AT THE NORTHERN GULF OF SUEZ (EGYPT)

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The sedimentary cycles of the Late Campanian to Early Eocene were investigated in the Galala Mountains, west of the Gulf of Suez (Eastern Desert, Northeast Egypt). This area represents a part of the northern edge of the African-Arabian Craton located on the outer shelf. In general three NNE-SSW-striking facies belts can be described. Deposits of the outer shelf in the north interfinger with a swell-zone (characterized by hiati) and with intrashelf basins further to the south.

The facies types in the study area exhibit two general depositional environments. During Late Cretaceous mixed clastic and carbonate sediments were accumulated on an outer distally steepened ramp. The sediments of the Early Tertiary document carbonate and clastic environs of a ramp which changes from a distally steepened towards a homoclinal geometry.

Late Cretaceous (distally steepened ramp):

The biostratigraphic subdivision and facies distribution of the Late Cretaceous succession reflects major transgressive-regressive events, which were interpreted with respect to sequence stratigraphy.

During the Late Maastrichtian decreasing P/B-ratios reflect regressive trends (in general) - in detail three sequences can be distinguished, due to three minor transgressive events: the first starts with the *G. gansseri*-zone, the second in the Late *G. gansseri* zone and the third during the *A. mayaroensis*-zone.

Paleocene to Early Eocene (distally steepened ramp):

The Paleocene succession was subdivided into several transgressive-regressive events and compared to the sequence stratigraphic concept. The major problem concerned the biostratigraphic subdivision and correlation, based on planktonic and benthonic larger foraminifera.

During the Early Paleocene a minor transgression (*P. pseudobulloides*-zone) is documented by sections in the south only. On the proximal ramp foraminiferal limestones above reflect the Highstand deposits of that sequence. The highstand of the overlying sequence contains floatstones with coralline algae and locally *A. (G.) dachelensis*. The subsequent sequences are composed of floatstones with accumulations of *A. (G.) levis* or *A. (G.) pilula* and *A. (G.) telemetensis*. Within the Late Paleocene the late Highstand deposits contain packstones/rudstones with corals and green algae. The high diversive communities of Miscellaneans, Operculines, Alveolines and smaller benthic forAmininifera together with red and green algae of the Late Paleocene sequences vanish within the earliest Eocene (*A. ellipsoidalis* -zone).

Early Eocene (homoclinal ramp):

The abundance of local build-ups with a low diversive or shoals increases in the Early Eocene (*A. ellipsoidalis*- to *A. corbarica*-Zone). The ramp morphology changes from a distal steepening to a homoclinal ramp in the Early Eocene . The massive limestones withdraw to the north, the conversion of the ramp geometry is generated by accumulation of eroded sediments from the inner parts of the elongating ramp.

SHOCK METAMORPHIC EFFECTS IN MINERALS: CORRELATION OF OPTICAL AND ELECTRONOPTICAL OBSERVATIONS

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Hypervelocity projectiles impacting planetary surfaces induce strong compression waves (shock waves), which propagate with supersonic velocity and are accompanied by a material transport behind the shock front. The material engulfed by the shock wave is dynamically deformed at high pressures (up to 2 - 3 Mbar), temperatures (up to 10000°C), and strain rates (10^6 - 10^9 s^{-1}). As consequence of these extreme deformation conditions minerals develop characteristic lattice defects or undergo specific phase transformations or dissociation reactions. These shock-induced changes, which are summarized under the collective and neutral term "shock metamorphic effects" or "shock effects", are not only diagnostic for impact events but also provide clues to the shock conditions (Stöffler and Langenhorst, 1994).

In the context of the debate on the origin of the Cretaceous-Tertiary boundary layer and other mass extinction horizons the interest in shocked minerals has been largely increased. Our knowledge about the nature, formation, and post-shock modification of shock effects has been significantly improved by recent transmission electron microscope (TEM) observations (e.g. Goltrant et al., 1992; Leroux et al., 1994; Langenhorst et al., 1995). According to these observations the following, most important shock effects can be distinguished: (i) formation of dislocations, kink bands, mechanical twins, mosaicism, planar fractures (PF), and planar deformation features (PDF), (ii) phase transformations to diaplectic glass, shock-fused glass, and high-pressure phases, and (iii) dissociation of minerals into new solid phases and gaseous species. There is no mineral showing all these shock effects. Olivine and pyroxene are instructive examples for dislocations, mechanical twins, mosaicism, and high-pressure phases, whereas quartz and feldspar are known for their good development of planar microstructures (PF and PDF) and transformation to diaplectic glass. Dissociation occurs mainly in minerals with volatile components such as micas, sulfates, and carbonates. In the talk, the characteristics and post-shock modification of shock effects will be discussed for various minerals with special attention to the correlation between the optical and electronoptical scale.

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SEQUENCE STRATIGRAPHY AND LITHOFACIES OF THE UPPER CRETACEOUS TO EOCENE CARBONATE DEPOSITS IN THE KATE-1 AND KORALJKA-1 OFF-SHORE WELLS (MID-ADRIATIC, CROATIA)

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Studied wells are situated in the central part of the Adriatic off-shore. Several lithofacies and system tracts were singled out.

Kate-1, shallow water depositional environment:

Lithofacies A: Maastrichtian, dolomitised coquina and microcoquina limestone. Back reef lagoon, late highstand, HST

Lithofacies B: Uppermost Maastrichtian-Paleocene, fenestral (WKST/ MDST) limestones. Very shallow restricted lagoon and tidal flats, LST.

Lithofacies C: Lower Eocene, limestone with a variable portion of pellets and peloids, "algal ball" oncoids, micritised benthic shells, small gastropods and ostracods. Restricted shoals, TST

Koraljka-1 (Kok-1), deep water depositional environment:

Lithofacies X: Maastrichtian-Paleocene, Eocene mud supported limestone (MDST/WKST), rich with planktonic foraminifera, intercalated with bioclastic limestone (PKST/GRNST/FLTST), allochthonous lowstand debris.

Lithofacies Y: Lower Eocene, chaotic breccia, autochthonous wedge.

Interpretation:

At the end of the Cretaceous, during the Laramian phase, in the wider region of the Adriatic Carbonate Platform sea level was changed. According to the lowstand, (fig. 1) emersion took place. Carbonate rocks were karstified, diagenetically changed and the bauxite deposits formed. Due to the paleogeography only in some places the sedimentation continuity at the K/T boundary is documented in brackish lagoons (lithofacies B, Kate-1) (fig. 2). In the regional scale it should be recognised as type 1 sequence boundary. In the Early Eocene (Cuisian) the sea level rose (TST) and the entire platform was flooded (fig. 3) (lithofacies C, Kate-1). At the same time in the deeper water environment, Upper Maastrichtian and Paleocene deposits which were eroded on the platform during the LST are via slope, transported to the basin (lowstand allochthonous debris, lithofacies X, Kok-1). Chaotic breccia, however, should be interpreted as the drowned debris flows and carbonate sands during the early stage (Couisian) of the sea level rise (autochthonous lowstand wedges, lithofacies Y, Kok-1). During the late TST deeper water deposits are significantly thinner.

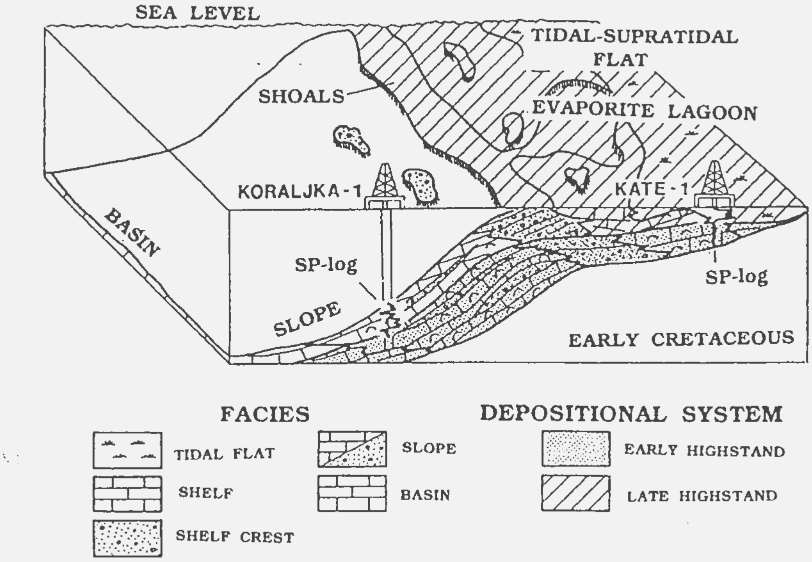

Fig. 1: Schematic illustration of lithofacies distribution during highstand (HST) in Late Cretaceous.

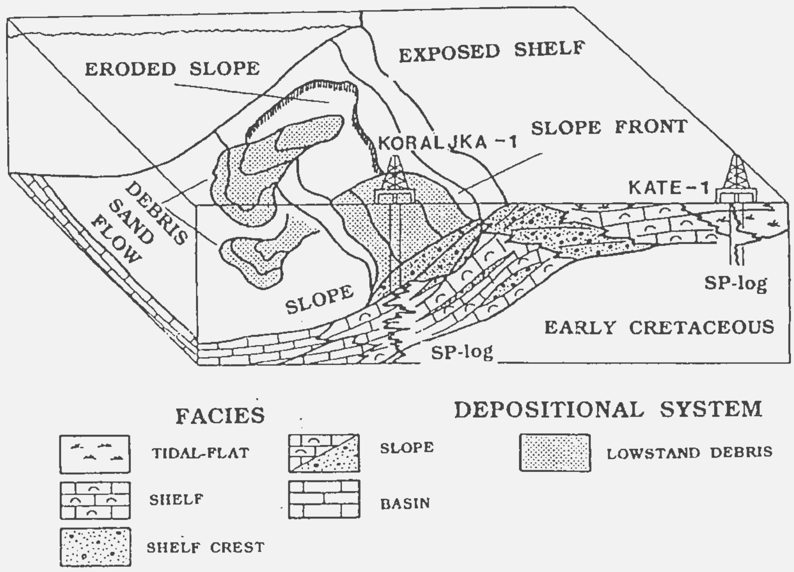

Fig. 2: Schematic illustration of lithofacies distribution during lowstand (LST) in Paleocene

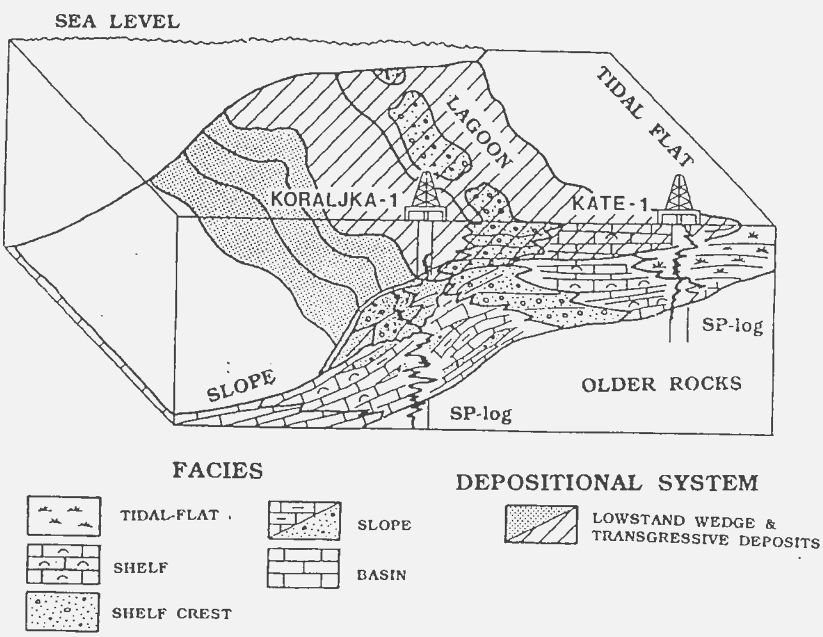

Fig. 3: Schematic illustration of lithofacies distribution during transgression (TST) in Early Eocene.

NEW DATA ON THE CARBONATE BRECCIA DEPOSITS OF SOUTH-ORIENTAL AREA OF MURGES (PUGLIA, SOUTHERN ITALY)

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During previous geological and palaeontological investigations of south-oriental area of Murges (Apulia Platform, Southern Italy) insufficient consideration has been given to the breccia deposits outcropping in the Fasano - Ostuni - Carovigno region.

This carbonate breccia is a product of the partial destruction of latest Cretaceous deposits. The present study is an attempt to analyse the stratigraphic position of this breccia deposits.

THE CRETACEOUS-TERTIARY TRANSITION IN THE SOUTHERN PART OF THE APULIAN PLATFORM

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In recent years, biostratigraphical research has been carried out on carbonate deposits belonging to the southernApulian Platform (Murge and Salento), in the upper Cretaceous-Palaeocene interval. In this paper microplaeontological and sedimentological data are presented.

Starting from the achieved results, the palaeogeographical evolution of the Apulian Carbonate Platform in the time of interest is discussed.

ON THE DISTRIBUTION OF THE METEORITIC COMPONENT IN SHOCK-MELTED MATERIAL AT IMPACT STRUCTURES

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Despite numerous and detailed investigations of the K/T boundary layer, the original mineralogical carriers of the so-called meteoritic component, i.e., contamination with siderophile elements from the projectile, is not established. Similarly, processes of projectile recondensation, and admixture of projectile material to volatiles and dust from the target are unconstrained [1, 2]. A systematic assessment of the distribution of the meteoritic component in different types of rocks and glasses from impact craters may contribute to resolve these named questions.

At large impact structures, the amount of projectile matter incorporated in impact melt rocks may reach up to 8 vol. %, but usually not exceed 1 % [e.g., 1, 3]. At some small craters, the meteoritic component range up to 20 vol. % or even more [4]. Larger impact melt bodies commonly show an irregular distribution of Ni, Co, Cr, Ir, Os and some other elements derived from the projectile, as documented, for example, at East Clearwater, Popigai, Chicxulub, and Lappajärvi [2, 5]. Taken into account the relative homogeneous distribution of major and minor elements in these impact melt bodies, this may be due to engulfing of the vaporized/melted projectile matter either after, or close to the end of the homogenization of the impact melt pool.

At Elgygytgyn and Zhamanshin craters, homogenized impact glasses are enriched in the meteoritic component in comparison to strongly shocked and partly melted target rocks, which are pumiceous and resemble slags [7, 8]. Moreover, individual samples of glassy impact melt with different granulometric characteristics contain significantly different amounts of siderophile elements diagnostic for the projectile. For example, at Zhamanshin, glass lapilli ranging in diameter up to 3 cm, are enriched in Co and Ni compared to glass bombs and fragments, which have the same major element composition but a larger size (up to 50 cm). Co and Cr are enriched by a factor of 2 to 4, and Ni by a factor of 5 or even more [8-10]. Still smaller glass spheroids (Ø less than 1 mm), however, have up to 0.4 wt. % Ni [11], exceeding the Ni content in the lapillis of up to 0.2 wt. % by one order of magnitude. A similar size-related distribution of the projectile-derived siderophile elements was discovered in different granulometric fractions of impact glasses from Wabar crater [12]: The average concentrations of Ir, Co, and Ni in beads sized up to 1 cm are higher than in large vesicular chunks of impact melt but significantly lower than in droplets and spheres of the sub-mm size. Data for impact glass material at the Meteor (Barringer) crater [3] corroborate this general observation of a simple relation between size of the melt particle, and amount of projectile contamination.

This relation indicates that the evaporated projectile matter most probably condenses preferably on melt droplets, possibly also on small solid particles. Because the surface to mass ratio increases with the power of two at decreasing grain sizes, small particles have a significantly larger relative surface compared to bomb-sized objects. This has to be taken into account if the total mass of the two populations, i.e., droplets and bombs, at one crater is compared. It is supposed further that this strongly dispersed melt was subjected to higher shock stress and temperatures than the larger melt bodies, and was ejected at higher speeds. Irregular distribution of the meteoritic component in large coherent impact melt bodies may reflect irregular incorporation of significantly different volumes of small particles from the ejecta cloud, which were carrier of Ir and other siderophiles. Condensation temperatures for PGEs are on the order of 4000 to 5000° C, indicating that the "coating" of the small ejected particles takes place very early in process of vapor plume expansion.

These data lead to the general conclusion that significant parts of the evaporated projectile condensate on the smallest liquid particles in ejecta cloud, and probably, in part, on tiny solid material as well. Just these fine particles may carry the meteoritic component, which, in addition, may show fractionation. Fractionation of PGEs is in accordance with the range in their condensation temperatures, as well as with observations at ejecta layers. Transportation of these small particles (dust) at high altitudes can result in thin deposits far away from the impact site and may lead to concentration of PGEs and other siderophiles. Diagenesis may obliterate the mineralogical proof for the impact event in thin layers, whereas, PGEs and chemically related elements are disturbed and transported only at the cm scale. Our conclusion is in line with the suggestion by [13]. These authors state for the K/T boundary that PGEs condensated on very small shocked quartz particles, which later settled out at various distances from the impact site, causing the well-known worldwide Ir anomaly at this boundary. Our model may explain why PGE enriched particles or even PGE phases have not been found so far in the K/T distant ejecta.

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GEOHISTORICAL STUDY OF FORAMINIFERAL BIOSTRATIGRAPHY AND ECOLOGICAL CHANGE OF CRETACEOUS-TERTIARY TRANSITIONAL FORMATIONS IN THE BLACK SEA REGION, REPUBLIC OF TURKEY

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Thirteen geologic sections from carbonate platform (Pontides Platform) were selected to provide a more detailed foraminiferal biostratigraphy, and strontium isotope and trace elements analysis for the purpose of study to give the shallow benthic fauna, its extinction and survival at the K/T boundary. In Devrekani, $^{87}Sr/^{86}Sr$ ratios of limestone samples from 803 to 810 are concentrated in a narrow range (0.707752-0.707834) which corresponds to range of sea water Sr isotope ratios in late Cretaceous to early Tertiary. Results of foraminifers indicate that the K/T boundary is between limestones of samples 806 and 807. In Gölpazari, where the fossils of foraminifers, algae, bryozoans, rudists, molluscs, echinoids, and corals of Maastrichtian and Danian-Thanetian occur in beds of 32m thick, K/T boundary showed beds between 502 and 504, and the Tetiary starts with *Planorbulina cretae* and *Laffitteina* sp. Extinction of biota is accompanied by peak of strontium isotope value, and by peak of concentration of elements as Cr, Co, Ni, and Zn, except Cu.

PLIOCENE VOLCANICLASTIC SEDIMENTS IN THE CROATIAN ADRIATIC OFF-SHORE REGION (DRILL-HOLE KRUNA-1)

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Late Cenozoic volcanic and pyroclastic rocks from the Croatian part of Adriatic off-shore and foreland fold-and-thrust belt of the Adriatic lithosphere and External Dinarides were scarcely documented: (1) Quaternary vitric tuff from Dalmatian zone (Šušnjara et al., 1994), (2) Pleistocene radioactive fine-grained pyroclastics in several off-shore drill holes (Tari Kovačić, 1995), and (3) the post-collisional calc-alkaline to shoshonitic volcanics in the External Dinarides (Lugović et al., submitted).

Numerous cores drilled in the Croatian off-shore region show radioactive markers also in the Pliocene horizons. These horizons, containing silty- to sandy-marls with abundant foraminifera, were for the first time proved for volcaniclastic material. Two analysed volcaniclastic horizons (880 m and 890 m) from the drill hole Kruna-1 contain leucitite lithoclasts and fine grained glauconite plus leucite crystaloclasts, respectively, whereby volcaniclasts do not significantly exceed 5% of total grains.

Wet-sieving and hand-picking were perfomed to separate fossils from clasts. Minerals were analysed with SX51 microprobe at the Mineralogisches Institut, University of Heidelberg using an accelerating voltage of 15 kV, beam current of 20 nA and beam width of 10 micro m for glauconite and foids.

Pliocene sediments were documented with 15 species of planktic and 34 species of benthic foraminifera. The absence of Quaternary fossils admixed to the Pliocene fossil assemblages rules out a redeposition of Pliocene sediments in the Quaternary time. The oldest Pliocene volcaniclastic horizons are marked by the extincion of planktic foraminifera *Globorotalia margaritae*. Volcaniclastic layers contain partly pyritized and glaucinitized planktonic foraminifera belonging to the evolutionary lineage from *Globorotalia puncticulata* to *Gt. bononiensis* and to the group of *Gt. crassaformis*, and therefore the age of pyroclastic deposits may be constrained to 3.4-2.3 Ma (Zachariasse et al., 1989) or to the M Pl 4 biozone of Early Late Pliocene (Sprovieri, 1992). This age of deposition is corroborated by the associations of benthic foraminifera which include *Uvigerina rutila* species.

Leucitite lithoclasts are porphyritic to seriate-textured with phenocrysts of leucite and clinopyroxene within a matrix consisting of the phenocrystic assemblage, titanomagnetite, interstitial nepheline and apatite. Clinopyroxene phenocrysts have relatively homogeneous, low pressure diopsidic cores and normaly or oscilatory zoned salitic rims. Fine granular glaucony from the lower volcaniclastic layer shows chemical composition typical of well ordered glauconite. Apatite, sphene and albite inclusions in the glauconite may suggest an alkali-rich pyroclastic precursor of the glauconite.

Since the ultrapotassic pyroclastic material from the Croatian off-shore Pliocene sediments appears at least 1 Ma older than its nearest on-land counterparts, e.g. from the Roman-Campanian Volcanic Province (Beccaluva et al., 1991), the volcanic source where this material was derived from remains unknown.

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NEW GEOCHEMICAL CONSTRAINTS ON URENGOITE, SOUTH URAL AND ZHAMANSHIN-IRGHIZIT IMPACT GLASSES

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In the asiatic part of Russia several fragments of impact glass have been found, of which the source crater is still unknown. The South Ural impact glass A-1 was collected near Magnitogorsk (53° 37' N, 60° 10' E), the three Urengoites (U-1, U-2 and U-3) were discovered in Late Pleistocene fluvioglacial sands close to the town of Urengoi (76° 57' N, 66° 07' E).

The 22.1 ±2.6 (2δ) to 26.0 ±2.8 Ma [1] Urengoites are natural bottle-green and pale green glasses. An age around 24 Ma is unknown, so far, for other tektites or impact glasses. All three Urengoites are silica-rich (87 - 96 wt. %) and show REE distribution patterns with $(La/Yb)_{cn}$ of 7.6 - 10.4 and Eu/Eu* of 0.69 - 0.75. Total REE abundance lies between 44 and 76 ppm and decrease with increasing SiO_2-content. Sr values for for the Urengoites cluster between 150 and 175, Nd is highly negative between -18 to -23 for. Nd model ages between 1.9 -2.3 Ga prove that Urengoites are a separate class of tektites, which originated from crustal target material of Proterozoic age.

The South Ural tektite-like glass has a K/Ar age of about 6.2 Ma and a unique chemical composition with 65.5 wt. % SiO_2 [2]. It shows a very steep REE distribution pattern with $(La/Yb)_{cn}$ of 17.1 and Eu/Eu* of 0.71; total REE content is sligthly higher with 110 ppm compared to the Urengoites. Sr, Nd isotopic composition (ΣSr = 252, ΣNd = -19.4) and the Nd model age of 2.0 Ga, underline that the South Ural sample A-1 is unique amongst all other groups of impact melt glasses and tektites.

To constrain the precursor material of Zhamanshinites and Irghizites, selected target rocks from the Zhamanshin crater were analysed: slates and quarzites, considered as Upper Proterozoic or Lower Cambrian; and andesites and acid volcanic rocks of Carboniferous age.

The Sr model ages of 315 to 360 Ma for acid Zhamanshinites are compatible with their suggested derivation [4] from Carboniferous volcanics, which, according to their Nd model parameters contained older components. For the Irghizites, a precursor material of Lower Proterozoic age was assumed [4], which would be in accordance with their Sr model ages. Nd model ages for Zhamanshinites, and Irghizites lie between 416 and 473 Ma, and 861 and 952, respectively [5]. Isotopic analyses will be performed to get further information of the target rocks.

The REE distribution patterns for the basic volcanic rocks and the Zhamanshinites and Irghizites are quite similar ($(La/Yb)_{cn} \approx 10$ and Eu/Eu* ≈1). The Upper Proterozoic slates and quarzites show totally different REE patterns with quite low REE contents indicating that impact melting of these lithologies did neither contribute significantly to the origin of Zhamanshinites nor of the Irghizites.

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FORAMINIFERS OF THE K/T BOUNDARY FROM THE KASTAMONU REGION (NW TURKEY)

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Foraminifers of the K/T boundary have been studied in the Devrekani sections of northeast Kastamonu and in Kiire-Seydiler sections of north Kastamonu region (NW Turkey) (Figure 1).

The lithological and faunal characteristics of both sections are similar. Benthic foraminifers such as *Siderolites calcitrapoides* Lamarck, *Sirtina orbitoidiformis* Brönniman, *Orbitoides medius* (D'Archiac), *Orbitoides apiculatus* Schlumberger, *Lepidorbitoides minor* (Schlumberger), *Hellenocyclina beotica* Reichel, *Praestorrsella roestae* (Visser) and macro faunas (only Devrekani section) such as *Trigonia* sp., *Turritella* sp., and rudists have been determined in Maastrichtian levels which are made of sandy limestones.

The overlying Danian levels contain abundant algae - bryozoa and benthic foraminifers such as *Anomalina* sp., *Eponides* sp., *Idalina* sp., *Textularia* sp., and especially abundant Miliolidae. Thanetian levels overlying the Danian, contain benthic foraminifers such as *Rotalia trochidiformis* Lamarck, *Mississippina binkhorsti* (Reuss), *Idalina sinjarica* Grimsdale, and algae species such as *Distichoplax biserialis* (Dietrich) and *Ethelia alba* Pfender.

The Upper Cretaceous to Paleocene Devrekani and Küre- Seydiler sections are characterized by shallow marine facies. No stratigraphic unconformity has been observed at the K/T boundary.

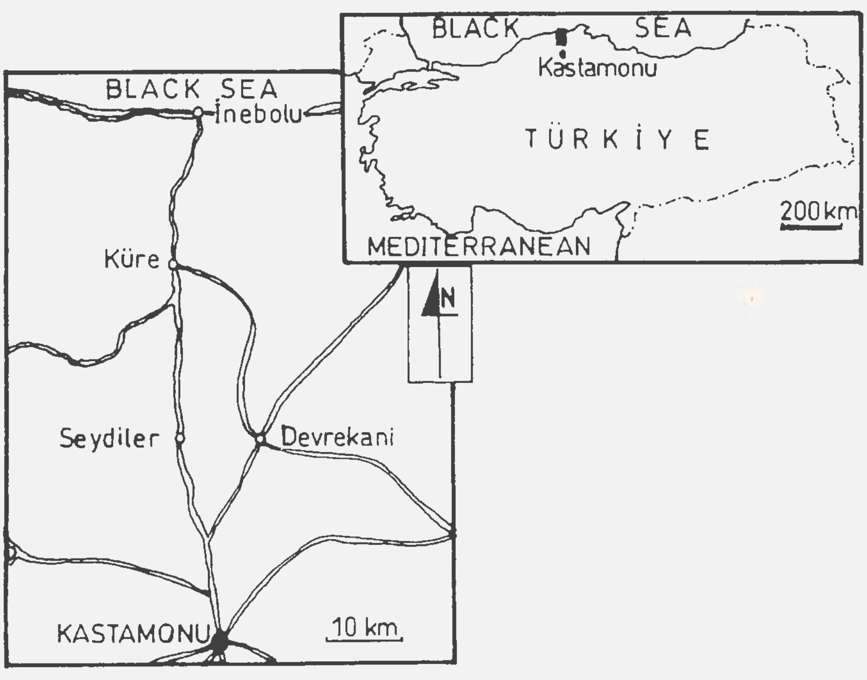

Figure 1. Location map of the investigated area.

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MERCURY ANOMALY AT THE CRETACEOUS - TERTIARY BOUNDARY; DOLENJA VAS, SLOVENIA

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Introduction

"The Ir anomaly", followed by meteoritic elements Ir, Ni, Co, Fe and Cr at the K/T boundary is accompanied with anomalies of non-meteoritic elements, As, Sb and Zn, according to Gilmour & Anders (1989). Their constant ratio (non Meteoritic Ir) gives rise to a conclusion that impact ejecta, soot and meteoritic particulates intimately mixed together before deposition. The results imply a short time-scale (<1Y) K/T "event" (Alvarez, 1987), favouring the impact hypothesis over volcanic or other "gradualist" scenarios.

The mercury is a typical volatile element, present in magmatic gases (Taran et al., 1995). Its anomaly at the K/T boundary may promote understanding of importance of volcanic eruptions and their role for elemental distribution and bio-mass extinctions. A possible influence of subaerial volcanic activity on Hg-content in terrestrial weathering products has been already observed in the bauxites of the Dinaric Carbonate Platform, reflecting volcanic phases of the Alpine Wilson cycle (Palinkaš et al., 1992). The Dolenja Vas sections (Drobne et al., 1995; Dolenec et al., 1995) was an appropriate object to study the role of Hg as a volcanic activity indicator.

The K/T boundary

In the eastern Dolenja Vas section (DVE) the K/T boundary situated between the rudist and the Paleocene micrite limestones, is marked by a hardground, whereas in the western section (DVW) it is characterized by 10 - 30 cm thick breccias (debris flow). The Cretaceous surface contains borings of *Paronipora* sp., often with pyrite and goethite spherules (20 to 70 μm) in matrix, formed by early diagenesis, under anoxic conditions in organic-rich sediments.

Material and method

Thirty-nine rock samples were collected along two profiles, the eastern DVE and the western DVW, at an irregular distance from the K/T boundary (Tab. 1 and 2). DVE section extends 45 cm below the boundary in the Cretaceous rocks and 60 cm above in the overlying Paleocene carbonates. DVW section is sampled from 85 cm below the K/T contact to 50 cm above it. The mercury analysis was performed by pyrolysis (8000) with a gold wire mercury vapor analyzer, AGP-1. Analytical sensitivity of 5 $\mu m\ kg^{-1}$ (ppb) was achieved.

The Hg concentrations vary between 6 and 290 $\mu m\ kg^{-1}$ (Tab. 1 and 2, Fig. 1 and 2). The maximum was obtained in the uppermost Cretaceous layer of DVE section (290 $\mu m\ kg^{-1}$) in a composite sample (breccia cobbles + matrix). The DVW section anomaly is less expressive (49 $\mu m\ kg^{-1}$).

Discussion

The meteoritic and non-meteoritic element anomaly, observed 60 cm below the K/T boundary (Hansen et al., 1995) is followed by negative $\delta^{13}C$ values, suggesting that abiotic changes in the sediments occurred before the biotic crisis at the K/T boundary (Dolenec et al., 1995). The natural input of Hg into environment is via volcanic activity primarily (Kaiser & Tölg, 1980), through Hg-vapour (4%), Hg (II) halide (25%), particulate form (4%) and the rest like organomercurals (Matheson, 1977). Particulate bound matter, susceptible to transportation and removal by impactation, and dry or wet precipitation was the probable way of the long-distance transport. Distinctive anomalies of As, Sb and Zn at several K/T boundaries (Gilmour & Anders, 1989) and Hg-anomalies at the Dolenja Vas sections speak in favour of episodic rather than long-term pollution of non-meteoritic elements. Large amounts of particulate, air-borne matter may scavenge volatile elements effectively. It does not exclude enhanced and prolonged volcanic activity, caused by meteorite impact, but removal of mercury from atmosphere ceased down immediately with diminished quantity of air-suspended matter in the atmosphere, which was its main global carrier.

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Table 1. Content of Hg (ppb) in the section Dolenja Vas - East

Sample	Age	Sample position*	Hg (ppb)
DVE - 20	Danian	50 - 60	44
DVE - 7	Danian	42 - 49	12
DVE - 6	Danian	35 - 42	32
DVE - 5	Danian	28 - 35	17
DVE - 4	Danian	21 - 28	10
DVE - 3	Danian	14 - 21	28
DVE - 2	Danian	7 - 14	24
DVE - 1	Danian	0 - 7	13
DVE - 21	Maastrichtian	0 - 2	290
DVE - 8	Maastrichtian	2 - 10	14
DVE - 9	Maastrichtian	10 - 14	32
DVE - 11	Maastrichtian	15 - 20	9
DVE - 10	Maastrichtian	20 - 25	29
DVE - 12	Maastrichtian	25 - 28	9
DVE - 13	Maastrichtian	30 - 40	6
DVE - 14	Maastrichtian	40 - 45	23

*sample distance from KT boundary (cm)

Table 2. Content of Hg (ppb) in the section Dolenja Vas - West

Sample	Age	Sample position*	Hg (ppb)
DVW - 12	Danian	43 - 50	6
DVW - 13	Danian	41 - 43	9
DVW - 14	Danian	34 - 40	8
DVW - 11	Danian	28 - 32	11
DVW - 10	Danian	22 - 28	19
DVW - 9	Danian	20 - 22	39
DVW - 8	Danian	15 - 20	17
DVW - 7	Danian	8 - 14	13
DVW - 1	Danian	0 - 2	49
DVW - 2	Maastrichtian	2 - 6	28
DVW - 3	Maastrichtian	6 - 10	19
DVW - 4	Maastrichtian	10 - 15	11
DVW - 5	Maastrichtian	15 - 22	7
DVW - 17	Maastrichtian	22 - 25	13
DVW - 18	Maastrichtian	41 - 46	11
DVW - 19	Maastrichtian	50 - 54	28
DVW - 20	Maastrichtian	54 - 58	11
DVW - 22	Maastrichtian	62 - 66	12
DVW - 23	Maastrichtian	66 - 70	33
DVW - 24	Maastrichtian	70 - 71	38
DVW - 25	Maastrichtian	71 - 75	18
DVW - 26	Maastrichtian	75 - 80	34
DVW - 27	Maastrichtian	80 - 85	29

* sample distance from KT boundary (cm)

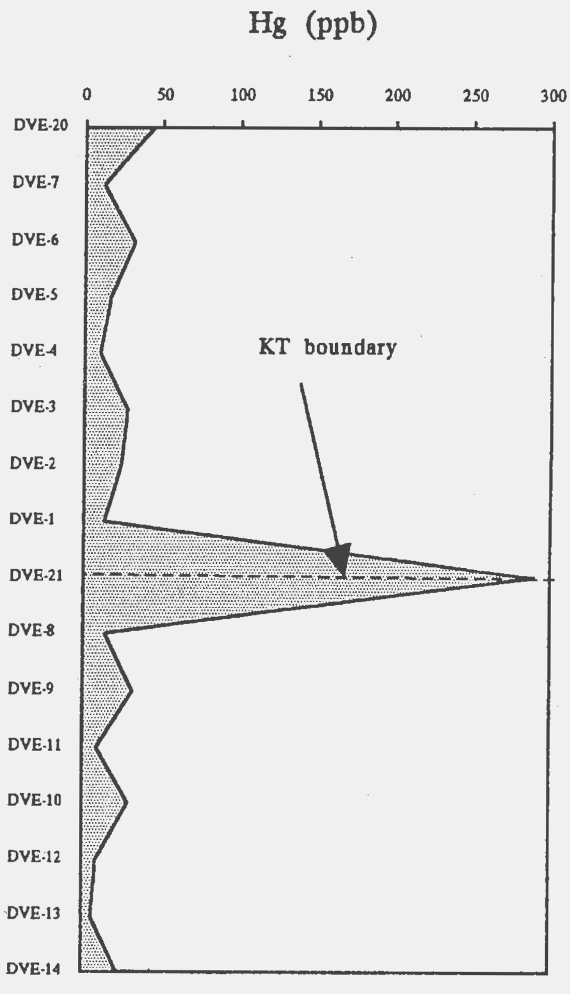

Fig. 1. Content of Hg (ppb) in the section Dolenja Vas - East. Sample number is given on vertical axes. For sample distance from K/T boundary see table 1.

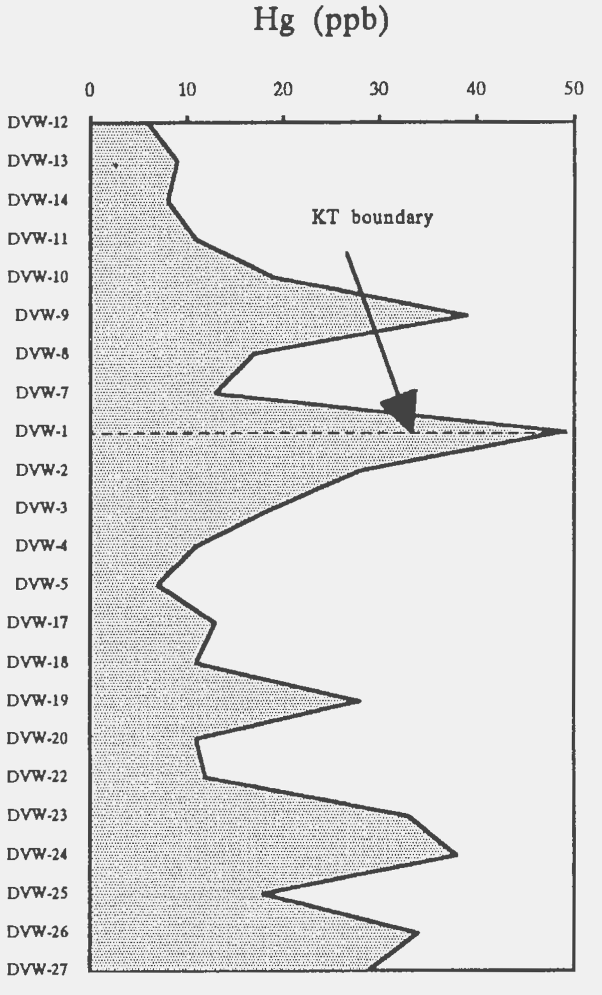

Fig. 2. Content of Hg (ppb) in the section Dolenja Vas - West. Sample number is given on vertical axes. For sample distance from K/T boundary see table 2.

THE GEOPHYSICAL SIGNATURES OF TERRESTRIAL IMPACT CRATERS

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The geophysical signatures of terrestrial impact craters are reviewed with a particular focus on results from the Fennoscandian Shield. The major advantages and drawbacks of the geophysical methods (gravity, magnetic, electric, electromagnetic, seismic, radar and palaeomagnetic) as applied to impact structures will be discussed with examples. In addition to methods listed above, the digital topographic and the lake bathymetric data have recently proven to be very useful materials in identifying new impact structures and in constraining the geometric crater models obtained with standard geophysical surveys.

The geophysical anomaly of an impact structure depends upon (i) the lithology and strength of the target rock, (ii) the morphology and geometry of the crater produced by the hypervelocity impact, (iii) the structural attitudes of the pre-existing (target) structures, (iv) the impact induced changes in physical properties of the impact and target rocks, (v) the size, type and arrival angle of the projectile (energy consideration), and (vi) post-impact deformation and erosion of the structure. Geophysical data have been gathered from impact structures at various altitudes:in drillholes, on the ground, by airborne and shipborne methods and from satellites. Since the geophysical anomaly of an impact crater depends strongly on the altitude, the anomalies differ in their size and shape and in the information content of the structure, such as depth and diameter. Gravity and magnetic measurements in particular have led to discoveries of new impact craters on the Earth; for example, the Iso-Naakkima structure in Finland (D ~ 3 km) was discovered by the pronounced circular negative (4mGal) gravity anomaly. These two methods still continue to be the major tools in searching for new impact structures.

Geophysical data have been used to calculate various morphometric data for several impact structures including estimates of the impact melt volumes in some craters, determinations of the depths and diameters of the subhorizontal units of some structures (e.g., the depths of the breccia and suevite layers). Petrophysical data of drillholes, on the other hand, have led to estimates of the depth-extent of microfracturing in the target rocks below some impact structures (e.g., Kärdla in Estonia). Although the age of the impact cannot be directly measured by geophysical methods, it can be constrained geophysically in three ways. First, the geophysical data often reveal evidences of buried pre- or post-impact sediments which have escaped erosion and thus are uniquely preserved in impact structures due to down-faulting. The biostratigraphic (microfossile) and/or palaeomagnetic age of these sediments can be determined which give constraints to the age of the impact event (e.g., Iso-Naakkima in Finland, Tvären in Sweden). Second, magnetic anomaly modelling, when coupled with paleomagnetic data of the impact rocks, provides a tool to estimate the age of the impact event using the APW dating technique on melts, breccias and sometimes on fractured target rocks (e.g., Suvasvesi in Finland; Siljan in Sweden). Third, the presence of magnetic polarity reversals in the impact rocks can provide constraints for the age of the impact event (e.g., Chixculub in Mexico).

The geophysical signatures of impact craters vary considerably and depend on many factors as discussed above. Some common features can, however, be found:

Simple structures

- have typically circular negative gravity anomalies where the maximum amplitude depends on D and h and on density contrasts. Density generally is subdued in the impact rocks due to increased porosity and it increases radially away from the impact center towards the value of unshocked target rocks.

- the magnetic anomalies are generally subdued due to decrease of susceptibility and NRM: occasional anomaly peaks can occur in places where impact melt is present. Breccias and suevites often have relatively strong magnetizations (i.e., enhanced Q-values) if TRM is acquired but in some craters the NRM of breccias is randomized probably causing the subdued magnetic anomaly patterns. In a few cases a SRM (shock remanent magnetization) has been isolated in impact rocks (e.g., Slate Islands in Canada; Siljan in Sweden).

- the electric and EM anomalies are also often subdued due to decrease of resistivity in impact rocks caused by decreased porosity and microfracturing.

- seismic data often reveal indications of sub-surface strata in impact structures: the modern high-resolution reflection data in particular are able to trace the fine details of the buried impact structures, such as the bottom of the crater, rim-uplifts and the central uplift (e.g., Mjölnir in Norway). The seismic velocities in impact rocks are reduced from their unshocked counterparts due to increased porosity (decreased density) and microfracturing caused by shock.

Complex structures

The geophysical signatures of the complex structures are basically similar to those of simple ones but with larger scale. The anomalies are broader but relatively less pronounced due to smaller diameter to depth ratio. A characteristic feature of complex craters is the geophysical signature of the central uplift, such as a central gravity or magnetic anomaly superimposed with the overallbroad impact anomaly.

The merits of the geophysical methods are that they provide a three dimensional view of the impact structures with high resolution and often give the first hint of a new impact structure. The main drawback is that the geophysical interpretation models are not always unique: their validity can only be verified by drilling. Fortunately, recent drilling of some impact craters has proven that the geophysical models are often valid (e.g., Lappajärvi in Finland; Kärdla in Estonia). The inambiguities of the modelling can be considerably reduced by integrating results obtained by various methods.

However, even though considerable work has been done in developing the geophysical apparatus, measuring techniques and interpretation methods, there has been little comprehensive 3-dimensional geophysical modelling of terrestrial impact structures of various ages and sizes (simple, complex, multiring) occurring in different environments (sedimentary basin, ancient shield, shallow marine, deep ocean floor, thick ice sheet, etc.). Such modelling would help in (i) discovering new craters, (ii) developing better criteria to recognize relict anomalies due to strongly eroded impact structures modified by orogenies, and (iii) to find impact craters on the ocean floor, which are still very sparse. These are some of the major tasks of geophysics in terrestrial impact cratering research in the near future.

ACCURATE MODELING OF THE CHICXULUB IMPACT EVENT USING HYDROCODES

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The climatic effects of the Chicxulub impact event and their relationship with the K/T boundary mass extinction have been difficult to quantify because of the complex target geology of the Yucatán Peninsula (México). We have tried to improve on previous simulations [1,2,3] by developing a more accurate model of the sedimentary layers that covered the site. For this work we have developed an improved equation of state for calcite [1] and anhydrite.

An impact simulation was carried out using Sandia's 2-D finite differences hydrocode CSQIII coupled with the semianalytical equation of state ANEOS. One hundred massless tracer particles which record the conditions of material at local positions have been regularly distributed in the projectile and target to determine the volume of original target and projectile material undergoing melting or vaporization, and to follow trajectory and thermodynamic history of the materials involved in the impact event.

In the simulation the target consists of a dunite mantle and an overlying 30-km layer of granite (crust). The local sedimentary sequence of evaporites and limestone is modeled by six 500-m thick alternating layers of anhydrite and calcite. The shallow sea that covered the site at the time of the impact is modeled with a 100-m thick layer of water which is, in turn, overlaid with an atmosphere for which the ANEOS air equation of state has been used.

Estimates of the size of Chicxulub crater vary from 180 km [4,5] to about 300 km [6]. In the simulation, a spherical projectile 5-km in radius impacts vertically the surface at a speed of 20 km/sec, corresponding to a crater about 200-km in diameter. We estimated the amount of climatically important species produced by event: CO_2, water vapor and sulfur (i.e. sulfate aerosols). Decarbonation of calcite occurs for shock pressures ranging from 20 [7] to 60 [8] GPa. We find that 355-470 km^3 of calcite is degassed, producing 4 - 5.4 x 10^{14} kg of CO_2, one or two orders of magnitude less than in [2] and consistent with our previous estimate [1]. Shock pressures around 100 GPa are believed to degas anhydrite [9,10].

We estimated that about 186 km^3 of anhydrite was degassed, producing about 10^{14} kg of sulfur. The estimate of the amount of water vaporized by the impact is about 10^{13} kg. This amount is very large when compared with the water vapor inventory of the stratosphere (~10^{10} kg), where most of the impact-produced water vapor is deposited.

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DISTRIBUTION OF KT-SPINELS IN THE MEDITERRANEAN AREA

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Continuous Cretaceous/Tertiary (K/T) boundary sections were studied in the eastern Balkan Mountains at the Black Sea coast near Bjala, Bulgaria [1], in the Apennines in the Scaglia Rossa, 25km north of Gubbio at Cerbara, Italy and at Caravaca, Spain. The magnetic spinels were separated from the K/T boundaries and investigated by X-ray powder diffraction, scanning electron microscopy (including EDS analysis) and instrumental neutron activation analysis (INKA). Spinels at the K/T boundary sites have sizes of 2-20μm; the majority are single crystals with octahedral shape, some with etching pits on the (111) and few with etching peak on the (100) faces. The single crystal spinels are Ni-rich magnesioferrite spinels with variable Cr-content and Ir-inclusions. The crystal structure is partially inverse but the crystal have no homogeneous composition (Tab.1); they show inside a higher Cr-content [2]. The formation of the spinels takes place by condensation in the hot fireball controlled by the oxygen fugacity of the mesosphere. The etched pits were produced by H_2SO_4 during the transport through the stratosphere. The distribution of the transported spinels with anomalous Ir-content from the HOT FIREBALL after the impact in Chicxulub, Mexico to the K/T sites were determined.

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Table 1

		CERBARABJALA			
		inside	outside	inside	outside
	Fe^{3+}	0.54	0.83	0.66	0.55
[4]	Mn^{2+}	0.00	0.01	0.02	0.03
	Zn^{2+}			0.00	0.05
	Fe^{2+}	0.46	0.16	0.32	0.37
	Mg^{2+}	0.46	0.73	0.56	0.44
	Ni^{2+}	0.08	0.10	0.10	0.11
[6]	Al^{3+}	0.10	0.24	0.32	0.18
	Cr^{3+}	0.37	0.28	0.25	0.14
	Fe^{3+}	0.99	0.65	0.77	1.13
	O^{2-}	4	4	4	4
$\frac{Fe^{3+}}{Fe\ total}$		0.77	0.90	0.81	0.82

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PLANKTONIC FORAMINIFERAL TURNOVER NEAR THE MIDDLE/LATE EOCENE BOUNDARY (NORTHERN ADRIATIC, CROATIA)

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Clastic sediments near the Middle-Late Eocene boundary (Zone P14) are examined for planktonic foraminiferal assemblages alternation in three exploration wells of North Adriatic Sea. These hemipelagic sediments consist of silty marls with thin intercalations of silts and sandstones (Premec Fuček et al., 1995).

Planktonic foraminiferal assemblages of the zone P14 were highly diversified. Dominant forms in assemblages were high-spired subbotinids (*Subbotina eocaena, S. cryptomphala, S. gortanii, S. corpulenta*) and large globigerinids (*Globigerina tripartita, G. ampliapertura, G. officinalis, G. venezuelana*) with over 40%. *Turborotalia cerroazulensis* lineage was represented with three species (over 20%). *Turborotalia pomeroli* decreased in number, *T. cerroazulensis* was predominant species of the lineage, and *T. cocoaensis* first appeared in the upper part of this zone. Muricate species were a significant part of assemblage with 10-15 % (*Truncorotaloides rohri, T. pseudotopilensis, Acarinina spinuloinflata, Acarinina triplex*). Globigerinathekids were well represented with 3-5 % . The most frequent species are *Globigerinatheka tropicalis, G. luterbacheri, G. barri* and *G. index*.

Near the end of the Zone all muricate species (10-12%) decreased in size and abundance and finally disappeared (Istra more-5 well, cored interval). After extinction level planktonic foraminiferal assemblages were dominated by high-spired subbotinids, large globigerinids and *Turborotalia cerroazulensis* group. *Pseudohastigerina* and *Catapsidrax* became frequent. *Globigerinatheka index* and *G. tropicalis* increased in number. Only a few specimens of small acarininids (*A. medizzai, A. rugosoaculeata*) survived this extinction event. *Globigerinatheka semiinvoluta* has never been found close after this level, but later above.

These facts indicate that in northern Adriatic muricate forms disappeared before the end of Zone P14, respectively before the end of the Middle Eocene. Although most authors use extinction level for definition of the Middle/Late Eocene boundary (Toumarkine & Luterbacher, 1985; Nocchi et al., 1988), it seems that their extinction depended on local ecological conditions (Premoli Silva & Boersma, 1988; and personal comunication, 1994). First appearance of *Globigerinatheka semiinvoluta* could be a better criterion for definition of the Middle/Late Eocene boundary in Mediterranean bioprovinces.

Zone P14 has the highest diversity in the Eocene. Many species first evolved during the Zone, and others persisted. Planktonic foraminiferal exchange started during the Zone, but noticeable step happened near the end, when muricate warm-water species disappeared and were replaced by cool-water species of subbotinids and large globigerinids which were better adapted for climatic changes.

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IMPACT INDUCED METASOMATISM OF GRANITIC TARGET ROCKS? KÄRDLA CRATER, ESTONIA

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Trends of possibly impact-related petrographic and chemical (Puura & Suuroja, 1992), petrophysical (Plado et al., 1996) and mineralogical (Puura et al.,1996) alteration of the granitic rocks at the 4 km wide and 0.5 km deep buried Kärdla crater have been reported earlier. Granitic rocks are prevailing in the crystalline basement that at the impact moment was covered by layers of siliciclastic, clayey and carbonate sediments (140m), and marine water (20-40 m). No impact melt rocks have been found at the Kärdla site. Interpretation of the published and new materials suggests that in the Kärdla case the chemical and mineralogical alteration of the target rocks is caused by impact-induced metasomatism. Interdisciplinary research based on the deep drill cores enabled to draw the following hypothesis on possible circumstances and regularities of the impact-induced rock alteration:

- the changes of target rocks identified at the Kärdla crater have occurred at the pressure and temperature levels insufficient for the formation of a melt rock sheet that could be produced from autochthonous breccias or autochthonous target rocks;
- consequently, the alteration of the rocks has to be regarded in relation to the reactions between the impact plume fluids and gases, and solid rocks;
- changes of physical parameters, such as density, porosity, P-wave velocity etc. testify that the permeability of the target rocks has a systematic decrease starting from the crater bottom; petrophysical alteration zone in the subautochthonous to autochthonous rocks is at least 500 m thick;
- through the whole zone of petrophysical alteration, rocks are finely penetrated by frequent systems of fractures and fissures; the fissures penetrated also mineral grains making them permeable for fluids as testified by substitution of primary high-pressure and high-temperature fluid inclusions of metamorphic granitoids by low-pressure and -temperature inclusions in highly impacted rocks;
- in thin sections, the changes of the bulk mineralogical composition are dependent on the above alteration, and they are expressed, first, in decomposition of plagioclase and formation of microcline and K-bearing mica and clay minerals; primary plagioclase crystals usually remain as pseudomorphs;
- chemical alterations of granites are expressed in drastic decrease in Na and increase in K content, and minor changes in Ca and Mg concentrations, accompanied by changes in concentration of many of trace elements;
- mineralogical and chemical alteration of the granitic rocks occurred both in allochthonous and autochthonous breccias, or, in rocks altered both within and beneath, respectively, the impact plume once existing; main trends of alteration of both allochthonous and subautochthonous granitic clasts and autochthonous brecciated target granites are similar;
- beside of the alteration of granitic rocks and feldspars, alteration of amphibolitic rocks, biotites and other minerals can be observed.

Related impact-induced mechanical, chemical and mineralogical changes of allochthonous and subautochthonous target rocks might be another factor of essential changes of the Earth crust under the influence of the meteorite bombardment. The intensity and chemical nature of the impact-related metasomatic changes generated by an impact without large-scale melting (or beside the melting in large impacts) may depend on the composition of the target and on the availability of chemically active volatiles in a solid target and/or in past hydrosphere and atmosphere. Granitic rocks are one most sensitive target rock to fix the changes. Impacts in shallow marine environments probably enrich the impact plume with volatiles. Therefore, complex targets composed of a water-saturated sedimentary cover and an underlying granite basement could be favourable for studies of impact-related geochemical and mineralogical alteration processes.

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USE OF ALVEOLINIDS FOR THE RECOGNITION OF THE PALEOCENE-EOCENE BOUNDARY IN THE SALT RANGE, NORTHERN PAKISTAN

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In Pakistan, the Lower Tertiary marine sedimentary succession is essentially a shalow shelf sequence of limestones and shales characterised by the occurrence of age diagnostic larger foraminifera.

The Salt Range is a classical locality to study the Lower Tertiary marine succession in terms of its biostratigraphic framework on the basis of larger foraminifera. The Salt Range is an important locality for geological investigation because it is easily accessible and the rocks are well exposed due to lack of vegetation as well as the presence of number of gorges cutting through the various rock units.

The present research which formed part of the IGCP Project 286 is based upon collection of Alveolinids from such easily accessible location, for example, the Nammal Gorge, the Nilawahan Gorge and the Lumshiwal Nala (see the accompanying stratigraphic section).

According to the literature (Davies & Pinfold, 1937), the Lower Tertiary succession of the Salt Range has been established as such

	Chorgali Formation	(formerly Bhadrar Beds)
Lower Eocene	Sakesar Limestone	(Sakesar Limestone)
	Nammal Formation	(Nammal Limestone and Shale)
	Patala Formation	(Patala Shales)
Paleocene	Lockhart Limestone	(Khairabad Limestone)
	Hangu Formation	(Dhak Pass Beds)

The present nomenclature has been approved by the Stratigraphic Committee of Pakistan.

In view of the recent investigations on the basis of larger foraminifera and the planktonic foraminifera, the Patala Formation, in part especially in the Western Salt Range (conventionally known as the Trans Indus Salt Range) is regarded to belong to the Lower Eocene.

Davies and Pinfold (1937), apart from establishing the stratigraphic framework, described and illustrated various groups of age diagnostic foraminifera. Regarding their findings about the Alveolinids, *Alveolina vredenburgi* was newly created by Davies (in Davies & Pinfold, 1937, p. 57, pl. 5, fig. 25) from the Patala Formation at Makerwal in the western Salt Range, (Lumshiwal Nala Section). They have figured an external view of the species which is having an elongated fusiform shape. The total distribution of *Alveolina vredenburgi* Davies was however, indicated by them both in the Lockhart Limestone and the Patala Formation. The rest of the Alveolinids have not been illustrated which are *Alveolina ovoidea* d'Orbigny, *Alveolina globosa* (Leymerie) from the Lockhart Limestone, *Alveolina globosa* (Leymerie) from the Patala Formation, *Alveolina globosa* (Leymerie), *Alveolina oblonga* d'Orbigny, and *Alveolina ovoidea* d'Orbigny from the Sakesar Limestone.

According to our investigations, the accompanying Plate explains the occurrence of Alveolinid fauna which is regarded as a useful indicator for the recognition of the Paleocene/ Eocene boundary.

Sameeni during his stay in Basel had an opportunity to examine the numerous specimens of *Alveolina cucumiformis* Hottinger as well as *Alveolina vredenburgi*. A careful perusal of the entire material led credence to believe that there is no morphological difference between the two and, therefore, the older name *Alveolina vredenburgi* has been retained and this taxonomic revision should be incorporated in the future Alveolinid biozonation.

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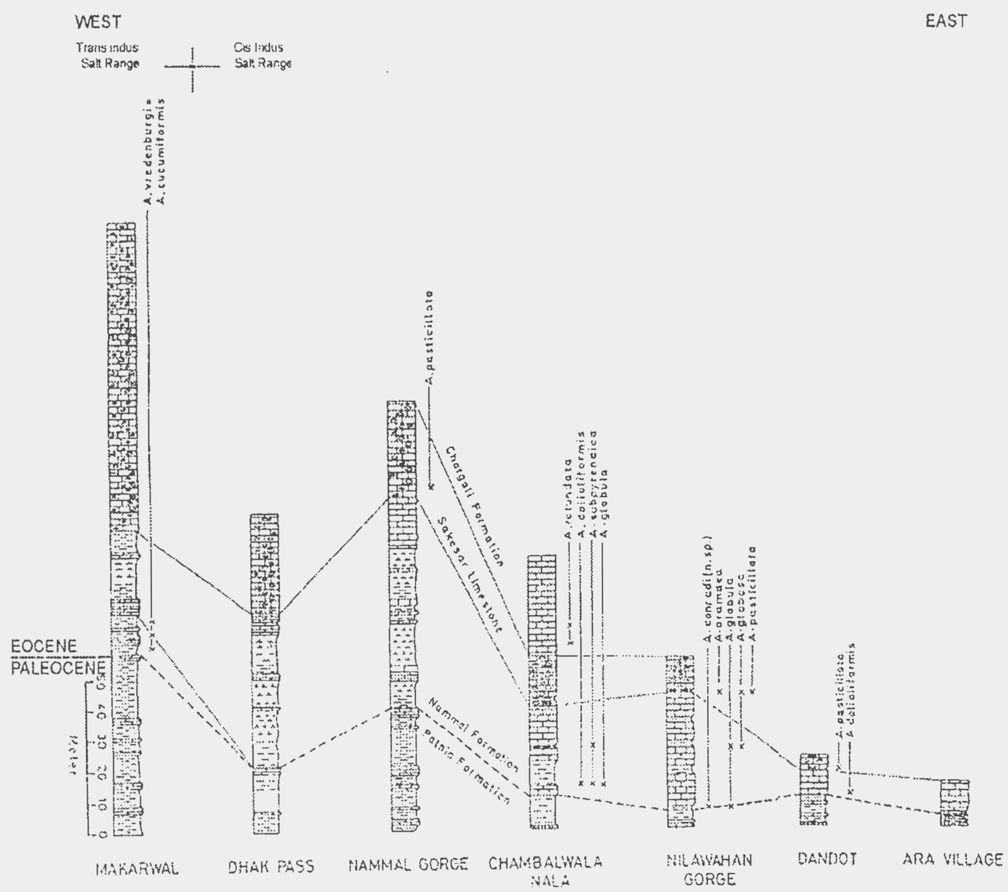


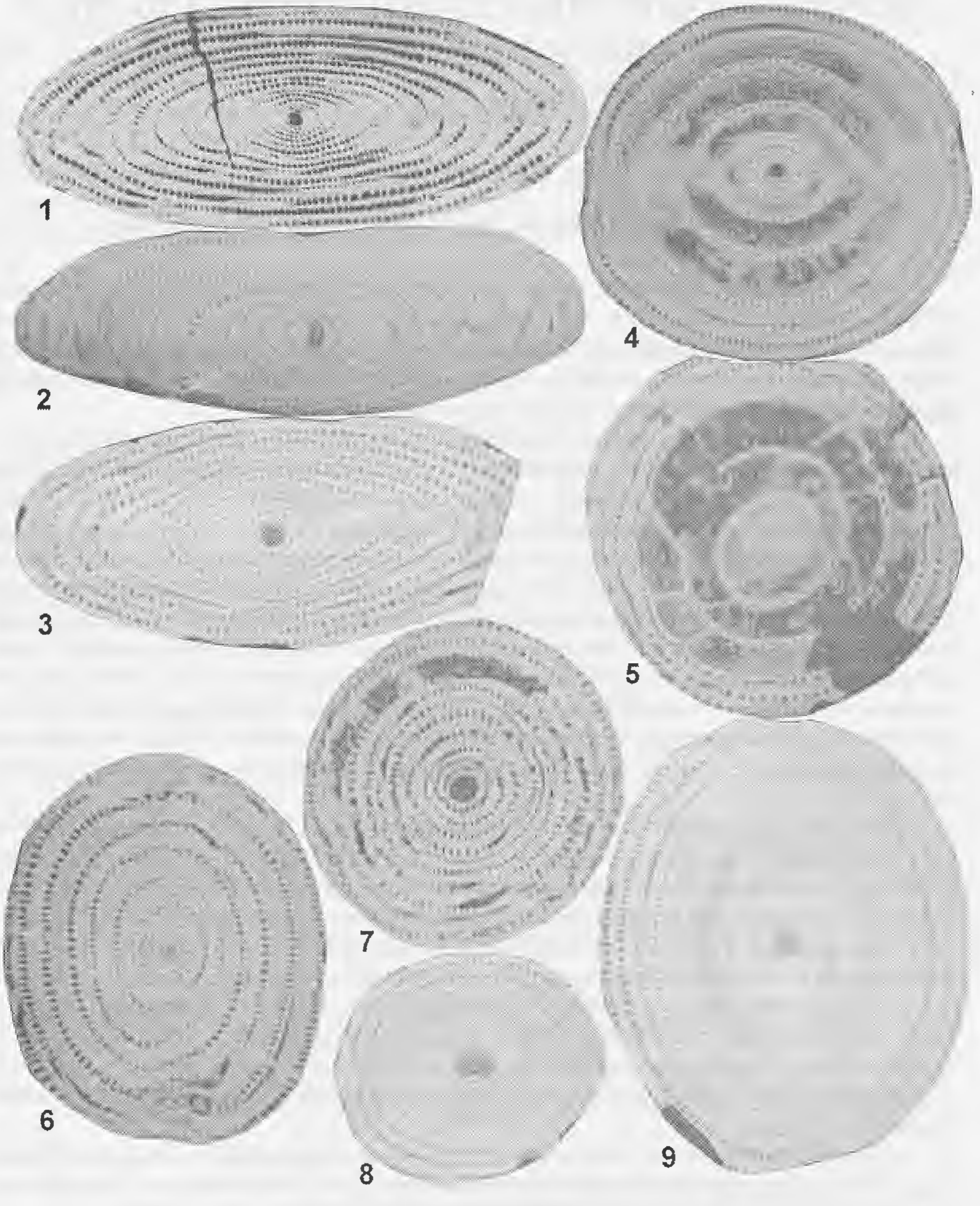
Fig. 1. Recognition of the Paleocene-Eocene boundary in the Salt Range, Northern Pakistan, on the basis of Alveolinids

Plate 1

Fig. 1. *Alveolina vredenburgi* Davies, 1937 = *Alveolina cucumiformis* Hottinger, 1960, top Patala Formation, Makerwal (topotype illustrated from the type locality), Salt Range.
Fig. 2. *Alveolina rotundata* Hottinger, 1960, Chorgali Formation, Chambalwala Nala, Salt Range.
Fig. 3. *Alveolina conradi* 1996 sp. nov., base Nammal Formation, Nilawahan Gorge, Salt Range.
Fig. 4. *Alveolina pasticillata* Schwager, 1883, Nammal Formation, Nilawahan Gorge, Salt Range.
Fig. 5. *Alveolina aramaea* Hottinger, 1960, Nammal Formation, Nilawahan Gorge, Salt Range.
Fig. 6. *Alveolina subpyrenaica* Leymerie, 1846, Nammal Formation, Chambalwala Nala, Salt Range.
Fig. 7. *Alveolina dolioliformis* Schwager, 1883, Nammal Formation, Dandot area, Salt Range.
Fig. 8. *Alveolina globosa* (Leymerie), 1846, top Nammal Formation, Nilawahan Gorge, Salt Range.
Fig. 9. *Alveolina globula* Hottinger, 1960, Nammal Formation, Nilawahan Gorge, Salt Range.

PLATE 1

x 15



GEOCHEMICAL EVIDENCE FOR EUXINIC CONDITIONS IN A WATER COLUMN DURING DEPOSITION OF THE CENOMANIAN-TURONIAN BOUNDARY SEDIMENTS AT CISMON (VENETIAN ALPS, ITALY)

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Dark shales, equivalent to the Livello Bonarelli at the C-T boundary in the Umbrian region (OAE2) (Arthur & Premoli-Silva, 1982), separate pelagic limestones of the overlying Scaglia Rossa from the underlying Biancone formations in the Belluno Basin. These shales (35 cm thick), finely laminated and without bioturbations, can be subdivided into five beds (5-10cm thick), differing slightly in colour. Selected geochemical data are presented in Table 1.

TOC-S plot (Fig.1) suggests that the Cismon shales, unlike the Atlantic DSDP Cretaceous shales, were deposited under euxinic conditions. It probably reflects the formation of syngenetic pyrite in the water column and at the sediment-water interface (Leventhal, 1983; Raiswell & Berner, 1985). Isotopically very light sulphur (about 50 permil lighter than the Cretaceous seawater sulphates) resulted from bacterial sulphate reduction in an open system and may confirm euxinic conditions. Heavier sulphur correlates positively with the TOC and may indicate thicker euxinic column slightly enriched in heavier sulphates during deposition of the black beds. Significantly lower manganese content in the Cismon shales in comparison to other Cretaceous shales (176 and 910 ppm respectively) also indicate their more reducing character. V/Ni+V ratio, which generally increases with anoxia (Wenger & Baker, 1985), is very high in the Cismon samples, except of the lowermost sample. This sample represents the beginning of the formation of euxinic condition and is also relatively depleted in redox sensitive and/or sulphide forming elements like Cd, Cu, Zn and As.

The high enrichment of some elements (enrichment factors: 10-50 for Cd, Ag, Mo and 5-10 for Cu, Zn, V, As) in the Cismon section is similar to the other CTBE settings (Brumsack 1986). However, it correlates well with TOC content and not with sulphide content. Iron sulphides formation in a water column was probably much faster than their formation inside of reducing sediments. In this case, shortage of time, directly related to the sorption of heavy metals from the water column and indirectly related to their diagenetic release from the other (both organic and inorganic) fractions of the sediment, was a possible reason for lower content of siderophilic elements in the sulphide fraction. Moreover, a content of metals coprecipitated with syngenetic pyrite may be diminished due to expulsion of some metals during recrystallization of precursor iron monosulphide. In a water column these metals would be recycled whereas in organic-rich sediment would be immobilized.

Generally monotoneous through the section and only slightly higher than in the "average shale" Si/Al ratios suggest moderate and continuous biogenic silica production. They are lower than in other C-T shales, and especially in the Bonarelli horizon.

Summarizing, an oxygen-minimum zone, probably existing in the Tethyan domain, could produce a stagnant euxinic bottom water in a marginal semiclosed basin like Belluno Basin, bordered by Trento Plateau to the west and Friuli Platform to the east. High content of heavy metals in the Cismon section suggest a Black Sea type of environment with a drastically reduced sedimentation rate. A cyclic sedimentation of organic-rich and organic-poor beds may result from the O_2-H_2S interface rises which influenced nutrient availability and surface bioproductivity.

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Table 1.

Sample	TOC %	S %	Ni ppm	Mo ppm	Cd ppm	As ppm	Si/Al	V/Ni+V)	$\delta^{34}S$ permil
C5 (top)	7.68	2.37	187	85	2.4	66	4.03	0.78	-37.96
C4	3.93	2.85	149	132	1.5	30	4.07	0.81	-38.14
C3	10.9	2.89	200	65	5.4	61	4.29	0.82	-35.45
C2	1.21	2.50	106	90	4.2	41	3.35	0.80	-39.31
C1 (bottom)	9.40	2.50	194	98	1.8	38	3.93	0.64	-37.05

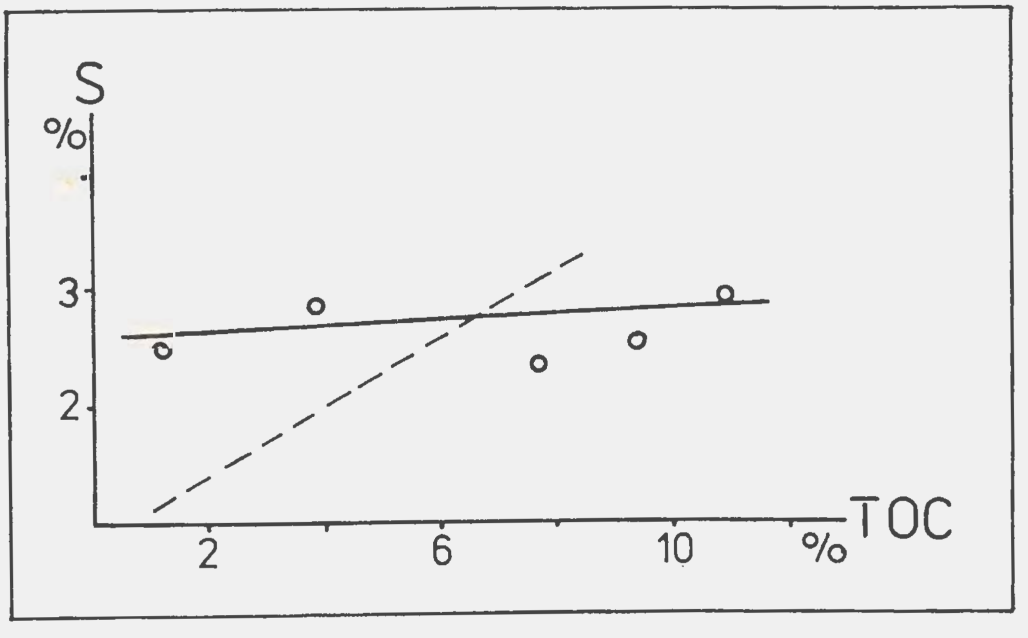

Fig. 1. TOC-S concentration plot for the Cismon C-T section. Dashed-line is for Cretaceous organic-rich shales from Atlantic DSDP sites (Dean et al. 1984).

FORMATION OF IMPACT MELT GLASSES IN EXPERIMENTALLY SHOCKED GRANITE

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For a better understanding of the physical, geological and mineralogical aspects of melt phenomena in cratering on Earth, we investigate experimentally shocked granitic whole rock samples using optical microscopy, REM and electron microprobe technique. The sample was heated at 935 K prior to the shock at 85 GPa in order to force whole rock melting [1]. After shock the sample was quenched.

The sample is a granite from St. Blasien, Black Forest (Germany) with a mean grain size of 0.1-0.3 mm, consisting of 31.6 vol. % quartz, 32 % plagioclase (An_8-38), 20.3 % k-feldspar, 14.3 % biotite, and 1.8 % apatite and zircon.

The main characteristics of the shocked granite is the total loss of the initial "granitic" texture. The recovered sample displays diaplectic as well as shock-fused melt glass with texture and compositional heterogeneities on the µm-scale. Most parts of plagioclase are transformed to melt glasses with an extremely high density of vesicles. The composition of this glass is incongruent to the unshocked sample due to an increasing Or content. K-feldspar glass shows a lower density of bubbles and is enriched in the Ab component compared to its unshocked counterpart. Biotite is transformed to vesicular melt glass with flow structures, pervading large parts of the sample. Chemical composition of the biotite melt glass is highly variable, and analytical data indicate substantial to total H_2O. We have observed for the first time in experimentally shocked rocks, tiny spinels (magnesiospinel-hercynite) and biotite crystals, which newly crystallised from the above mentioned shock-induced biotite melt [2].

Evidence for the total melting of quartz grains is lacking; the cores of individual grains consist of diaplectic glass with a high density of bubbles. These are aligned along roughly parallel planes and may represent fluid inclusions of the unshocked quartz. Quartz fragments (≤50 µm) incorporated in mobile vesicular melts, show an 2 µm thick glass rim containing up to 80 wt. % SiO_2 reflecting incipient dissolution and mixing with the surrounding melt. Still smaller fragments containing low amounts of Al_2O_3, FeO, and CaO are transformed to shock-fused quartz glass.

Original grain boundaries between K-feldspar, biotite and plagioclase are sometimes lined with a melt glass containing schlieren, which reflect the compositional heterogeneity on the µm scale. The brown to yellow, "biotitic " schlieren are enriched in SiO_2 and Al_2O_3 and contain significant amounts of CaO (≤5 wt. %), Na_2O (≤3 wt. %) and P_2O_5 (≤5 wt. %), elements, which are below the detection limit in biotite of the unshocked reference. Chemistry of the transparent schlieren is close to a feldspar, yet, CaO, Na_2O and K_2O are significantly depleted in comparison to the crystalline feldspars of the unshocked sample, and the schlieren contain up to 10 wt. % FeO+MgO+TiO_2. Despite the fact, that the peak pressure in the recovery experiments is only close to 1 µs, the beginning formation of chemically heterogeneous and mixed impact melts is clearly documented by the presence of melt glass with schlieren documents. In their overall characteristics, the experimentally shocked granites resemble highly shocked gneiss clasts of the allochtonous breccia lens at the Haughton Dome, Canada [3].

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EJECTION OF PLUMES CREATED DUE TO IMPACTS AGAINST THE EARTH

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Biological consequences of catastrophic impacts onto the Earth are substantially determined by atmosphere contamination due to ejection of the ground and impactor materials. The impact leads to creation of upward-directed jet (plume) composed of air, vapor and aerosole particles [1]. This plume can rise to high altitudes (up to several thousands kilometers) and cause a contamination of the upper atmosphere. The recent S-L9 Comet impacts onto Jupiter have verified a reality of such phenomena.

An evolution of the "impact explosion" and shock wave propagation are highly directional and differ dramatically from the case of point explosions. This is accounted for by the wake created during the flight through the atmosphere [2]. An angle of trajectory inclination is very important for plume origin and rising.

In this paper the evolution of plumes created in the Earth's atmosphere due to impacts is investigated by 2D and 3D numerical simulations.

Our results show that for vertical impact the plume moves up along the wake. If trajectory has a small angle to horizon, an influence of the wake is almost negligible (for rather big bodies penetrating to the ground surface). The wake looks like a tube of rarefied air. A gas density within the tube is critical for the plume formation and lifting. This density may be affected by radiative cooling and Kelvin-Helmholts instabilities development. Our simulations show that radiative cooling leads to a decrease in temperature of shock compressed air and expansion of hot channal behind the falling body. This involves an increase in the wake density. Kelvin-Helmholts instabilities can cause a fragmentation of the plume and deceleration of its rising.

2D gasdynamic code based on solving of equations for multyphase flows was used to follow the motion of dust particles through the atmosphere due to impacts. Impactor sizes were varied in the range from 50 to 500 m. The lower value corresponds to Tunguska scale event.

The main result of our investigations is that plumes created in the atmosphere due to the impacts of rather small asteroids and comets (50 - 500 m in size) can influence the evolution of the Earth. An effect of such impacts is comparable with the most intensive volcano eruptions. And a probability of these events (about one per thousand years) is much greater than that for huge impacts.

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OCCURRENCE OF THE GENUS *SISTANITES* RAHAGHI, 1983 (FORAMINIFERIDA) IN TWO LOCALITIES OF TURKEY

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This study deals with the first occurrence of the rotaliid genus *Sistanites* Rahaghi (type species, *S. iranica* Rahaghi) in Turkey, which has been first described and figured by Rahaghi (1983) from the Upper Paleocene of Sistan area, Iran. The Anatolian specimens illustrated in Pl. 1, which were found at the Yarýţlý place, W of Burdur, S of Turkey and the Polatlý area, SW of Ankara, Central Turkey, show the following features of generic rank: Test large, low conical, up to 1.8 mm in diameter, dimorphic rotaliid, unequally biconvex, spiral side more convex and evolute, have two and half to three whorls of large chambers, chambers increase rapidly in breadth in the last whorl (Pl. 1, fig. 11-14); large umbilical opening filled by thick horizontal and vertical plates (Pl. 1, fig. 1, 2, 4-7) that form numerous cavities in the umbilical area (Pl. 1, fig. 8, 9); wall calcareous, two layered with very thin inner layer (imperforate microgranular) and thicker hyaline outer layer of radial structure (Pl. 1, fig. 1, 2, 4, 5, 12), aperture cribrate (Pl. 1, fig. 3, 9, 13). Two types of proloculus with different sizes suggest the existence of megalospheric and microspheric generations (Pl. 1, fig. 4, 7, 10, 11, 14), Paleocene (Thanetian).

S. iranica is abundant in hard, light-brown coloured Thanetian limestone of Yarýţlý place, W of Burdur, Southern Turkey with rich foraminiferal species, namely *Bolkarina aksarayi* Sirel, *Miscellanea globularis* Rahaghi, *Miscellanea primitiva* Rahaghi, *Idalina sinjarica* Grimsdale, *Laffitteina mengaudi* (Astre), *Laffitteina erki* (Sirel), *Globoflarina sphaeroidea* (Fleury), Miliolidae and Algae. It is associated rarely in the Thanetian algal limestone of Babayakup section, SE of Polatlý, SW Ankara with *B. aksarayi, M. primitiva, M. globularis*, keramospherid specimens (Delheidia?) and Miliolidae.

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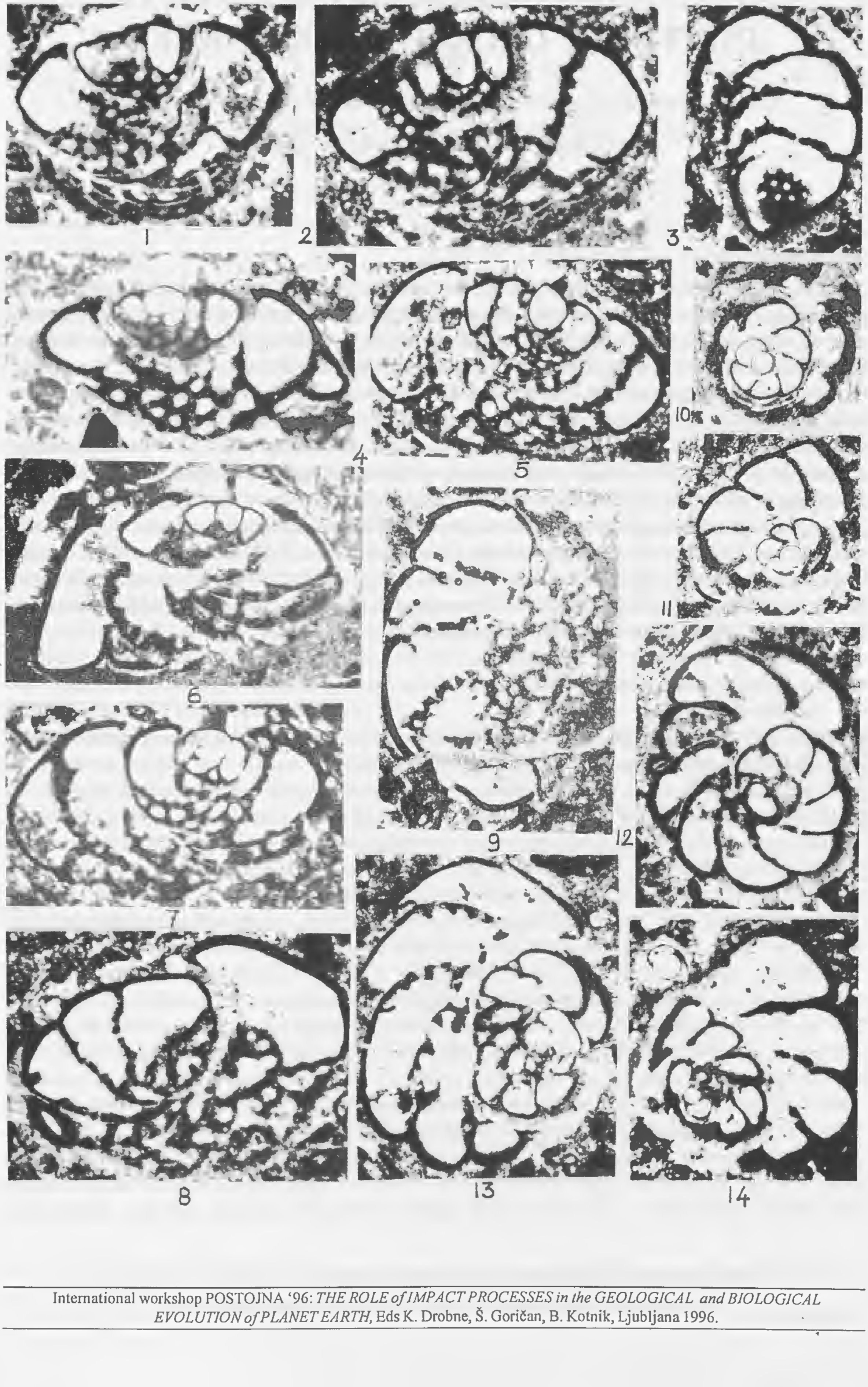
Plate 1

Sistanites iranica Rahaghi, 1983
(Thanetian, Yarýţlý place, W of Burdur, Southern Turkey, all figs. X 35)
Figs. 1, 2, 4-7 - Axial sections, collection numbers, B.I-M /1/5, B.I-N/1/2, B.I- M/1/1, B.I- F/ 2/1, B.I-N/1/3, B.I-F/I/3 respectively.
Figs. 3, 8, 9 - Tangential sections, col. num. B.I-A/3/2, B.I-F/1/2, B.I-F/1/1, respectively.
Figs. 10-14 - Equatorial section, col. num. B.II-D/1/1, B.II-E/ l/1, B.I-M/1/3, B.I-F/2/2, B.I-O / 1/2 respectively.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REVISION ON THE SPECIES OF PSEUDOLACAZINA CAUS 1979 (FORAMINIFERIDA) FROM THE DIFFERENT LOCALITIES OF TURKEY

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The megalospheric and microspheric specimens of the one fabularid species were first described and figured as Fabularia alpani Sirel and Lacazina blumenthali Reichel & Sigal respectively by Sirel (1972, p. 280-283, Pl. 2, fig. 1-6; Pl. VI, fig. 1-4; Pl. VII, fig. 1-3), from the Ilerdian exotic limestone blocks within the ophiolitic melange near the village of Pernavut, S of Kars, Eastern Turkey. This large fabularid species is reexamined on the new material from the above mentioned locality. In the result of this study, megalospheric specimens F. alpani and microspheric specimens L. blumenthali were renamed as a species of Pseudolacazina Caus "Pseudolacazina alpani (Sirel)" by the following generic features: all the chambers of the megalospheric specimen are arranged in biloculine mode; microspheric specimens start growth with quinqueloculine chambers cycles reduced biloculine and monoloculine; chambers subdivided by continuous, longitudinal partitions (as septula) in both generations. On the other hand, the Anatolian Thanetian species Psedolacazina oeztemueri (Sirel) and the Yugoslavian species Pseudolacazina donatae (Drobne) are described and figured. The specific differences of P. alpani, P. oeztemueri and P. donatae are discussed with the other species of Pseudolacazina.

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THE K/T BOUNDARY CHICXULUB IMPACT EVENT: A REVIEW

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Since the first evidence for impact (Ir anomaly) [1, 2] at the K/T boundary has been found, the impact-extinction theory has been in the spotlight of the earth sciences, and controversial. The theory in fact consists of two parts: the evidence for impact, and the evidence linking the impact to extinctions. Although a few still doubt the (evidence for a) major impact has now widely been accepted, because all the predictions made at the launch of the theory have been fulfilled, in contrast to competing theories such as Deccan trap volcanism. First, worldwide, impact spherules have been found with crystalline (clinopyroxene, Ni-rich spinels) interior (microkrystites) [3]. Next [4] , shocked minerals have been detected in the same K/T boundary layer, that only can be explained by the high shock pressures (>90 kbar) of a major impact. Then stishovite [5] and diamonds [6] have been uncovered in the K/T boundary layer. Recently, impact glass [7] (mainly in Beloc, Haiti) around the gulf of Mexico, centering on the large Chicxulub impact crater [8] in Yucatan Mexico, has been uncovered at the K/T boundary. The chemistry and isotope systematics of the impact glass precisely matches the characteristics of the target rocks. For instance, the Sm/ Nd model ages [9] of basement and ejecta (glass as well as zircons discovered in the K/T layer) point to a young (Pan-African) basement. Last but not least, the $^{40}Ar/^{30}Ar$ ages [10] of the melt in the Chicxulub crater are, within a very small error, the same as the impact glass at the K/T boundary in Beloc, Haiti and Mimbral, Mexico.

So far so good, but the evidence for impact linked extinctions is apparently less obvious. The mechanisms leading to a mass-extinction are poorly known. A few suggestions have been proposed, such as darkness and cooling followed by warming (greenhouse atmosphere), but little supporting evidence has been uncovered. The evidence linking the impact to the extinctions is based on the fact that the (marine) mass-extinction level coincides exactly with the impact layer, without preceding significant changes in the biota. The latter evidence is challenged by a.o. Keller [11] who downplays the extinctions at the K/T boundary and suggests that the extinctions were well underway before the impact. However, a paleontological "blind test" in the Kef section (Tunisia) did not confirm these pre-K/T extinctions [12]. Less obvious is the macrofossil extinction record. Rarefaction of the fossils often leads to the misconception that extinctions precede the K/T boundary. For instance, for years it has been suggested that the ammonites were extinct well before the K/T boundary. Later, more thorough examination of the same and additional sections had shown that the ammonites last untill the K/T boundary, and that some may even have survived the boundary (Limburg, Netherlands) [13]. The same holds true for the vertebrate record. Many paleontologists still believe that the dinosaurs vanished before the K/T boundary [14]. However, more detailed searches have turned up dinosaur remains and footprints in the interval between the K/T boundary and the supposed 'last occurrence' of dinosaurs. Also in SW Europe (Garumnian facies) the last dinosaurs were supposed to vanish well before the K/T boundary, but new finds have shown that they last until the K/T boundary. It is evident that a satisfactory answer will

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probably not come from the extinction record, which always will remain incomplete. The best evidence for a mass-extinction event is the recovery after the K/T mass-extinctions. Large ecospaces are available following a mass-mortality event, if the standing crop of species is unable to refill the vacated niches, because they became extinct. Apparently, that is what happened at the K/T boundary. Evolution of planktic foraminifers is amazingly fast just above the K/T boundary, showing the following sequence (El Kef section) [15]: A mass-mortality coincides with the deposition of the ejecta layer, directly, or shortly afterwards, followed by extinctions. The so-called boundary clay resting on the ejecta layer, represents about 5kyrs of "strangelove" ocean conditions, in which the productivity in the oceans was relatively low (negative $\delta^{13}C$ anomaly). After this period the planktic biota recovered with the evolution and proliferation of surviving (*Guembelitria*) and new so-called opportunist species (*G. eugubina*). These pioneering biota were quickly replaced (< 50kyrs) by more stable, equilibrium species (*Globigerina,* Morozovellids). The vertebrate record displays a similar recovery "event", at least in North America. An ancestral stock of placental mammals (*Protungulatum*) reacts on the disappearance of their competitors and predators (a.o. the dinosaurs) with an amazing proliferation in numbers [16] (the Bug Creek Anthills event): The first fluvial channel above the K/T boundary holds millions of teeth of this ancestral species of many modern mammal species. In the succeeding channels, its successor species are apparently more equilibrated, because they show normal abundances.

The K/T boundary event is thus foremost characterized by a mass-mortality event at the deposition of the Chicxulub ejecta layer, leading to a low-productivity ocean, followed by an opportunistic rebound of new species in an empty ecospace.

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INVESTIGATION OF SPHERULES IN THE KABA CV3 CHONDRITE FALL AREA

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In every report of meteorite fall observations we can hear or read about detonations, crackinks, spreading of fragments, smoke etc., indicating that there are numerous small particles in the fall area.

Kaba is a little village in the Great Hungarian Plain, but since 15 april 1857 it is world famous for the chondrite, which fell nearby. The fall is well documented, and upon the chondrite fragments found in this site we decided at the beginning of the extraterrestrial spherule investigations in Hungary to launch the field study of the Kaba meteorite fall area.

As some topographic features changed in the past 140 years, first we had to compare the modern topographic maps with the old (1826-66 and 1861-68) ones in order to prepare the fieldwork plan.

The suggested meteorite fall area covers approximatelly 40 km^2. The rate of soil accumulation is around 10 cm/hundred years, therefore, considering the migration of microparticles, we tried to collect the samples from 10-15 cm deepth. For the reconstruction of the possible dispersion area, the samples were collected first from 4 different zones: along the profile of suggested fall direction; near the site where the great meteorite fragments were found; around the village bordering the fall area; and near the banks of the stream as a material accumulation zone. 52 soil samples were collected weighing 1-1,5 kg each.

After washing, cleaning, sluicing, sorting and separating we have identified more than 400 spherules and micro-particles so far. The material is very rich in spherules, their size ranges between 20-500 µm (mainly 100-150 µm).

They include black, shiny magnetospherules (30%), dark-grey, dark-brown siderospherules, light-brown, yellow, water-clean glassy spherules, some viscous drops, one green dumb-bell-like microtektit (?), some industrial scoriceaous spherules and some wonderful, redish-brown spherules in the matrix (partly metamorphosed chondritic fragments). Upon the distribution of different particles in different samples the meteorite fall area can be reconstructed (see the map), and further field-work can be planned. We hope that further investigations will give an impetus to meteorite fall reconstruction studies.

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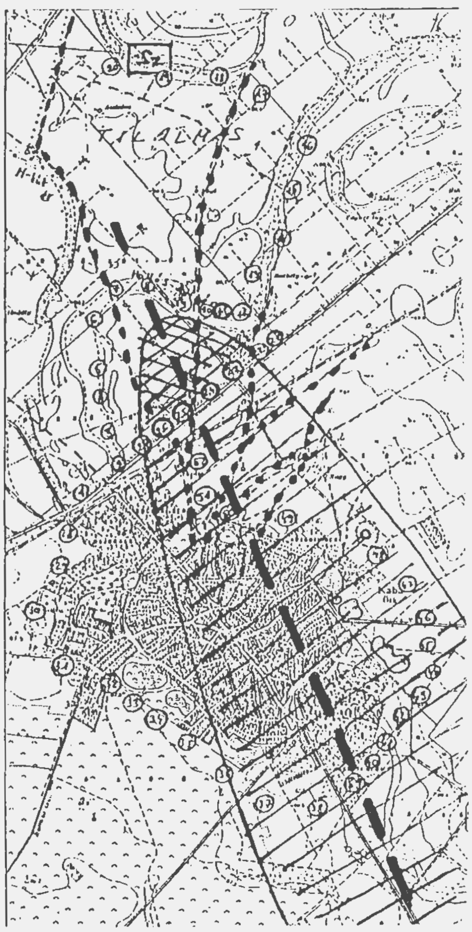

Legend

— place of great fragments

— old tracks in 1857

1.-52. — samples

— fall direction vector 170°-350°

— possible strewn field

Map of the Kaba meteorite fall area

CONCEPTS, GOALS, AND ACHIEVEMENTS OF THE 1993 - 1995 ESF SCIENTIFIC NETWORK "IMPACT CRATERING AND EVOLUTION OF PLANET EARTH"

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Concepts and goals

Since about 1990 a group of European researchers of impact craters and shock metamorphism recognized the urgent need for a coordinated multidisciplinary effort on a European level in order to improve the knowledge, understanding, and recognition of impacts as a fundamental geological process on Earth. The proposed concept for a ESF Network has been stimulated by one the most innovative impacts of solar system exploration on the paradigms of "terrestrial" geoscience: The recognition and understanding of the decisive role of interplanetary collisions for the origin and evolution of terrestrial planetary bodies, in particular for the evolution of the Earth's crust, lithosphere, atmosphere, climate, and for the origin and evolution of life.

In a paradigmatic sense, the Network has been calling for a reassessment of the role of catastrophic events in geoscience - an important aspect widely neglected by the conventional geoscience community. The initiators of the Network felt that progress in this innovative field of geo- and planetary science requires an interdisciplinary and coordinated approach with input from very different and seemingly quite unrelated disciplines. It appeared undoubtful that successful developments in this field would have an important feed-back to classical research and education in geosciences.

Achievements

The evaluation of the achievements of this Network should be made on the basis of the situation prior to the start of the Network, which can be characterized by (1) a general lack of recognition of the fundamental importance of the Network's research topic, (2) the absence of coordinated and focussed research cooperations in and between western and eastern European countries and between impact researchers and scientists from important neighbouring fields, such as material science, planetary astronomy, and paleontology, and (3) difficulties for small research groups and individual researchers all over Europe to get access to modern research equipment and to plan for long-term studies.

Through the activities of the current Network, this unsatisfactory situation has significantly changed, and the following achievements can be listed:

- Development of a highly interactive scientific research community in Europe with strong links to leading experts from USA, Canada, and Russia; Integration of scientists from eastern European countries, and of scientists from economically non-favored countries in Europe into this community
- Completion of four highly successful Workshops in 1993, 1994, and 1995
- Establishment of a communication system for the Network and for the outside community by publication of a NEWSLETTER and establishment an ERASMUS teaching programme

- Support of six small research projects promoting the exchange of young scientists between various countries
- Support of the conservation of drill cores and establishment of a comprehensive data base of drill core, geophysical and other data, in the countries of the former Soviet Union
- Production of a directory of European impact researchers

Future needs

Because of the great potential of this field to rejuvenate some basic paradigms in the geosciences and to reorganize the respective university education, it needs to be institutionalized and developed in Europe on a broad base. However, this requires a continued and enhanced coordinated European support that is beyond the limited possibilities of national funding agencies. The research community involved with the current Network would form an excellent nucleus for a broad European research programme in this field.

IUGS CLASSIFICATION AND NOMENCLATURE OF IMPACT METAMORPHIC ROCKS: TOWARDS A FINAL PROPOSAL

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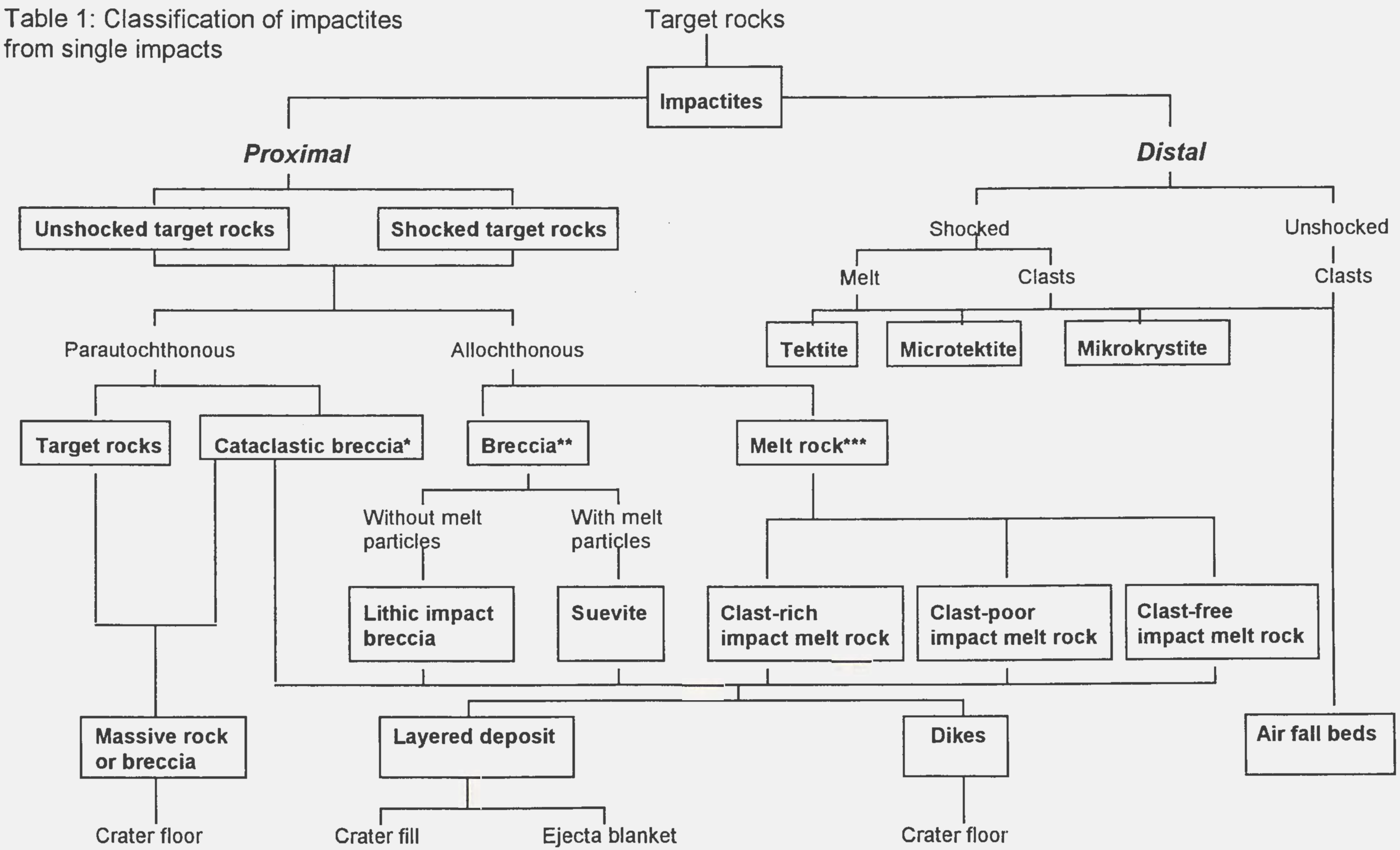
The Subcommission on the Systematics of Metamorphic Rocks (SSMR) of the IUGS has asked a Study Group on "Impactites" to work out a proposal for the classification and nomenclature of impactites. After having evaluated proposals by the members of the Study Group and by scientists working with impactites, we are presenting a final proposal for the classification and nomenclature of such rocks as a basis for approval by the SSMR.

The term "impactite" is defined as a collective term for all rocks being affected by (an) impact(s) resulting from collision(s) of planetary bodies. A classification scheme is proposed for products of single and multiple impacts (Table 1). It is applicable to terrestrial and extraterrestrial rocks. The basic classification criteria are based on texture, degree of shock metamorphism, and lithological components. Additional criteria for a subclassification of the main types of impactites relate to the mode of occurrence with respect to the parent impact crater and to the geological or structural setting of the impactites (Table 1).

Impactites from a single impact are classified into 3 major groups irrespective of their geological setting which is not known for most extraterrestrial rocks such as meteorites and lunar rocks: Shocked rocks are defined as non-brecciated rocks which show unequivocal effects of shock exclusive of whole rock melting. Impact melt rocks are subdivided into three subroups according to the content of clasts. These subtypes may be subclassified into glassy, hypocrystalline, and holocrystalline varieties. The first two subtypes include "impact glass" as well as "tektites" (Table 1). Impact breccias fall into three subgroups according to the degree of mixing of various target lithologies and their content of melt particles. Lithic breccias and suevites are generally polymict breccias except for single lithology targets.

Impactites from multiple impacts as known from the Moon and from the meteorite parent bodies are subdivided into two main groups: 1. Impact regolith (unconsolidated impactoclastic debris) and 2. Shock lithified impact regolith (consolidated impactoclastic debris). The latter is subclassified into 2.1 Regolith breccias (with matrix melt and melt particles) and 2.2 Lithic breccias (without matrix melt and melt particles). The term lithic breccia is synonymous to "fragmental breccia" which has been used for lunar rocks and meteorites.

Table 1: Classification of impactites from single impacts



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THE EROSION OF THE ATMOSPHERE CAUSED BY THE IMPACTS: NUMERICAL SIMULATIONS

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It is well known that the atmospheric gas escapes from the planet after an impact of a sufficiently large body [1-3]. This process might play a significant role in the Earth evolution. Interaction of the impactor with the atmosphere goes primarily with fast-moving ejecta. Small impactors do not cause atmospheric erosion, enriching the volatile content of the Earth. Huge impactors may, in principle, push away all the atmospheric gas that is present above a plane tangent to the impact point [4] that is about 0.05 percent of the atmosphere.

Estimates show that all the vaporized mass is decelerated in the present-day atmosphere for impactors smaller than 2 km in diameter. For 0.5 - 2 km bolides, a very small amount of the gas can escape from the planet due to upward acceleration of the shock wave in the exponential atmosphere [5]. Impactors larger than 75 km in diameter are insensitive to the presence of the atmosphere. All the atmospheric gas which is intercepted by the rebounded material is blown off. The amount of this gas depends on a solid angle which encloses the ejecta. This angle depends, in turn, on the material, shape, and velocity of impactors. The size of sufficiently large bodies do not play a significant role. Ejecta of very porous huge impactors (of 0.01g/cm^3 density) moves upward in a wide angle [6] that could result in escape of about 0.02 percent of the atmosphere.

Impactors of intermediate size (2-75 km) are more effective in heating and erosion of the atmosphere [2]. The mathematical solution [5] for a massless explosion is inapplicable in this case. The effect of impact-induced escape has been modeled in [1, 7-9] for silicate impactors of moderate velocity and, recently, in [10] for a potential K-T impactor. To refine the quantitative investigations, I have carried out numerical simulations of vertical cometary impacts. Cylindrically chaped impactors, 2-20 km in diameter, with velocity of 50 km/s and equation of state of water were taken for computations. A hydrocode based on a free-Lagrangian method [11] was employed. The simulations include the fall of the bolide in the atmosphere, formation of the wake, an impact on the silicate surface, and interaction of the ejected material with the atmospheric gas.

The main result is that cometary impactors are not more effective than the stony ones. The ejecta spreads approximately inside a cone with an angle less than about 60 degrees between the axis of symmetry and the cone generatrix. An impactor commensurate with the K-T event could push away only about 0.01 percent of the modern atmosphere. A major fraction of the vapor cloud of high-velocity impactors escapes in contrast with impactors of moderate velocity considered in [10]. Despite the inefficiency in direct atmospheric erosion, the atmospheric response to K-T sized events can cause tremendous biological and climatic consequences. The main mechanisms are radiation impulse, re-entry of ejecta and vaporization of the ocean.

Impact induced erosion might be significant in the Earth evolution if the number of the impactors was very large (tens of thousand, at the accretion stage) or in the case of some unusual but very effective events: multiple impacts, grazing impacts, collision of planetesimals at the surface.

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THE UPPER CRETACEOUS-PALEOGENE CARBONATE SEDIMENTS IN WELL ISTRA MORE-5, (NORTHERN ADRIATIC, CROATIA)

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The wildcat well Istra More-5 is located in the Northern Adriatic, northwest of Pula - the Belluno Basin's southeast part (CATI et. al., 1987). Lower Eocene and Paleocene deep-sea sediments have been bored in the interval 1725-1770m. Drilling was stopped at depth of 1880m in the Upper Cretaceous deep-sea sediments.

Upper Cretaceous (Maastrichtian):

Maastrichtian sediments are composed of gray limestones (pelagic micrites) with thin intercalations of bioclastic limestone.

Pelagic micrites are characterized by high portion of compact carbonate mud - micrite, in which variable amount of fine fossiliferous detritus (fragments of rudists, echinoderms, etc.) and few fragments of large benthic foraminifers occurred, together with numerous planktonic forams (*Contusotruncana contusa, Globotruncanita pettersi, G. stuarti*).

Bioclastic limestones are somewhat darker in color than micrites mentioned above, with thickness varying from few millimeters to several centimeters. Most often consisting of clasts 0.18-0.24mm in diameter, limestones could be classified as fine-grained calcarenite. Among particles, subangular bioclasts from reef predominate (mostly fragments of rudists, benthic forams, echinoderms, coralline algae, etc.).

Considering structural and lithological rock characteristics, deposition of sediments took place in region distal to source of the material, lower slope - basin.

Paleocene - Lower Eocene:

Sedimentation of Paleocene - Lower Eocene marly limestones with laminae and intercalations of bioclastic limestones uninterruptedly continued on pelagic Maastrichtian micrites.

Marly limestones are greenish-brown, intersected with thin submillimeters to millimeters laminae of dark grayish-green clay and/or slightly wavy stylolites. These limestones sporadically contain light brown rounded clasts (1mm-1cm in size) of older Cretaceous limestones, brown chert nodules and ellipsoidal or elongate bioturbations. Bioturbations are filled with coarse-grained carbonate detritus and slightly brighter than surrounding sediment. In places very fine lamination is observed. The main particularity of limestones is micrite with numerous small planktonic foraminifers (*Parasubbotina pseudobulloides, Praemurica trinidadensis, Planorotalites pseudomenardii, Morozovella gr. subbotinae*), together with minor quantity of fine detritus from nearby platform. Besides Paleogene taxa, resedimented Maastrichtian fossils are found as well (*Contusotruncana contusa, Globotruncanita stuarti, Globotruncana arca*).

SEM analyses show that laminae of clay are illite-chlorite association which includes accumulations (0.1mm in size) of cryptocrystalline dolomite, calcite, neutral plagioclase, flaky chlorite, muscovite and sporadically nannoplanktons.

Bioclastic limestones are similar to previously described bioclastic limestones (Maastrichtian). They differ only by composition of microfossil assemblages. In detrital matrix resedimented nummulites, fragments codiaceans, bryozoans, echinoids and other organisms that lived at the carbonate platform margin are found.

Allochthonous bioclastic limestones were formed by activity of turbidite flows of low viscosity which had shifted accumulated material from the edge of the platform or upper part of the slope into the basin. Detritus impact often eroded autochthonous micrite mud which had been sedimented on the slope, breaking off mud pieces, and as a stirred up sediment-laden suspension transported them further down the slope under the influence of gravity.

Predominance of the autochthonous lutitic grain size pelagic detritus, well sorted material and small amount of fine terrigenous admixture in marly limestone composition, pointed out a relatively long transportation and deposition distally from a shore in lower slope area or in basin.

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COMPUTER SIMULATION OF THE POPIGAI IMPACT EVENT (COMPRESSION AND INITIAL EXCAVATION STAGES) AND SOME CONSEQUENCES ON GLOBAL DISPERSION OF PROJECTILE AND TEKTITE GLASSES.

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1. The unique 100-km Popigai impact crater of ~35 Ma-age in the Northern Siberia is the most perspective candidate for global Eocene/Oligocene extinction as well as possible source of Ir anomaly, shocked quartz, and glass and spinel microspherules documented in boundary layers of Massignano (Italy), ODB Site 689B (Antarctic) and other places. So, it was of a definite interest to make a numerical simulation of the event in order to estimate its possible contribution to some impact features found in the boundary layers.

2. The numerical simulation of the Popigai event was made on the basis of "Stereo-PC" Software System by Dr. B.P. Krukov et al. This System can provide a calculation of high-energy impact and explosive processes with a complex interaction between shock and rarefaction waves at varying geometry of the flow. "Individual particles method" by [1] was used. The task was carried out in two-dimentional axis-symmetrical hydrodynamic approach; a gravity and a strength of the impacting bodies were not taken into account. A laboratory-scale model of the event was obtained by means of special non-dimensional coefficients and similarity criteria important for impact cratering [2], and calculated using p-theorem of similarity by [3]. Experimental field in our model (80 mm on Z-axis x 50 mm on R-axis; 1 mm of the field is equal to 1 km of natural event) has the spatial resolution of 2 cells per 1 mm. The following parameters of the Popigai event were taken into account: (i) two-stage target, represented by Archean gneiss basement (density~2.9 g/cm^3), and sedimentary cover (including Mesozoic rocks with density down to 2 g/cm^3); (ii) energy of the event, $E = 6.24*10^{22}$ J; (iii) mass of projectile, $m = 2.06*10^{11}$ t. Tillotsons' EOS were used for materials of the bodies in our experiment, where the projectile, sedimentary cover and gneiss basement were represented by gabbroid anorthosite, halite and granite, respectively.

3. Numerical simulation of compression and initial excavation stages for Popigai impact event, carried out in our laboratory model, show that 2 factors seem to be important for this part of the cratering: (i) an intensive vaporization of projectile and adjacent target rocks; and (ii) a cumulative effect, with vertical jet of vaporized projectile matter (vapor density 0.0009 to 0.4 g/cm^3) at the velocities up to 14.59 km/s.

4. Up to $0.3*10^9$ t of vaporized material of projectile was ejected at the velocities >11.2 km/s, enough to escape the Earth. Up to $1.7*10^{10}$ t of the same matter was ejected at the velocities 2 to 11.2 km/s, enough to leave the crater along the ballistic trajectories with distal dispersion of meteoritic material, giving rise to Ir anomaly in boundary layer (and to spinel microspherules also ?). The rest of the projectile excavating at the velocities 0.1 to 2 km/s was deposited mainly in upper horizons of crater-fill impact formation, and in proximal ejecta blanket. Later these horizons were eroded.

5. Vaporized material (r of 0.03 to 1.2 g/cm^3) of sedimentary cover was ejected at the velocities up to 5.4 km/s, being partially able to long-distance flight and global dissemination. Condensed products of this vapor (microglobules of the highly-quenched glass) were then deposited in boundary layer. The amount of the material ejected at the velocities >2 km/s is estimated to be ~$1.5*10^{12}$ t. The most accelerated ejecta were derived, in first turn, from cape Mesozoic loose sandy-clay members, giving rise to tektite-like glasses.

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LATE EOCENE IMPACT EJECTA AT DSDP SITE 689B (MAUD RISE ANTARCTICA): STRETCHING UP THE STREWN FIELDS OF THE LATE EOCENE IMPACTS

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The discovery of well preserved microtektites and microkrystites of Late Eocene age at DSDP site 689b may drastically expand the suggested strewn fields for the North American microtektites and Pacific microkrystites. The DSDP 689b microtektites and microkrystites have chemical compositions very much alike those described for the North American and Pacific strewn fields, and coincide with an Ir anomaly. Occurrences of microtektites and microkrystites overlap in the core in a 20 cm interval. Due to the small amount of spherules per gram sediment, we could not determine statistically if the microtektites and microkrystites are from slightly different stratigrapic levels, as is the case for the North American and Pacific strewn fields.

Isotope analyses of the tektites are underway, and may confirm the correlation with the source of the North American tektites, or alternatively, suggest the existence of a third Late Eocene impact crater.

Oxygen and carbon isotopic data of the coccolith ooze across the impact layer in core 689b shows a cooling event associated with the impact. No extinctions are reported, on the contrary, a carbon isotopic shift at the impact layer may point to an increase in productivity of the surface dwellers. This productivity increase could be explained by increased nutrient availability in the surface water due to the enhanced vertical mixing of the water column at the cooling event. The cooling itself is possibly caused by the ejected dust cloud of the impact, shielding the light of the sun.

GORSKI KOTAR - ASTROBLEMA - MULTIRING BASIN - K/T BOUNDARY?

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Geological investigations of the Gorski Kotar indicate on the most complicated structure within the Dinarides, being one of still unsolved problems. However, by comparison of numerous geological researches with the Landsat-1 scannogram (February 6, 1973), a circular geomorphological structure of a possible astroblema was discovered. Its diameter is approximately 20 km, with probable extension into the multiring basin, c. 50 km in diameter, with the center in the western part of the Lokve accumulation lake. The problem of the neotectonic disintegration of the crater is explained by emersion of the Dinaric strike, and erosion into the High Karst Zone above 700 m a.s.l. Possible predisposition of the asteroid impacts and deep lithosphere fractures is related to differential vertical movements of tectonic blocks from the Upper Carboniferous to the Cretaceous. In this context the intrusion of the cold eruptive body (andesite near Fužinski Benkovac in the Gorski Kotar) and resistance of the crater structure to the horizontal tectonic movements from the NE against the subduction of the Rijeka-Vinodolski Zone have been explained. A distinct anomaly of underground water movements in relation to the superficial water divide is connected to the extensive "fossil" sinkholes in the Lokve valley, Golubinjak and Lič poljes, formed by a collapse of the crater edge and discharge of the crater lake. Influence of very common thick-bedded rocks, which are favourable to plastical or elastical deformation, on the morphology of the shatter cone and smaller multiring basins has been analysed. Namely, the crater from the Gorski Kotar area is morphologically completely different from the shatter cones of a similar size in Steinheim (Germany) and Köfels (Tirol, Austria).

Lack of high-pressure phase impactites is explained by the complete destruction of the crater in the Gorski Kotar, from 350 to 600 m below its base. This would also explain rather infrequent findings of low-pressure impactites, like shatter cones, their fragments and conjugate fractures. They could be compared with the similar group from the astroblems of Ries, Ševetin, Karske, Janisjarvi and Sobolevski crater. Concerning the extreme erosion and transport along the main groundwater flows, impactites, especially those of the higher-pressure phase, could be find in deeper parts of the "fossil" sinkholes, in deeper sediments of the Rijeka bay and Vinodol channel, as well as in few km deep Karlovac depression. By the examination of the core of the structural well Crni Lug-1 it has been determined that it represents a typical profile of the astroblema, with the Palaeozoic beds in the central part of the ancient crater. Sporadic steeply-inclined beds have been found there, as a relic of the "base" of the eroded central uplift, approximately 3 km in diameter. Distribution of the stratigraphic units indicate on the impact of the asteroid in the shallow sea on the Cretaceous/Tertiary boundary; therefore, pulverised material of the Gorski Kotar catastrophe should be found in these beds. Reconstruction of the submarine impact and morphology of the crater require analysis of formation of the hollow central uplift created by subsequent explosion of gases and steams, as well as the intrusion of the sea-water into the crater filled with melted rocks. These post-impact processes had significant influence on the complete destruction of the Gorski Kotar crater structure.

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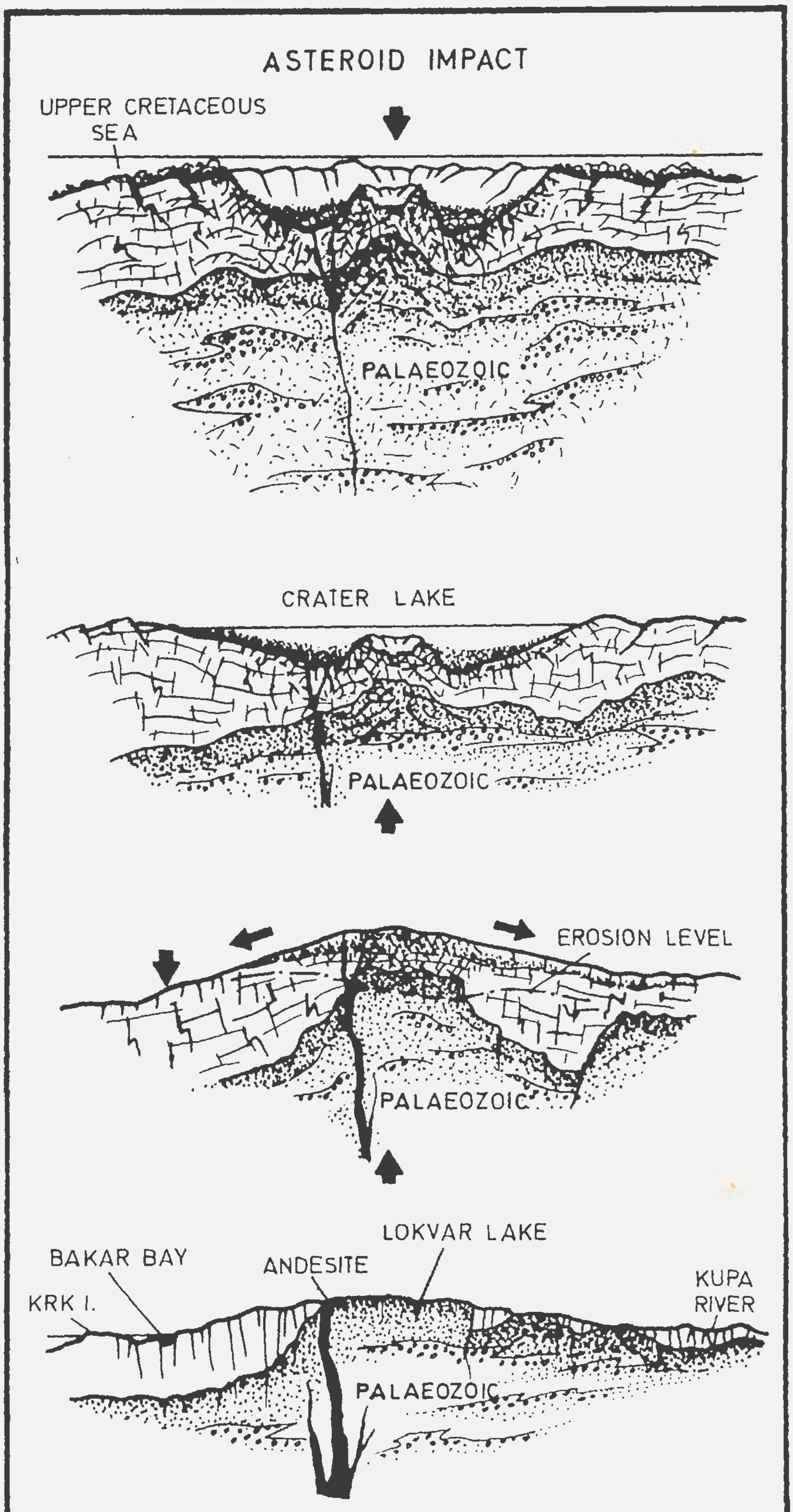
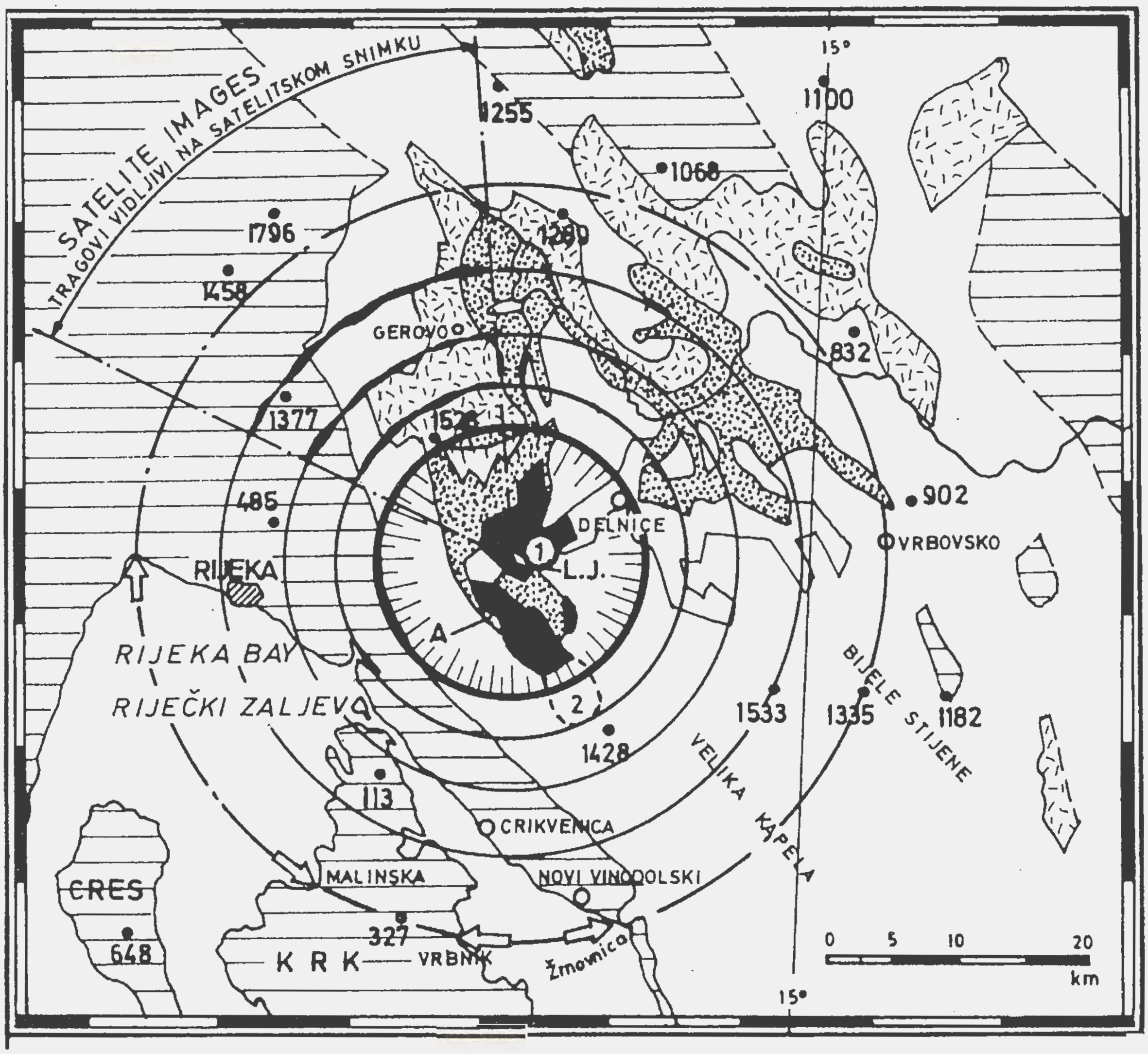


POST-IMPACT EVOLUTION OF THE CRATER AND MULTIRING BASIN GORSKI KOTAR



PALAEOZOIC ROCKS — BOUNDARY OF THE CRATER D=20 KM

L.J. – LOKVE LAKE — (1) – LOKVE, GOLUBINJAK AND LIČ POLJE (2)

A – ANDESITE — EXTENSIVE "FOSSIL" SINKHOLES

SITUATION MAP OF GORSKI KOTAR ASTROBLEME, MULTIRING BASIN – K/T BOUNDARY ?

HOLLOW CENTRAL UPLIFT OF THE CRATER - SUBMARINE IMPACT INDICATOR?

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The question of the existence of a hollow central uplift of the complex crater in the case of a submarine impact has been considered during the reconstruction of the crater structure of the Gorski Kotar in Croatia.

Hypothetical model of the hollow central uplift is based on dynamics of the expanding tsunami waves, followed by drowning of newly formed impact crater under the sea and explosion of gases and steams.

When the sea-water, expulsed by the explosion, intrude again in the newly formed crater filled with melted rocks, mutual reaction connected with sudden temperature change culminates by release of gases and steams. This leads to the second explosion of amazing proportion. In the mutual connection of tsunami and blast explosive geyser literally wrench out apical part of the central uplift, thus forming the central hollow. The central uplift of the crater, composed of the most fractured rocks, has been exposed, during the post-impact phase of the basin, to the shallowing, emersion and numerous geotectonic processes and climate changes, resulting in deep erosion and complete destruction. Among approximately 150 mostly eroded impact structures on the Earth (i.e. astroblems), only few have a ratio between the diameter of the inner and outer ring within a range of 1:4 to 1:6. Typical example of the proposed model is Sierra da Cangalha, 3/12 km in diameter, formed approximately 220 MY ago. Since the crater is located in the inner part of spacious Central Brazilian basin, it has been gradually covered by sediments, and thus protected from the erosion. Subsequently the basin was uplifted to c. 300 m a.s.l., and surrounding sediments were washed out by rains and river flows. Once covered, the crater was again unroofed, preserved until the present. In the same basin there is another, nearly located impact structure - Araguainha Dome, around 250 MY old. Such impact structures with similar morphological anomaly have never been found on the surface of the Moon, or any other terrestrial bodies in the Sun system. Therefore, it may be concluded that their origin is probably connected to the submarine impact.

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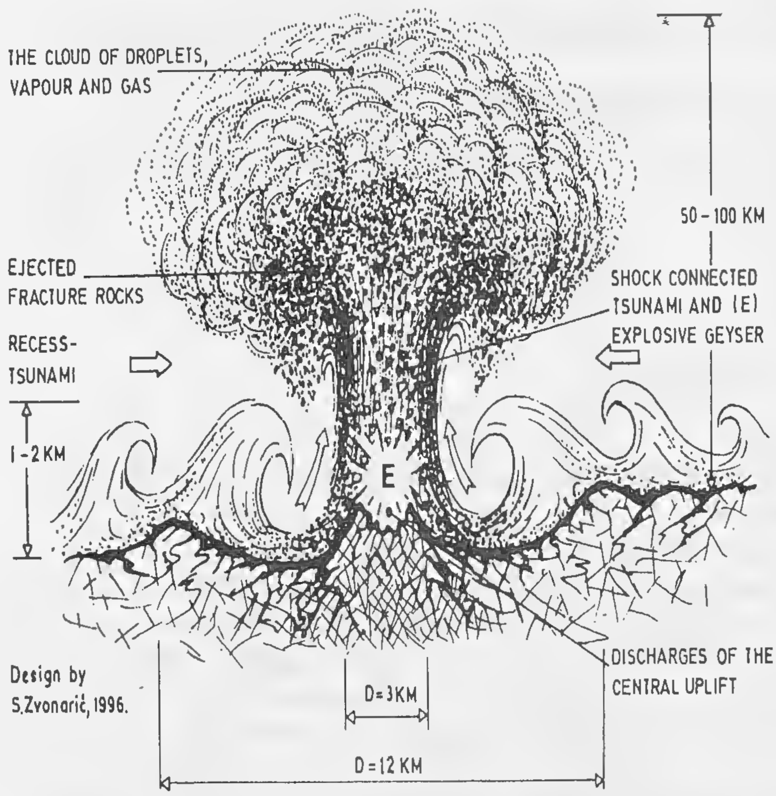
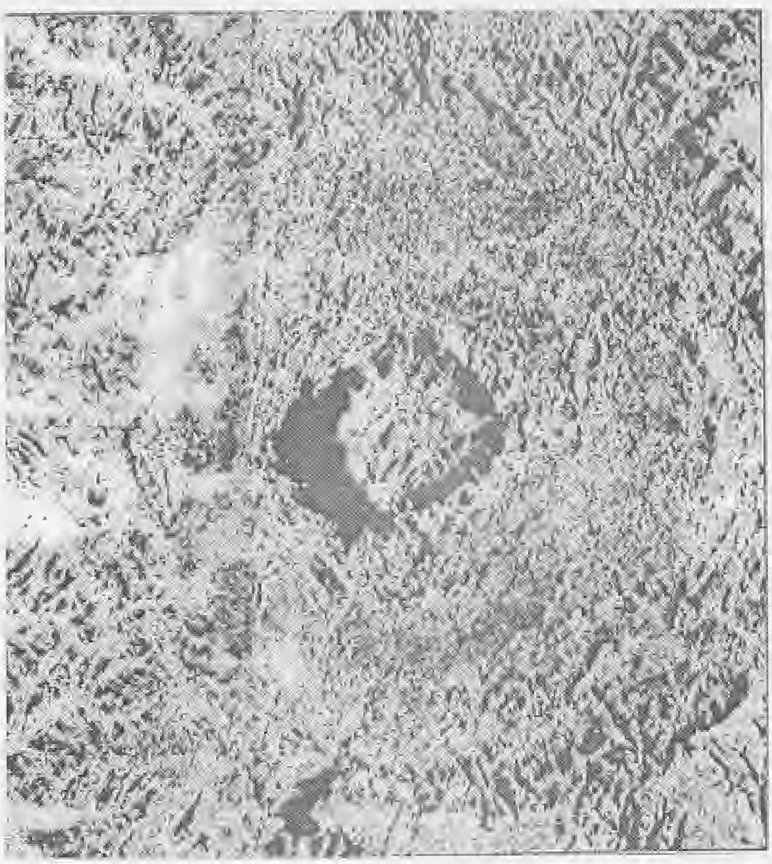


Hollow Cenral Uplift of the Crater-Submarine Impact Indicator?



SERRA DA CANGALHA

SHATTER CONE - KÖFELS (TIROL, AUSTRIA)

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The poster represents shatter cones, "bimsstein" (pumice-stone), phases of the formation of a simple impact cone and the area of the crater.

Köfels valley has been studied since 1863, when Picher discovered and described so-called bimsstein (German word for pumice-stone). Until 1930 all researchers considered pumice-stones as a product of volcanic activity. In 1936 Suess and Stutzer have independently connected these rocks with the impact of a giant meteorite. In the same context G. Kurat and W. Richter (1972) designated "bimsstein" as impactite. A different approach to the interpretation of origin of the Köfels valley was given by L. Marsh, E. Preuss and H.R. Wenk (1985): since there was a lack of other impactite structures they compared it with the Langtang valley near Katmandu, Nepal, i.e. proposed a landslide origin. Attracted by the lack of other impactites during my visit to the Köfels valley in the summer of 1986 I have found in the center of the valley 29 cm high shatter cone in "augengneiss" rock, which was penetrated along the axis. Another, larger shatter cone, remained on the outcrop. These findings undoubtedly define the Köfels valley as an impact crater. Very rare findings of pumice-stone in impact craters, e.g. the Köfels case, could be explained by an impact in the middle of the winter. Namely, sudden melting of abundant snow caused numerous floods which filled fractures occupied by melted rocks, resulting in formation of the pumice. This interpretation would explain findings of pumice-rocks along deep trenches at the bottom of the ancient crater lake.

The problem of two different types of the impact crater morphology, i.e. existence of simple craters (e.g. the Köfels crater, 4 km in diameter) and complex craters (e.g., 3.5 km in diameter), is possible to solve by the analysis of the deformability of the rocks beneath the crater. Namely, rocks beneath the Köfels crater exhibit no significant plastical-elastical deformation, while in the case of the Steinheim crater the basement is composed of deformable rocks of Schwabische Alb - 950 m thick succession of clayey limestones, clays, marls, sandstones, etc. The latter example is similar to the origin of the complex multiring structure of the Gorski Kotar area in Croatia.

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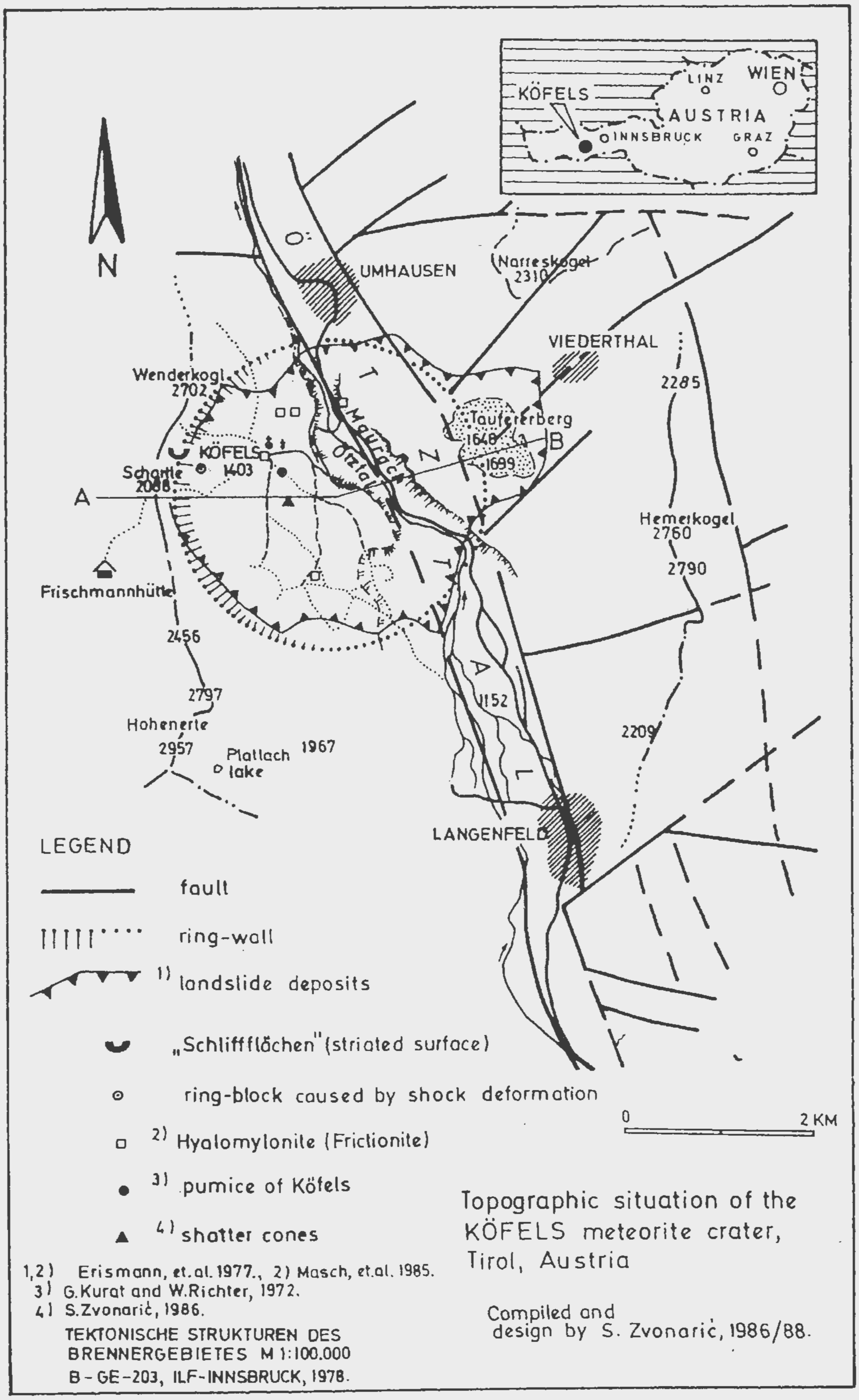
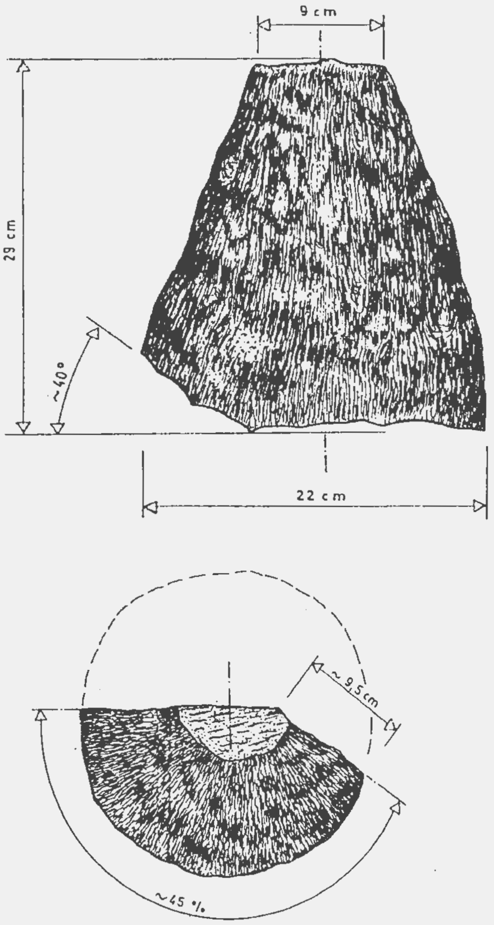
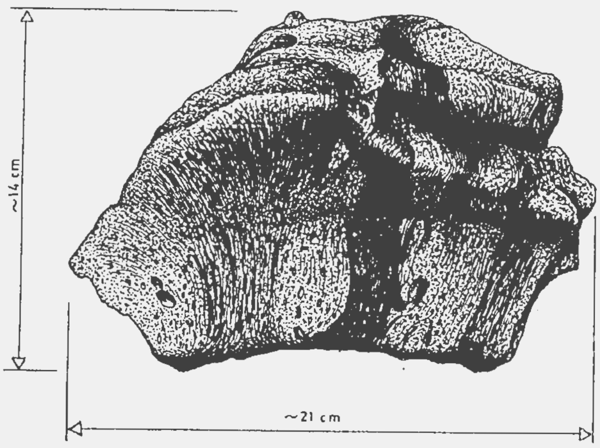


Topographic situation of the KÖFELS meteorite crater, Tirol, Austria





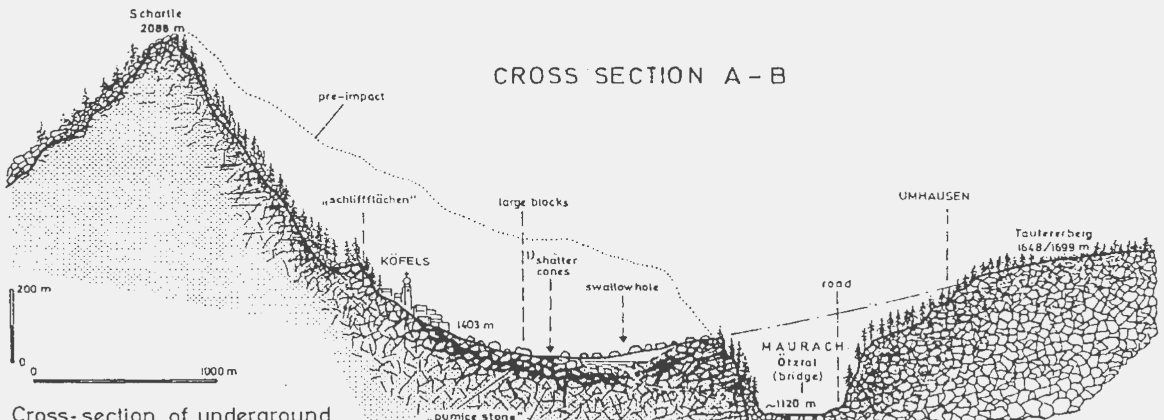
Surface view of a pumice

Pumices from the KÖFELS meteorite crater
(Found by S. Zvonarić, 1986.)

Design by S.Zvonarić, 1986.

Shatter cone from the KÖFELS meteorite crater
(First discovery of shatter cones: S.Zvonarić, 1986.)

Design by S.Zvonarić, 1986.



Cross-section of underground stucture of KÖFELS meteorite crater, Tirol, Austria

(1) First discovery of shatter cones- S.Zvonarić, 1986.)

Reconstruction and design by S.Zvonarić, 1986.

GEOLOGY OF WEST SLOVENIA

CONTENTS

GEOLOGY OF WESTERN SLOVENIA AND ITS PALEOGEOGRAPHIC EVOLUTION

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Introduction

Knowledge about geological setting of western Slovenia in time and space helps in solving important question of geological structure of the Dinarides and Southern Alps. In this territory, the Central and Eastern Alps come into direct contact with the Southern Alps that continue into the Apennines in one side and into the Dinarides on the other side. In structural and stratigraphic sense the Southern Alps represent a part of the Dinarides. The Southern Alps and the Dinaric Mountains are just two distinct geographical units which cannot be distinguished geologically. The Periadriatic Lineament represents the major tectonic line which separates the Austro-Alpine units in the north from the Southern Alps and the Dinarides in the south. The general vergence of the southern units is toward south and southwest (cf. Placer, this volume), whereas the Austro-Alpine units were overthrust northward. Early Paleozoic rocks in the Austro-Alpine units are metamorphic, but south from the Periadriatic Lineament they remained unmetamorphosed. Coeval strata on both sides of the lineament show different stratigraphic evolution.

Structural units of the Central and the Eastern Alps belong to the Eurasian Tectonic Plate, whereas the Dinarides and the Southern Alps are a part of the African Plate or the Adriatic Plate respectively. The Periadriatic Lineament represents the position of the former subduction zone along which the African Plate subducted under the Eurasian Plate.

Different paleogeographic evolution which is reflected in the lithology and tectonic structures of Slovenia is also the basis for subdivision of the Slovenian part of the Dinarides. From north to south they are devided into the Southern Alps, the Inner Dinarides and the Outer Dinarides. The Southern Alps comprise the southern Karavanke Mountains, Julian Alps and Kamnik-Savinja Alps. Their basement is composed of Carboniferous and Permian clastics of a flysch-molasse facies. The Southern Alps are characterized mainly by shallow-marine limestones and dolomites, which accumulated on the Slovenian and Julian Carbonate Platforms. The Inner Dinarides mostly consist of Mesozoic deep-marine rocks of the Slovenian Basin, and they crop out in a narrow belt in central Slovenia (Fig. 1). The Outer Dinarides comprise Matajur, Mija, Banjšice, Trnovski gozd, the Trieste-Komen Plateau, Hrušica, Nanos, the Logatec Plateau, Krim, Mokrc, Mala gora, Velika gora, Suha krajina and Kočevsko. They correspond to the ancient Slovenian and Dinaric Carbonate Platforms.

The Julian Carbonate Platform continued westward in Italy in the Trento Platform, whereas the Dinaric Platform in the Friuli Platform. During recent research we found that the intermediate Slovenian Basin pinched out in the area of the present Soča Valley (Buser & Debeljak, 1996), and that presumably it had no connection with the Belluno Basin of northern Italy, as thought before (Aubouin, 1963; Cousin, 1970, 1973). The Slovenian Basin continued eastward to the neighbouring Croatia north of Zagrebačka gora, and farther east to Hungary. We no longer presume that this basin continued to the southeast into the Bosnian Basin, as it was considered before (Buser, 1989; Haas et al., 1995).

International workshop POSTOJNA '96: *THE ROLE of IMPACT PROCESSES in the GEOLOGICAL and BIOLOGICAL EVOLUTION of PLANET EARTH*, Eds K. Drobne, Š. Goričan, B. Kotnik, Ljubljana 1996.

Since the purpose of this paper is to recapitulate geologic events in the Mesozoic and at the beginning of the Tertiary, the emphasis is given to the description of conditions that led on the territory of Slovenia to the formation of stable carbonate platforms with the intermediate central Slovenian Basin. Paleogeographic and sedimentary evolution are described through the important chronological periods. Schematic reconstruction of the paleogeographic evolution is shown in Figure 2. The emphasis is also on the stratigraphic correlation between distinct paleogeographic units in Slovenia and neighbouring northern Italy. This paper is primarily designed to the participants of this international workshop. In order to familiarize geologists from abroad with the Slovenian geologic literature, I deliberately included as much literature data as possible.

Forming of the Slovenian Carbonate Platform

After the deposition of the terrestrial Gröden (Val Gardena) Formation, caused by Saalic orogenic phase, a widespread transgression took place on the territory of the present Dinarides. Consequently, large areas were covered by shallow sea and the formation of the very extensive Slovenian Carbonate Platform began in this area (Buser, 1989). In the southern Karavanke Mountains only dolomites and cargneule of the Karavanke Formation are developed in the Upper Permian (Buser, 1974; Buser et al., 1986). Upper Permian limestones with brachiopods, bivalves and corals (Žažar Formation) are present in the central part of western Slovenia (Ramovš, 1958; Grad & Ferjančič, 1976). In the Early Triassic also terrigenous material was transported to the carbonate platform; sandstones, siltstones and marls are interbedded in limestones. Terrigenous input was more intensive in the southern Karavanke and in the western part of central Slovenia, in wider surroundings of Idrija (Buser, 1979). Typical of the Lower Triassic Werfen Formation are oolitic limestones that form several tens of meters thick intercalations between marl and siltstones.

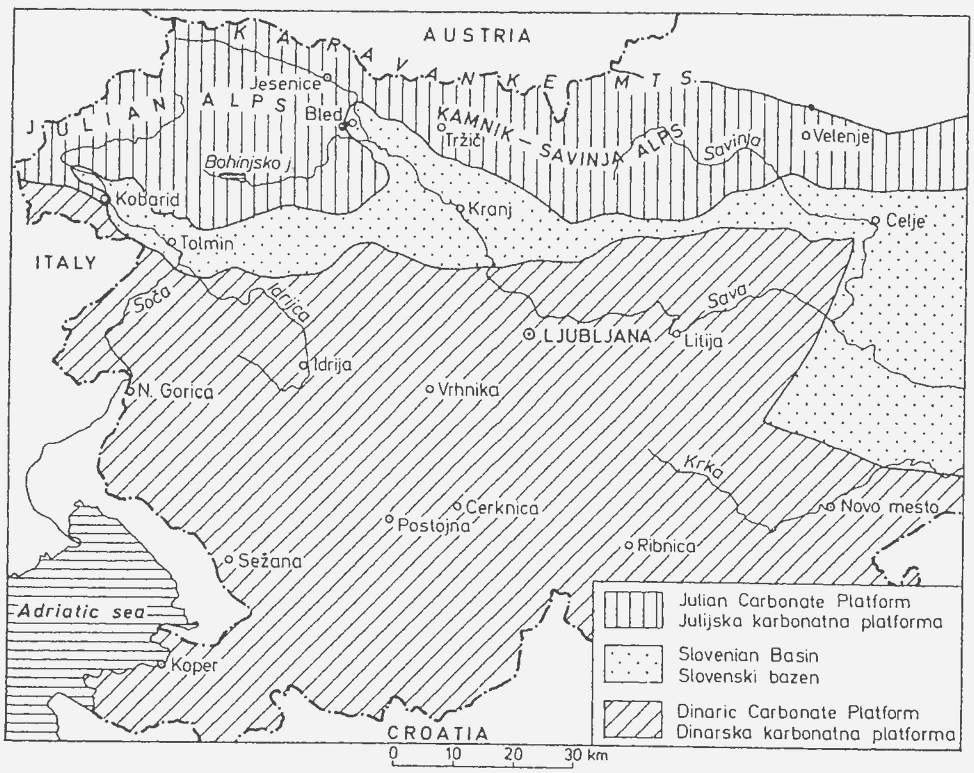


Fig. 1: Present extension of the ancient Julian and Dinaric Carbonate Platforms and the intermediate Slovenian Basin (Buser & Debeljak, 1996)

The Slovenian Carbonate Platform was reestablished in the Early Anisian. Several hundred meters thick limestones were deposited on it, and later mostly altered to dolomite. Primary limestones with the characteristic association of calcareous algae are preserved only at rare places in the Julian Alps and southern Karavanke. In the Late Anisian wide open troughs were formed along faults in the carbonate platform. Reddish, nodular marly limestone of the Han Bulog type with ammonites was deposited in these troughs (Kühn & Ramovš,1965). In places, the limestone contains also conodonts (Kolar-Jurkovšek, 1983) and radolarians (Goričan & Buser, 1990). In close relation to the limestones of the Han Bulog type there are also tuffs (pietra verde) which indicate the beginning of the oldest Middle Triassic volcanism in Slovenia.

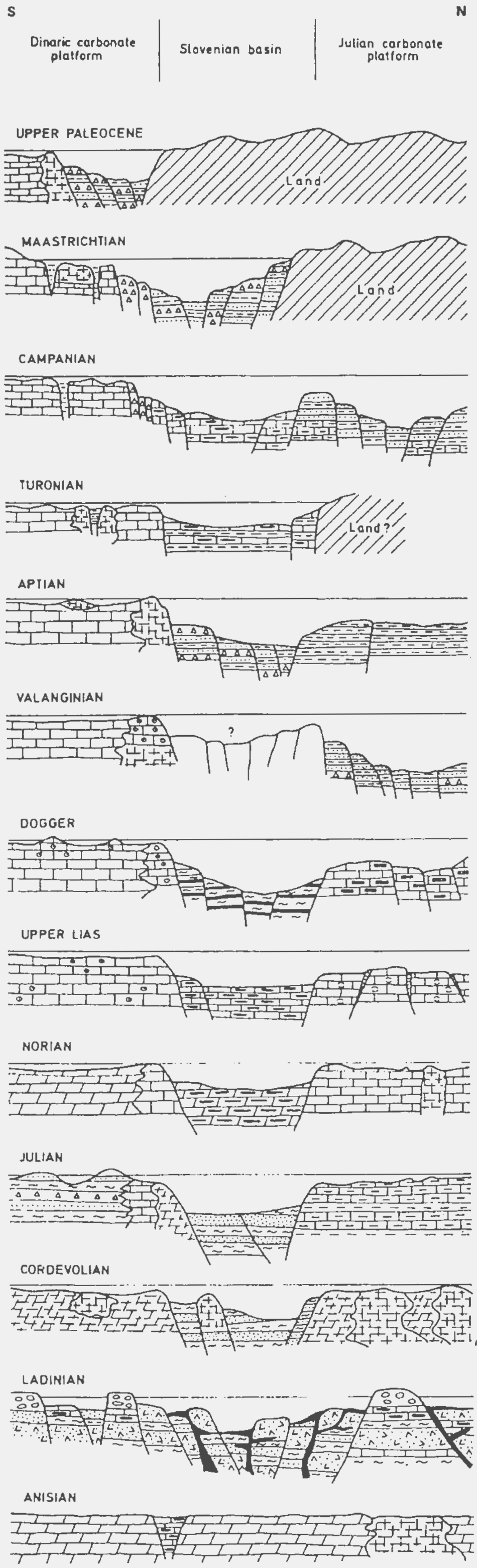
Disintegration of the Slovenian Carbonate Platform

In the Ladinian a vigorous tectonic activity took place on the territory of present Slovenia. Due to the Idrian tectonic phase the Slovenian Carbonate Platform was broken along regional faults of east-west and north-south directions and segmented into blocks. Some of them subsided more or less deep below the sea level, while others were uplifted and became subaerially exposed (Fig. 2). Thus, a variety of different sedimentary environments was formed; lateral facies changes are great over short distances. Due to increased igneous activity, volcanic rocks of spilite-keratophyre composition and associated tuffs were formed through extensive extrusions of lava-flows and eruptions along deep faults. The most extensive outcrops of Ladinian volcanites are in central Slovenia, where the faults reached very deep in the earth crust or even to the mantle. The central part of Slovenia was the most subsided and shales, sandstones and tuffs were deposited; numerous extrusions of quartz keratophyre, porphyrite and diabase occur. The southern Karavanke and part of the Julian Alps are characterized by marls and conglomerate breccias of the Ugovizza type. In southern Slovenia thin-bedded limestones in alternation with tuffs prevail. These beds contain a rich bivalve (*Daonella*) fauna (Jurkovšek, 1984, 1985). The formation of the mercury ore-deposit in Idrija is also closely related to this very intensive tectonic and magmatic activity (Placer & Čar, 1977; Placer, 1982; Mlakar & Drovenik, 1972). Only in few places the sedimentation of shallow-water limestones took place.

Forming of the Julian and Dinaric Carbonate Platforms

In the Early Carnian, in Cordevolian, the activity of the Idrian tectonic phase entirely ceased. The block of central Slovenia remained a deep trough which represented the beginning of the Slovenian Basin. The territory of the southern Karavanke, Julian Alps and Kamnik-Savinja Alps was stabilized and the Julian Carbonate Platform was formed. Likewise, southern Slovenia evolved into a very stable carbonate platform which existed until the Eocene. In the Cordevolian massive limestone with diploporas was deposited on both carbonate platforms, which was later, especially on the Dinaric Carbonate Platform, mostly altered into the characteristic saccharoidal coarse-crystalline dolomite. In the Julian Alps, Cordevolian reef limestones are developed locally (Ramovš & Turnšek, 1984). To the Pokljuka region in the Julian Alps an intraplatform deep-marine trough extended from the Slovenian Basin. It is characterized by white limestones with chert and conodonts (Kolar-Jurkovšek, 1991). In the Slovenian Basin Amphiclina Beds were deposited during the entire Carnian. They consist of claystones in alternation with sandstones, whereas in the upper part limestones with conodonts occur (Flügel & Ramovš, 1970; Buser & Krivic, 1979). In their basal part reef limestones with corals and sponges are found south of Hudajužna (Buser et al., 1982; Senowbary-Daryan, 1981; Čar et al., 1981; Turnšek et al., 1982, 1984).

Because of the Slovenian tectonic phase in the Julian and Tuvalian (Buser, 1980), thin-bedded limestones and chert with bivalves, conodonts and radiolarians accumulated on the Julian



Carbonate Platform (Jurkovšek et al., 1984, 1987; Kolar-Jurkovšek, 1991; Jamnik & Ramovš, 1993). Limestones with chert and conodonts were formed in the intraplatform trough on the territory of present Pokljuka. The above mentioned intraplatfrom troughs were accompanied by coral reefs (Turnšek & Buser, 1989; Ramovš & Turnšek, 1991). Patches of *Halobia* lumachelles, containing conodonts, were found within the reef limestones (Kolar-Jurkovšek et al., 1983). At some places on the Julian Carbonate Platform, Dachstein Limestone and Main Dolomite (Buser, 1986), as well as limestone alternating with marl (Ogorelec et al., 1985) were formed in the Julian and Tuvalian.

The major part of the Dinaric Carbonate Platform became subaerially exposed in the Julian. Terrestrial variegated sandstones, claystones, breccias, and bauxites were formed. The northern part of the platform was flooded by a shallow sea, in which black limestones and marls with very abundant bivalve fauna were deposited (Jelen, 1990).

The Norian and Rhaetian were stable and quiet periods for both carbonate platforms. During this time, Dachstein Limestone was formed on the Julian Carbonate Platform. The several hundred meters thick succession is exposed at many places in the Julian Alps (Buser et al., 1982; Turnšek & Buser, 1991). The time-equivalent deposits on the Pokljuka Plateau consist of reddish Hallstatt limestone with conodonts (Kolar-Jurkovšek et al., 1983). On the Dinaric Carbonate Platform Main Dolomite was deposited during the Norian and Rhaetian (Ogorelec & Rothe, 1993). Dachstein Limestone was formed only at the northern margin

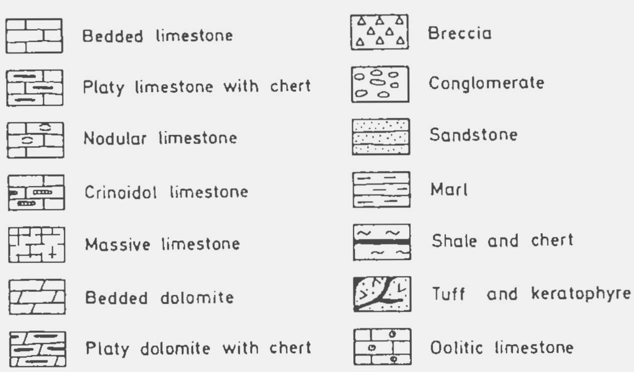


Fig. 2: Paleogeographic evolution (Buser, 1989)

of the platform. In the Slovenian Basin the Norian and Rhaetian are represented by bedded dolomite with chert (Bača Dolomite).

Both carbonate platforms subsided in the Early Liassic. Therefore, the supratidal influence was no longer present during sedimentation, and the limestones contain no stromatolitic layers that were characteristic of the Upper Norian and Rhaetian beds. An abrupt mass appearance of oolitic limestones is remarkable. On the Dinaric Carbonate Platform typical rock-building lithiotid bivalves appeared in the Middle Liassic. Their lumachelles are almost exclusively associated with dark, micritic, in places marly limestone and bituminous dolomite. The intermediate beds that do not contain bivalves mostly consist of oolitic and biosparitic limestone (Buser & Debeljak, 1996). Lithiotid bivalves are characteristic only of the Dinaric Carbonate Platform. On the Julian Carbonate Platform *Lithiotis* bivalves occur only in the surroundings of Bovec. It appears almost impossible that this shallow-marine fauna could migrate from the Dinaric Carbonate Platform to the northerly lying Julian Carbonate Platform across the deep sea of the Slovenian Basin. Presumably, the Slovenian Basin pinched out in the area of the present central part of the Soča Valley.

Consequently, there is an essential difference between the Julian Carbonate Platform in Slovenia and the Trento Carbonate Platform in Italy, where the main localities of Grey limestones ("Calcari grigi") with typical bivalves occur (Bosellini & Broglio Loriga, 1971). The same facies with the same fossil association was deposited in Slovenia only on the Dinaric Carbonate Platform.

The Julian High

The Julian Carbonate Platform was disintegrated along east-west and north-south trending faults into several blocks which were uplifted above the sea level. Liassic limestones were intensively karstified, at some places completely corroded to the Upper Triassic Dachstein Limestone. Deep open tension-joints were karstified and in some places widened into large vertical and horizontal cavities. In the Middle Jurassic (Bajocian), and at some places probably already in the Late Liassic (Toarcian), the Julian Carbonate Platform was suddenly drowned and the Julian High evolved on which pelagic deposition started. By a rapid subsidence the Middle Liassic oolitic limestones and Upper Triassic Dachstein Limestones were deeply submerged and the newly established deep-marine plateau, similar to the Trento High in the neighbouring Italy (Geyer, 1993), was covered by pelagic sediments. In the beginning, up to 300 metres deep karstified tectonic fissures and horizontal karstic channels (neptunian dikes) were filled with red and grey crinoidal limestones, which in the Kanin area contain numerous brachiopods. In the Krn Mountains 30 to 40 meters wide cracks were filled with limestone breccia composed of Upper Triassic limestone clasts in a red crinoidal to marly limestone matrix. In the surroundings of Bovec and in the Krn Mountains, the dikes and the lowermost part of overlying Jurassic pelagic sediments contain light grey micritic limestone with filaments that represent lumachelles of bivalve species *Bositra buchi* (formerly *Posidonia alpina*). According to the correlation with an equal horizon on the Trento High in Italy, this horizon is probably of Bajocian or Bathonian age (Geyer, 1993). Upwards, or at places directly on the neritic limestones, nodular limestone of the rosso ammonitico type occurs. In the lower part this condensed facies contains characteristic deposits of manganese, frequently in the form of round manganese nodules. In the Julian Alps manganese deposits appear on Mangart (Jurkovšek et al., 1990), in wide surroundings of Bovec, on Kobariški Stol, in Krn Mountains and in the Triglavska jezera Valley (Buser, 1986). Manganese ore from these beds was exploited on the Begunjščica Mountain (Teller, 1899). On Begunjščica Toarcian ammonites were found in pelagic limestone (Mihajlović & Ramovš, 1965). Colourful limestone breccias, filling tectonic fissures within Dachstein Limestone, are also present. On Kobariški Stol, in the Triglavska jezera Valley and on Begunjščica red radiolarites or strongly silicified limestones overlie the rosso ammonitico limestones. In a complete succession, ammonitico rosso limestone is overlain by thin-bedded Biancone limestone with calpionelids, aptychi and crinoids (Jurkovšek et al., 1990; Jurkovšek & Kolar-Jurkovšek, 1988). However, Tithonian-Berriasian Biancone limestone directly overlies the neritic Jurassic oolitic and Upper Triassic Dachstein Limestone at some places. At rare places in the Julian Alps there occur also Aptian-Albian flysch marls with nannoplankton (Pavšič, 1994). Above Jurassic pelagic limestones or directly on Jurassic and Upper Triassic neritic limestones, reddish Upper Cretaceous marly limestones were deposited with hiatus at above mentioned localities. They contain numerous globotruncanas of Turonian to Santonian age. The youngest beds in the Julian Alps are represented by Campanian-Maastrichtian flysch. After the deposition of these sediments the region was uplifted and subaerially exposed at the end of Cretaceous. Later on, it was affected by marine transgression not earlier than in the Middle Oligocene.

The Slovenian Basin in the Jurassic and Cretaceous

Deep-marine sedimentation in the Slovenian Basin continued during the entire Liassic. Thin-bedded micritic limestones with chert sheets and nodules were formed. In the northern part they alternate with calcarenite and crinoidal limestones. In some places, in the upper part platy limestones with chert pass into brownish mottled marls and marly limestones ("Fleckenmergel" and "Fleckenkalk").

Liassic limestones are overlain by some tens of meters thick succession of dark grey chert alternating with shale. In the upper part cherts are of green and red colour and contain numerous radiolarians of Callovian-Kimmeridgian age (Goričan, 1984).

Radiolarian cherts of the Slovenian Basin are overlain by thin-bedded Biancone limestones with calpionelids of Tithonian and earliest Cretaceous, Berriasian age. However, these limestones are only fragmentarily preserved, since they were subsequently eroded and resedimented in carbonate breccias. No Valanginian to lower Aptian sediments are known in this area. The overlying upper Aptian-Albian chaotic breccias indicate the beginning of flysch sedimentation. These breccias contain numerous clasts of Biancone limestones. The flysch basin was filled also from the southerly lying Dinaric Carbonate Platform, as suggested by resedimented orbitolinas. Between Mrzli vrh near Tolmin and Trnovo in the Soča Valley, the entire turbidite succession consists of coarse grained breccias alternating with calcarenites and marly limestones. These calcareous turbidites were deposited on the southern slope of the Slovenian Basin, i.e. on the northern slope of the Dinaric Carbonate Platform.

In Bohinj and on Pokljuka Plateau crinoidal and oolitic limestones with ammonites and numerous brachiopods occur in the Liassic (Härtel, 1920). These are basin sediments that were deposited in a larger intraplatform trough which extended from the Slovenian Basin to the Julian High. The overlying deposits consist of Dogger to Lower Malm siltstones, marls and cherts, which correspond to radiolarites in the Slovenian Basin. These strata are overlain by up to 200 meters thick succession of Tithonian-Berriasian Biancone limestone with calpionelids. After the deposition of this limestone the intense Bohinj tectonic phase took place at the end of the Berriasian and in the Valanginian (Buser, 1980). The flysch, which was deposited during the Valanginian and Hauterivian, is older than Lower Cretaceous flysch in the Slovenian Basin.

Deposition of Aptian-Albian flysch in the Slovenian Basin continued in the Early Cenomanian. Then it was replaced by formation of thin-bedded calcimudstone and calcarenite with chert which contain globotruncanids, and which alternate with red marls. These strata are overlain by the Volče Limestone - thin-bedded calcareous turbidites with chert. On the basis of globotruncanas it belongs to the Coniacian-Campanian (Ogorelec et al., 1976). Already during the deposition of the Volče Limestone, intensive destruction of the northern margin of the Dinaric Carbonate Platform started due to the Intragosau tectonic phase and the basin began to advance on the platform territory. Thus the Volče Limestone in places directly overlies shallow-marine Jurassic and Upper Triassic limestones. The Laramian phase caused the deposition of the flysch in the Slovenian Basin. Disintegration of the Dinaric Carbonate Platform and progressive shifting of the flysch basin towards the south was particularly intense at the end of the Cretaceous (Buser & Pavšič, 1978). Remarkably large quantities of the Upper Triassic, Jurassic and Cretaceous shallow-marine limestones were resedimented as chaotic breccias into the flysch basin (Kuščer et al., 1976).

The Dinaric Carbonate Platform during the Upper Liassic to Eocene

Middle Liassic beds with lithiotid bivalves are overlain by usually alternating micritic, sparitic and oolitic limestones assigned to the Upper Liassic-Dogger. Their age could be mainly constrained on the basis of their stratigraphic position. Only at rare places foraminifers and algae were found (Dozet & Šribar, 1981). On Trnovski gozd, that represents the former northern margin of the Dinaric Carbonate Platform, light grey to yellowish crinoidal-oolitic limestones contain abundant Early Liassic brachiopods and also Dogger foraminifers in the upper part. Lithologically, they are similar to San Vigilio oolitic limestone (Buser, 1978; Geyer, 1993). On Trnovski gozd in the lower part of the Malm (Oxfordian) several ten meters thick succession of thin-bedded limestone with chert occurs. Presumably, it was formed within an intraplatform trough which was connected to the Slovenian Basin. On Trnovski gozd, Banjšice and Mija a several hundred meters thick complex of reef limestone with corals and stromatoporoids was formed during the Oxfordian and Early Kimmeridgian. This reef represents the prolongation of the reef complex which was drilled in the Cesarolo 1 borehole in the Venetian Plain (Cati et al., 1989). It extends more or less continuously several hundred kilometers farther towards the southeast. On the basis of stromatoporoids two facies belts can be distinguished within the reef (Turnšek, 1966, 1972; Turnšek et al., 1981). Large parts of the fore-reef area on the norhernmost margin of the carbonate platform are composed of bioclastic (reef-derived) calcarenites and subordinately of breccias.

South of the reef there was a large lagoon. Biomicritic limestones with *Cladocoropsis mirabilis* were formed in it, interbedded with the lense-like intercalations of oolitic limestone containing small patch reefs. The Upper Kimmeridgian and Tithonian are developed above reef limestones as a sparitic and oolitic limestone with alga *Clypeina jurassica*. Limestones with *Cladocoropsis* are overlain by the alternating layers of dolomite and limestone which contains clypeinas as well. On the Logatec Plateau and Nanos lense-like intercalations of bauxite occur under the limestone containing clypeinas.

The Berriasian and Valanginian are represented by similar limestones as the Tithonian. They contain aberrant tintinids, and on Trnovski gozd also nerineas (Krivic, 1974; Turnšek & Buser, 1966). In the Hauterivian and Barremian light grey micritic and sparitic limestones with only scarce fossils were formed. In their upper part platy limestone with chert occurs. Favourable conditions for the massive thriving of bivalves, foraminifers and calcareous algae began in the Aptian and Albian. On Trnovski gozd and in Sabotin light grey bedded limestones with rudists, orbitolinas and alga *Salpingoporella dinarica* are found (Koch, 1988; Koch *et al.*, 1989). On the territory of Banjšice, corresponding to the northern margin of the carbonate platform, coral reefs also grew (Turnšek & Buser, 1974). These limestones show also cyclic sedimentation (Grötsch et al., 1994). Aptian to Lower Cenomanian deposits on Hrušica, Nanos and on the Logatec Plateau are dark grey, bedded, bituminous limestones which were partly dolomitized (Šribar, 1979a, 1979b). On the Trieste-Komen Plateau mostly dark grey bituminous dolomites with intercalations of dark micritic limestone are developed in the discussed periods (Pleničar, 1979). In this area the carbonate platform was frequently subaerially exposed. During these longer-lasting emersion phases the carbonate rocks were karstified. Bituminous dolomite contains brown bauxite clay and breccia-filled paleokarstic relief.

In the late Cenomanian conditions were extremely favourable for growth of rudist and chondrodont bivalves, as well as foraminifers (Šribar & Pleničar, 1991). White rudist limestones are known on Trnovski gozd, on Banjšice Plateau, and at Sabotin. Coeval limestones from the Trieste-Komen Plateau are generally darker (Pleničar, 1961). They can be subdivided in several formations and members, as for example the Repen and Kopriva formation. A very distinct lithologic type is the Komen thin-bedded limestone with chert, well known for fossil-fish Lagerstätten (cf. Ogorelec et al., this volume).

Turonian strata are represented by rudist limestone which occurs on Trnovski gozd and at Sabotin, and by a characteristic horizon of dark grey thin-bedded limestone and dark grey rudist limestone on Nanos. The Trieste-Komen Plateau is characterized by darker rudist limestone alternating with limestone beds without rudists (Sežana Formation, cf. Jurkovšek et al., this volume). Locally (Hrušica, Sabotin) Turonian or somewhat younger limestones include bauxite pockets which evidence subaerial exposure of the carbonate platform (Buser et al., 1977).

The Coniacian to Campanian time was favourable for the development of rudist biostromes. At that time the Dinaric Carbonate Platform was rather uniform, therefore similar rudist limestones occur from the Trnovski gozd, Sabotin, and Nanos to the Trieste-Komen Plateau. The northern Dinaric Platform margin was characterizd by coral reefs which were later completely destroyed and resedimented as coarse-grained turbidites. On the Komen Plateau and on Nanos rudist limestones with characteristic genus *Hippurites* occur (Pleničar, 1973, 1974, 1975). A part of these limestones is defined as the Lipica Formation (cf. Jurkovšek et al., this volume). In the upper part the rudist limestone interfingers with thin-bedded limestone with chert.

Maastrichtian was a fatal episode in the history of the Dinaric Carbonate Platform. The flysch basin already prograded to the northern part of the Banjšice Plateau. On Trnovski gozd and at Sabotin, and partly on Nanos long open fissures were formed. In deeper troughs red marl and marly limestone (Podsabotin beds) with globotruncanas and nannoplankton accumulated (Pavšič, 1973, 1977, this volume; Šribar, 1967). On the structural highs between deep troughs rudist limestone was still deposited at the beginning. The Trieste-Komen Plateau was uplifted in the early Maastrichtian; as a consequence limestones were subjected to karstification. At some places (Vremski Britof, surroundings of Lipica) coal deposits were formed. The area between the Vipava Valley and Divača was, again, characterized by shallow-marine sedimentation during the Maastrichtian. Bedded biomicrites and biosparites (Vreme Beds of the Liburnian Formation) developed. They contain *Rhapydionina liburnica* and other foraminifers (Hötzl & Pavlovec, 1979; Drobne, 1979); beds with rudists are still intercalated (Pleničar, 1961, 1993; Drobne et al., 1988).

The K/T boundary is characterized in a small part of Trieste-Komen Plateau by the extinction of large number of index fossils of uppermost Maastrichtian as rudists, *Rhapydionina liburnica*, *Fleuryana adriatica* (De Castro, Drobne, Gušić, 1994). On the K/T transition at first the increase of trace elements occurs, and also, for a thicker sequence, the high negative values of $\delta^{13}C$. In this part of sediments the Ch 29R is established (Drobne et al., 1995; Ogorelec et al., 1995).

The part of the carbonate platform south of Divača remained subaerially exposed until the Early Paleocene when a transgression took place. Paleokarstic relief with bauxite deposits, resulting from a longer emersion period, is overlain by marine Lower Paleocene Kozina Limestone (Delvalle & Buser, 1990). Lithologically, the Kozina Limestone is similar to the Vreme Beds except that no coal is interstratified. Upsection the Kozina Limestone is replaced by the miliolid limestone of the Slivje Formation. During the deposition of this limestone on the Trieste-Komen Plateau, the former northern margin of the Dinaric Carbonate Platform (Trnovski gozd, Banjšice Plateau) already evolved into the flysch basin. In the Early Eocene Alveolinid-nummulitid limestone accumulated on the southernmost part of the carbonate platform (Drobne & Pavlovec, 1979). Alveolinid-nummulitid Limestone is the youngest carbonate unit of the southern Slovenian part of the Dinaric Carbonate Platform. It is overlain by Eocene flysch.

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NEW RESULTS OF THE GEOLOGICAL RESEARCHES OF THE TRIESTE-KOMEN PLATEAU AND COMPARISON WITH OTHER AREAS OF THE DINARIC CARBONATE PLATFORM

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Cretaceous and Paleogene beds of the Trieste-Komen plateau were deposited in the northwestern part of the Dinaric Carbonate Platform. On the basis of present outcrops the size of this platform is estimated at 200 x 800 km. The platform became consolidated during the Late Triassic (Buser, 1989; Gušić & Jelaska, 1993). It persisted, more or less continuously, to the end of the Late Cretaceous, and in places even to the Paleogene. It must be emphasized that under the term Dinaric Carbonate Platform the karstic territory of Slovenia, part of Italy, Croatia, Herzegovina and Montenegro is considered, and that the term is consequently equivalent to the Adriatic-Dinaric Carbonate Platform (Gušić & Jelaska, 1993; Jelaska et al., 1995; Šribar, 1995; Šribar et al., 1995). Herak (1986, 1989, 1991) distinguished the Dinaric (Dinaricum) and the Adriatic (Adriaticum) carbonate platforms with the labile intraplatform belt (Epiadriaticum) inbetween. Separation into the Dinaric and Adriatic platforms is, however, advocated by Placer (1995) who unites them as the Outer Dinarides.

In the examined territory of the Trieste-Komen plateau (Fig. 1) Jurkovšek and others (1996) defined the following lithostratigraphic units (Fig. 2): Brje Formation (Barremian-Aptian), Povir Formation (Albian-Cenomanian), Repen Formation (Cenomanian-Turonian), Sežana Formation (Turonian, Coniacian, Santonian), Lipica Formation (Santonian-Campanian), Liburnian Formation (Maastrichtian-Paleocene), Formation of Alveolinid-nummulitid limestone (Eocene) and Flysch (Eocene). For the same lithostratigraphic units in Slovenia, Croatia, Italy and different parts of

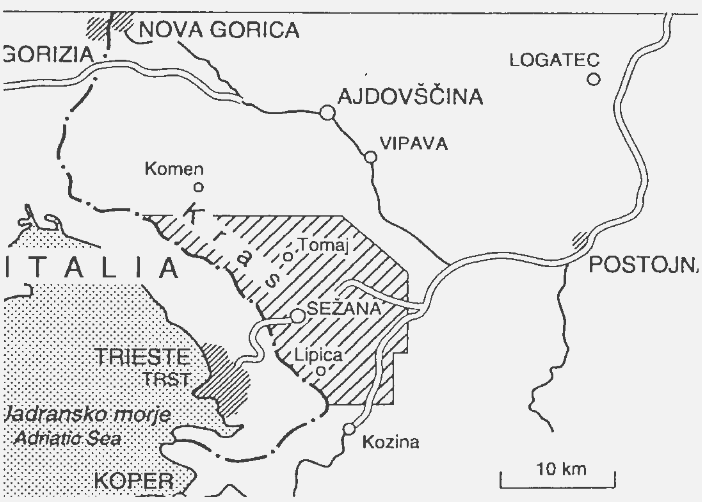

Fig. 1. Geographic sketch of study area.

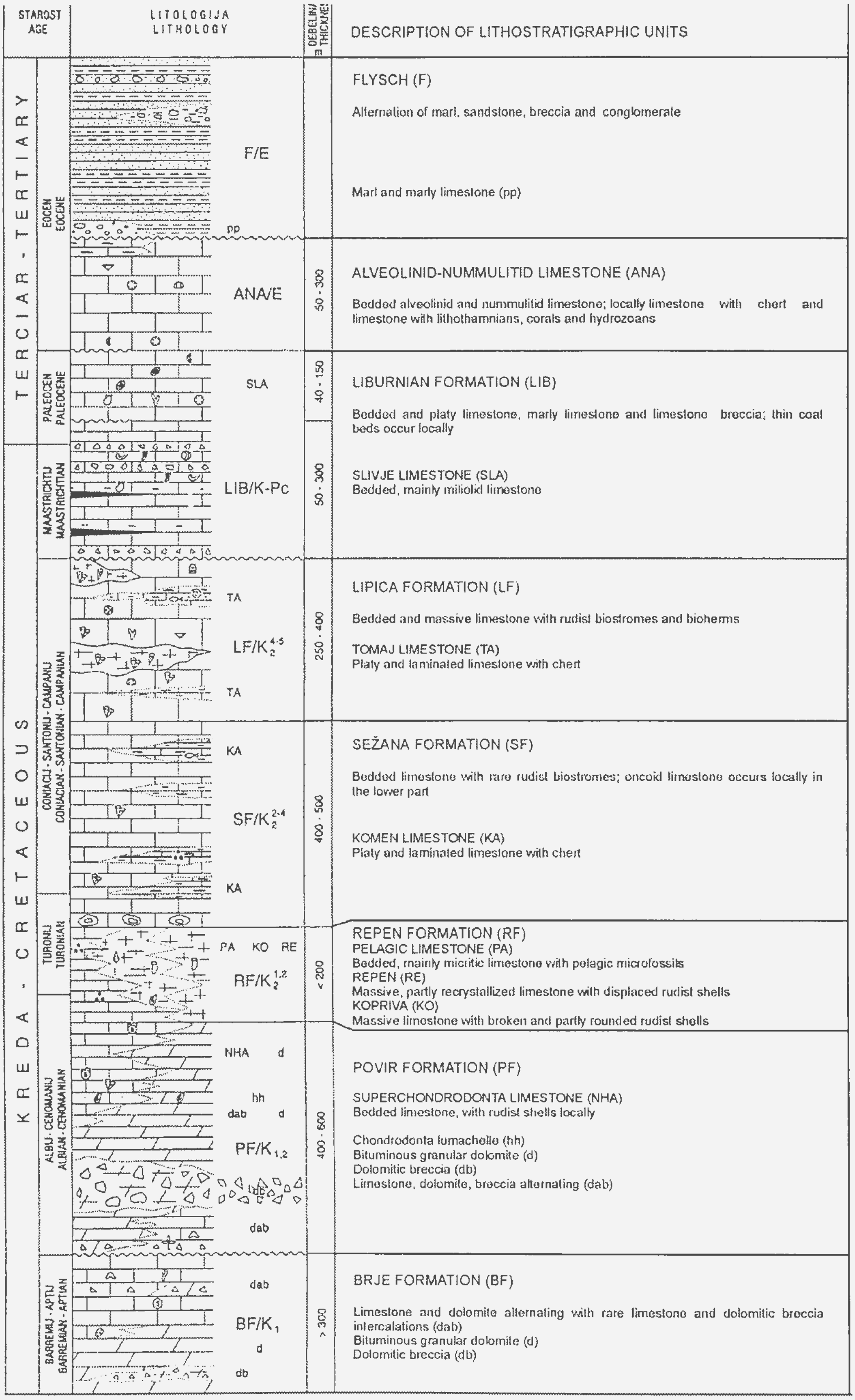

Fig. 2. Stratigraphic sequence of the southern part of the Trieste-Komen plateau (after Jurkovšek et al., 1996).

former carbonate platform many times different names are used that would need to be correlated for the entire area of the Dinaric Carbonate Platform (Fig. 3).

The carbonates of the southern part of the Trieste-Komen plateau were deposited in the Cretaceous in the interior part of the Dinaric Carbonate Platform that was uniform in the paleogeographic sense in the Early Cretaceous and early Late Cretaceous. This is supported by certain stratigraphic levels that are developed in the entire territory. In the lower Cretaceous these are the *Palorbitolina* level, *Mesorbitolina* level and the emersion breccia between them; in the Cenomanian and Turonian the *Chondrodonta* horizon, Pelagic limestone of the Repen Formation and the Oncoid horizon. In the Campanian a slow paleogeographic differentiation of the region became observable that is indicated by different age of the emersion boundary between the Lipica and Liburnian Formations in a wider area of the Trieste-Komen plateau.

Differentiation of the territory continued during the early Maastrichtian and Paleogene. The Liburnian Formation was deposited in diverse sedimentation environments of the shallow carbonate platform. In the northern part of the mapped territory, shallow subtidal and episodically intertidal environments prevailed, whereas in the southern part of the platform somewhat more lagoonal conditions were predominant.

An important event occurring within the Liburnian Formation is the K/T boundary. It is characterized by a hiatus of short duration. The time of depositional non-record is estimated to at least 40.000 years (Hansen et al., 1995). Lithologically, the hiatus is manifested by one or more conglomeratic breccia levels of cm to dm thickness or by a hardground. Rudists and several foraminiferal species make their last appearance just below the boundary (Drobne et al., 1988, 1989, 1994; Pleničar et al., 1992). Abiotic changes around the boundary are documented by shift in $\delta^{13}C$ toward more negative values (Dolenec et al., 1995) and by enrichment in some elements (Ga to 450 ppb, Ni to 12 ppm, Co to 32 ppm, V to 85 ppm, Sm to 25 ppb, Zr to 45 ppm) (Ogorelec et al., 1995). An increase of iridium (5.8 ppb) in comparison to under- and overlying limestones was observed in the breccia bed of the Dolenja Vas section (Hansen et al., 1995) which is assigned to magnetochron 29R (Marton et al., 1995).

During the Middle and Late Paleocene the region of the platform, on which the rocks of the present Trieste-Komen plateau were deposited, was slightly subsided and became again more open (Pugliese et al., 1995). The trend of subsidence continued in the Ilerdian, while in the Cuisian the disintegration of the carbonate platform occurred, as well as the beginning of flysch sedimentation.

Comparison of the Slovenian part of the Trieste-Komen plateau with other regions of the Dinaric Carbonate Platform, and principal geologic events on it

In this chapter parallels to principal events on the mapped territory with neighbouring regions of the Dinaric Carbonate Platform are presented, especially with presently the best defined stratigraphic development of the Upper Cretaceous on the island of Brač, and with the Trieste Karst in Italy. Individual formations and their stratigraphic ranges in considered regions are comparatively shown in Fig. 3.

The oldest carbonate rocks of the southern part of the Trieste-Komen plateau belong to the Brje Formation that is separated from the Povir Formation by an Upper Aptian emersion horizon. Limestones and dolomites of the two formations are quite similar lithologically. The reason for their subdivision into two formations was beside the lithological differences also the existence of this continuous emersion horizon that can be observed throughout the entire Dinaric Carbonate Platform where Upper Aptian sediments are exposed (Velić et al., 1989; Gušić & Jelaska, 1993; Velić et al., 1995). On the Italian side of the Trieste-Komen plateau the oldest Cretaceous rocks

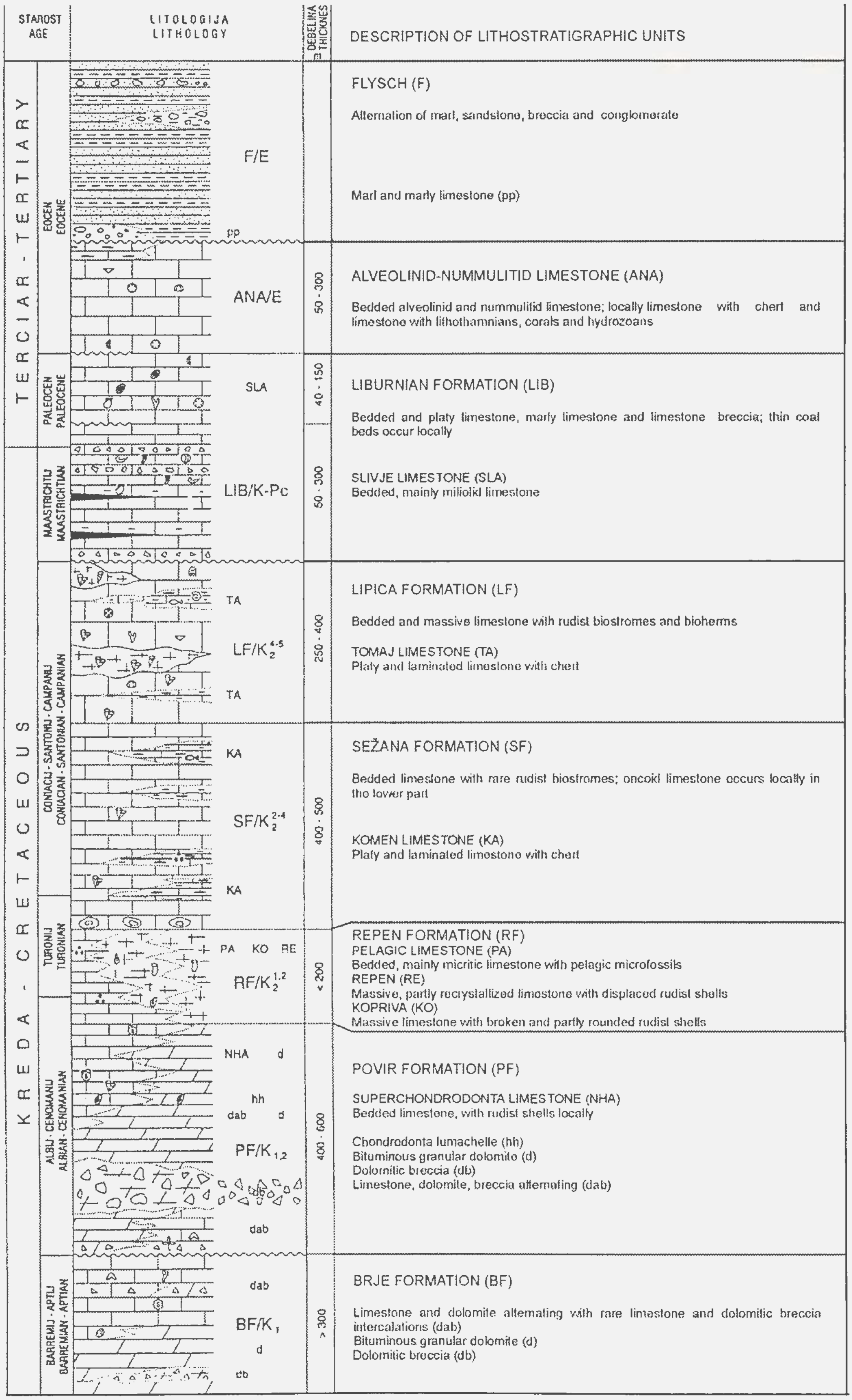

Fig. 3. Comparison of lithostratigraphic units of Brač Island and a wider region of Kras (Karst).

have been attributed to the Monte Coste member by Cucchi and others (1989). These authors placed the boundary between the Monte Coste and the overlying member somewhat higher into the Albian level of dolomitic breccias, whereas the UpperAptian emersion level has not been shown in the stratigraphical column. A similar subdivision was worked out by Tentor and coauthors (1994) who named this oldest Cretaceous formation in the Gorizia Karst the Limestones of Cellina, and terminated it with the Upper Albian emersion horizon. The event of the Aptian-Albian emersion phase on the mapped territory is associated with the generally known eustatic drop of the sea level on the Dinaric Carbonate Platform (Haq et al., 1987). The decline of the sea level below the margin of the carbonate platform, and its renewed rise resulted into the deposition of a new sequence on the platform.

The equivalent of the Povir Formation in the Italian part of the Trieste-Komen plateau is the Rupingrande Member (Cucchi et al., 1989). The only difference between the two formations is the lower boundary, as mentioned in the previous paragraph. The Monrupino Formation of the Gorizia Karst (Tentor et al., 1994) corresponds to the upper part of the Povir Formation and to the Repen Formation. In the Monrupino Formation, in addition, the dolomite member and the *Chondrodonta* limestone are distinguished. On the island of Brač the equivalent of the upper part of the Povir Formation is the Milna Formation. The lower part of the Milna Formation is not exposed on Brač, whereas the upper boundary is represented by pelagic limestone of the Sv. Duh Formation. An interesting stratigraphic level in the Povir Formation is the *Chondrodonta* horizon. It is developed in the entire Dinaric Carbonate Platform (Jelaska et al., 1994), and it bears clear evidence of similar paleogeographic conditions on the platform in the Upper Cenomanian.

The following important geologic event on the platform took place at the Cenomanian-Turonian boundary. At that time the entire platform of the southern part of the present Trieste-Komen plateau was submerged. Limestones that were deposited during that time have been assembled into the Repen Formation. In a similar manner Gušić and Jelaska (1990) attributed the calcispheral limestones above the beds with chodrodonts on the island of Brač to the Sv. Duh Formation. In the Italian part of the Trieste Karst the equivalent of the Repen Formation is the Zolla member (Cucchi et al., 1989). The mentioned authors subdivided it into the lower interval that consists of bioclastic limestones, and the upper interval that is represented by calcispheral limestones. The several meters thick level of calcispheral limestones in the Gorizia Karst is included into the Monrupino Formation (Tentor et al., 1994).

In the Late Turonian the sudden drop of the eustatic sea level (Haq et al.; 1987) interrupted the deposition of the Repen Formation. This change in sea level had its expression in rapid lithologic transition from calcispheral limestones to shallow marine biomicritic limestones, often with disiccation pores, and locally to oncoidal limestones. A similar stratigraphic succession can be observed on the island of Brač where Gušić & Jelaska (1990) named the Gračišće oncolite. In the Trieste and Gorizia Karst the oncoid level has not been mentioned by the Italian authors. The entire stratigraphic succession from calcispheral limestones to the Campanian-Maastrichtian emersion is considered a single unit. In the southern part of the Trieste Karst this is the Borgo Grotta Gigante member (Cucchi et al., 1989), and in the Gorizia Karst the Aurisina limestones (Tentor et al., 1994).

The stratigraphic succession of the Sežana Formation is very similar to the Gornji Humac Formation on the island of Brač (Gušić & Jelaska, 1990). The only difference is furnished by isolated intercalations of bituminous laminated and platy limestones in the Sežana Formation. They were partly deposited in anoxic conditions that, at least in the limited area, interrupted the development of benthic organisms. The upper boundary of the Sežana Formation is represented by the passage into bedded and massive limestone of the Lipica Formation.

At present there is no unified opinion on the reflection of the Upper Santonian-Campanian eustatic sea level rise in the sedimentary rocks of the Trieste-Komen plateau. Šribar (1995) and

Šribar and others (1995) placed between Formation 3 (that corresponds approximately to Sežana Formation) and Formation 5 (approximately Lipica Formation) the Formation 4 which has been interpreted as the result of the Upper Santonian-Campanian eustatic rise of the sea level. Yet Jurkovšek and Kolar-Jurkovšek (1995), Summesberger and others (1996a,b) believe that certain higher levels of the Tomaj limestone within the Lipica Formation could be associated with sea-level oscillations of the Santonian-Campanian transgression on the Dinaric Carbonate Platform. This is supported by numerous finds of ammonites with aptychi preserved in the living chamber in the surroundings of Dobravlje and Kazlje (NE of Sežana).

The following important geologic event on the platform was the emersion in the upper part of the Campanian that lasted until Late Maastrichtian. The mentioned emersion phase is well recognizable in stable parts of the Dinaric Platform.

In all mentioned areas the deposition was resumed during the Maastrichtian. On the Trieste-Komen plateau the present authors joined the shallow marine subtidal, intertidal and supratidal sediments into the Liburnian Formation. In the Trieste Karst the equivalent beds are called the member of Monte Grisa (Cucchi et al., 1989) that is subdivided into the lower and upper interval. The upper interval is equivalent to the Slivje limestone. In the area of the Soča (Isonzo) Karst, Tentor and others (1994) subdivided the entire succession of beds into the Liburnian group (Gruppo "Liburnico") and miliolidal limestones (Calcari a miliolidi). The Liburnian group was further subdivided into the Upper Maastrichtian Vreme beds ("Strati di Vreme") and Danian Kozina beds (Strati di Cosina) between which they observed the emersion boundary. Miliolidal limestones (Calcari a miliolidi) are equivalent to the Slivje limestone and the upper interval of the Monte Grisa member of the Liburnian Formation on the Trieste Karst. On the island of Brač the sedimentary rocks above the Campanian-Maastrichtian emersion are represented by the Sumartin Formation that comprises the lower (especially Cretaceous) part of the Liburnian Formation. The upper boundary of the Sumartin Formation, however, is of the emersion type.

The Liburnian Formation on the Trieste-Komen plateau is followed by the Formation of Alveolinid-nummulitid limestone that was deposited during advancing transgression on the carbonate platform. Deepening of the environment progressed from northwest to southeast. Rich foraminiferal fauna in the Alveolinid-nummulitid limestone enabled biostratigraphic subdivision of this formation which is based on nummulitids (Pavlovec, 1963) and alveolinids (Drobne, 1977). The equivalent beds in Trieste Karst were named the Opicina member (Cucchi et al., 1989), and in the Isonzo Karst the Nummulitic-alveolinal limestone ("Calcari a nummuliti e alveoline") (Tentor et al., 1994). Everywhere in these regions the lower boundary reaches into the Lower Eocene, and on the island of Brač, where it is named Alveolinal-nummulitic limestone, into the upper part of the Lower Eocene (Cuisian).

The last important geological event in the investigated area is represented by the disintegration of the carbonate platform in the late Ilerdian when the deposition of flysch started. In the investigated territory the boundary between the carbonate and the flysch deposition is mainly erosional. Also in the Isonzo Karst the contact is erosional (Tentor et al., 1994). In Istria the deposition of the Alveolinid-nummulitid limestone continued up to the Middle Eocene (Lower Lutetian), in accordance with the subsidence of the carbonate platform and gradual shifting of the flysch basin southwards (Drobne, 1979; Drobne & Pavlovec, 1991).

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KARST OF TRIESTE

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The Trieste Karst is characterized by a carbonate stratigraphic sequence ranging from Aptian-Albian *partim* to early Eocene. Taking in account the basic sources of the literature (Stache, 1889 ; D'Ambrosi, 1953, 1955; Martinis, 1951, 1962) this sequence was included in the provisional and informal "Trieste Karst Limestone Formation" consisting of the Mt. Coste, Rupingrande, Zolla, Borgo Grotta Gigante, Mt. Grisa and Opicina members (Cucchi et al., 1987).

The Trieste Karst represents the southern limb of a slightly asymmetrical anticline with NW-SE axis. This limb is characterized by a reverse fault in its south-western sector. The bedding presents an average dip of 10°-35° southward, abruptly increasing along the seaward edge of the Karst plateau.

Two regional NW-SE reversed and transcurrent faults "Raša fault" and "Divača fault") are identified in its north-eastern sector. Moreover, numerous minor faults are recognized in the Monfalcone area ("Colle Nero fault", "Vallone fault", etc.) and in the Trieste area ("Monte Spaccato fault", "Monrupino fault", etc.). In the Rosandra valley, located north-east of Trieste, a rather complicated tectonic structure is present. It can be considered as a part of the "Čičarija imbricate structure".

The Mt. Coste Member (Aptian-Albian *partim*) is mainly represented by blackish limestones of restricted settings. They represent the first anoxic episode of the environmental evolution recorded in the Trieste Karst area. Dolomitic lenses of very restricted setting are also present in the lower part of the member. Furthermore, in its middle part a thin requienid horizon testifies the first build-ups of the Trieste Karst sequence. Detailed data concerning the Aptian-Albian are available in Masoli & Ulcigrai (1969), Colizza et al. (1987) and Cucchi et al. (1988).

The Rupingrande Member (upper Albian to mid-lower Cenomanian) mainly consists of dolostones and dolomitic breccias of very restricted settings, sometimes affected by evident sinsedimentary tectonics. In addition, well diffused pockets of red-yellow micritic limestones and dedolomites indicate frequent emersion episodes. Detailed studies of these lithotypes are due to Ulcigrai (1976) and Colizza et al. (1987, 1989).

The Zolla Member (mid-upper Cenomanian) is subdivided in two parts. The lower part is represented by dark mud-supported limestones of restricted lagoon settings. The fossils are mainly represented by *Chondrodonta joannae* (Choffat) and radiolitids, which colonize the substrates allowing a richer and richer benthic life (Caffau et al., 1994-95). The upper part consists of grey limestones with *Pithonella* specimens and rare planktonic foramifers. These limestones testify settings characterized by an increased depth, where the building activity of the previously cited molluscs is prevented. Observations regarding the limestones with *Pithonella* are reported by Cucchi et al (1986).

The Borgo Grotta Gigante Member (upper Cenomanian-Maastrichtian) is constituted (from bottom to top) by bioclastic (rudist) limestones, rudist limestones, dark platy laminated limestones and grey rudist limestones. The bioclastic limestones can be associated to ramp deposits which testify a high carbonate productivity (Caffau et al., 1995a). These limestones contain *Chondrodonta joannae* (Choffat) and abundant radiolitids, which begin colonizing the substrate during upper Cenomanian. The dark and platy limestones indicate restricted and sometimes anoxic lagoon. They are overlain by limestones of lagoon settings where the rudists (radiolitids and hippuritids) become more and more abundant. Their building activity develop from Turonian to late Senonian, together with a richer and richer microbenthic (foraminifers) life. The uppermost part of the rudist limestones present paleokarstic features ("breccia bianco-rosea", *Paronipóra* occurrence, paleosoils, etc.) testifying emersion phases.

The Monte Grisa Member (Danian) consists of dark peritidal limestones (stromatolitic layers, bioturbations, *Paronipora* occurrence) and limestones of restricted lagoon settings sometimes influenced by fresh and brackish water inputs (lower Danian). They are overlain by limestones of open lagoon settings with very abundant benthic fossils (algae, foraminifers, gastropods, corals, etc.), in the late Danian. Detailed data concerning these lithotypes are available in Masoli et al.

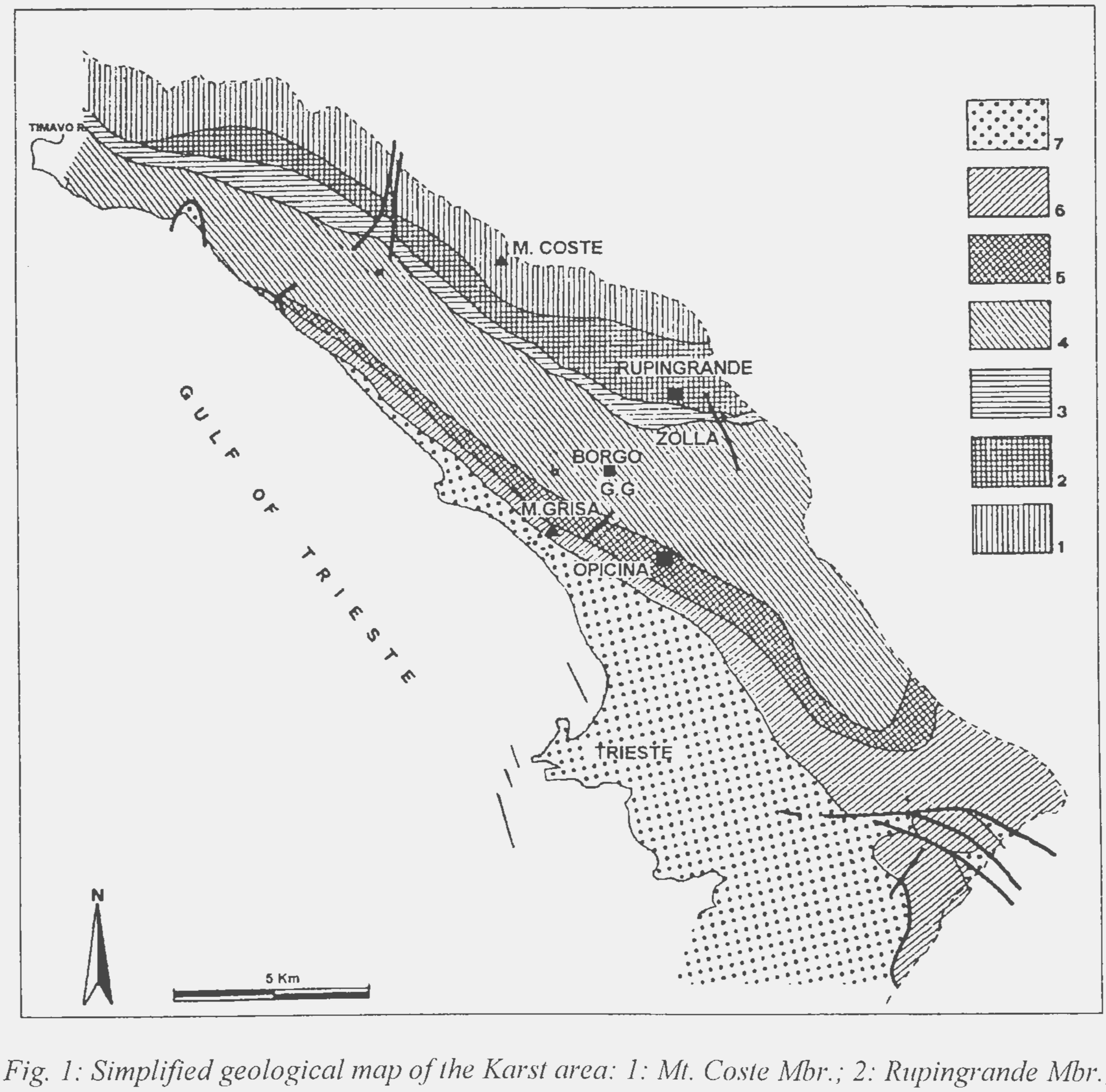

Fig. 1: Simplified geological map of the Karst area: 1: Mt. Coste Mbr.; 2: Rupingrande Mbr.; 3: Zolla Mbr.; 4: Borgo Grotta Gigante Mbr.; 5: Mt. Grisa Mbr.; 6: Opicina Mbr.; 7: Flysch Formation. (after Cucchi et alii, 1987, *modified)*

(1978), Ciliberto et al. (1982), Pirini Radrizzani et al. (1987) and, recently, Caffau et al. (1995b).

The Opicina Member (Thanetian-Ilerdian) is characterized by limestones which present very abundant fossils (algae, foraminifers, such as conical agglunitated forms and alveolinids, corals, etc.), in the Thanetian, overlain by aveolinid and nummulitid limestones, in the time-span from Thanetian *partim* to Ilerdian. These limestones mainly testify coastal marine settings. The uppermost part of the member is characterized by marly limestones with an increasing occurrence of planktonic foraminifers. These limestones indicate an increasing depth and the decline of the previously taxa, preluding to the drowning of the carbonate platform in relation to terrigenous turbidites (Flysch). Detailed data concerning these lithotypes are available in Castellarin & Zucchi (1966), Bonnes et al. (1976), Pirini Radrizzani et al. (1987) and Caffau et al. (1995b).

In conclusion, additional remarks concern the K/T boundary, which recently has been identified in correspondence of a "breccia" level of the Padriciano sequence in the eastern Trieste Karst (see Brazzatti et al., this volume). Actually, the paleontological data, the iridium anomaly (Hansen et al., 1995) and the drastic $\delta^{13}C$ depletion (Dolenec et al., 1995), together with a peak of susceptibility and intensity of intensity of remanent magnetization (Marton, personal communication, 1995), confirms the existence of this boundary. Moreover, the origin of this "breccia" is still under discussion, in that it is considered as intertidal-supratidal breccia or debris flow.

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TECTONIC STRUCTURE OF SOUTHWEST SLOVENIA

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Although the present structure of southwest Slovenia is a product of geologic events throughout the entire geologic history, its main features were formed mostly in Cretaceous and in Tertiary, in the last stages of the Alpine orogeny. In order to understand the events in the given region, we must consider the genesis of western Slovenia where all three megatectonic units of the Dinarides meet: Southern Alps that comprise the Julian Carbonate Platform, Inner Dinarides that are composed of rocks of the Slovenian Basin, and Outer Dinarides that comprise the Dinaric Carbonate Platform and the Adriatic Platform. All units except the Adriatic Platform consist of thrusts and extended nappes with directions of structural elements W-E in the Southern Alps and Inner Dinarides, and NW-SE in the Outer Dinarides.

The Dinaric Carbonate Platform and the Adriatic Platform underwent through the prevailing part of Mesozoic only insignificant vertical oscillations manifested by minor transgressions, regressions and emersions. This evolution was radically interrupted during the Laramian tectonic phase. However, in the utmost, presently the northwest part of the Dinaric Carbonate Platform in the Tolmin area, its disintegration started during Senonian already with the transgression of Volče limestone with chert, rudist and calcarenitic limestone and marl of the flysch facies on the Upper Triassic and Jurassic carbonate beds. Deposition was continued in Maastrichtian with limestone breccia, marl and flysch and further with flysch facies up to Eocene inclusively. The Senonian and Maastrichtian beds are sediments of the Slovenian Basin that were deposited on the margin of the Dinaric Carbonate Platform. Senonian and Maastrichtian flysch covers at present the northernmost parts of the Dinaric Carbonate Platform, while towards south and southwest the carbonate basement is overlain by younger and younger flysch beds; this is an evidence of the south- or southwestward migration of the flysch basin. This could be hipothetically explained by the start of extensive nappe thrusting, and with it uplifting of the Julian Carbonate Platform, or of the structure that is equivalent to it. It began at its northern margin in Senonian and gradually involved younger and younger nappe units in the southern direction.

Characteristic for evolution in the remaining part of the Dinaric Carbonate Platform and the Adriatic Platform in the Laramian tectonic phase is differentiated vertical oscillation that resulted into forming of NW-SE oriented land masses and basins with variable depositions of Cretaceous-Paleocene, Paleocene and Lower Eocene beds. The appearance of flysch is connected with formation of the nappe structure of the Outer Dinarides that started in the inner part of Outer Dinarides and then gradually attained younger and younger nappe units towards the Adriatic Platform, culminating during the Illyrian-Pyrenean phase. Accordingly the hiatus between the Cretaceous basement and Tertiary beds is largest in the present northeastern margin of the flysch basin in the Hrušica nappe and the Snežnik thrust sheet. In the southwest, however, the transition from Cretaceous into Tertiary is interrupted with smaller gaps only. In the sketch map of tectonic structure of southwest Slovenia (Fig. 1) this pecularity is emphasized with the discordance between flysch and

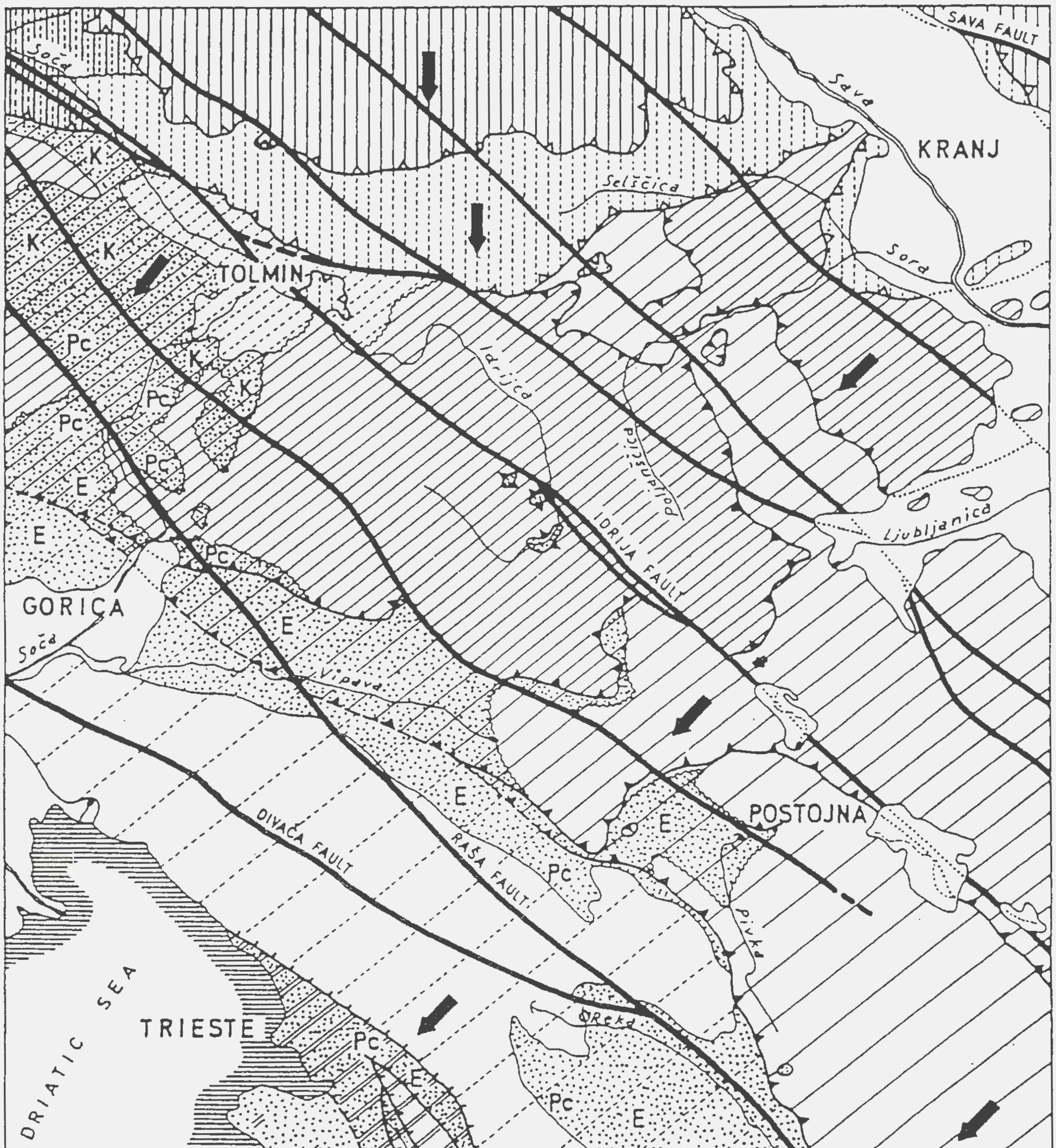


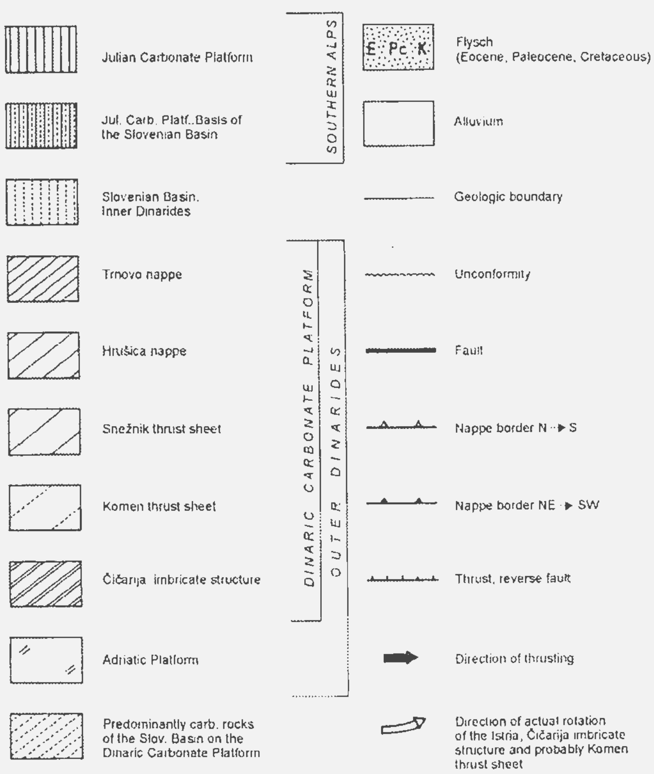
Fig. 1: Tectonic sketch of southwestern Slovenia (After Geological maps of SFR Yugoslavia, 1:100000 and Guides; Placer, 1981, 1996)

its base. Not shown in the map is the narrow band of Paleocene beds that represent in fact the basal beds of flysch.

In the present constellation of nappe units of western Slovenia the Southern Alps and the Inner Dinarides are thrust from north southwards on the Outer Dinarides that are rotated with respect to the first mentioned units for 30 to 45 degrees. This is an indication of the complexity of the thrusting dynamics of the considered territory. The nappe structure of the Outer Dinarides dates from the Illyrian-Pyrenean tectonic phase, while the structure of the Southern Alps from the Rhodanian phase between Miocene and Pliocene.

From this context follows in western Slovenia the existence of two flysch basins, respectivelly two complexes of flysch beds that are presently connected but different according to time and place of origin. The first flysch basin was a consequence of events of the region of the Julian Carbonate Platform, possibly associated with thrust nappes, and the second flysch basin, as the consequence of thrusting and uplifting of the Outer Dinarides. The formal boundary between the two regions might be, according to present knowledge, the thrust plane of the Trnovo nappe in the Outer Dinarides, but its true position could be established only through additional structural-kinematic, paleomagnetic, paleontologic, sedimentologic and paleogeographic investigations.

At the end also the significance of subvertical faults that strike NW-SE, SW-NE, W-E and N-S should be mentioned. All were started during Mesozoic and later often reactivated. It appears that the most important for paleogeography were faults striking NW-SE. In Mesozoic, and at Cretaceous/Tertiary transition, in the Laramian phase, in the Outer Dinarides especially along these longitudinal ridges and basin were formed. These faults also play the leading role in recent seismic activity. The more important among them are shown on the tectonic sketch map. Herewith the results of the paleomagnetic investigations of the Maastrichtian to the Oligocene rocks of Marton et al. (1995) should be mentioned. They established counterclockwise rotation of the Istria peninsula, that is a part of the Adriatic Platform, against upper nappe units of the Dinaric Carbonate Platform, which suffered clockwise rotation. Raša fault should represent the boundary of the divergent rotation. Romandić (1990), whose work is based upon Aljinović & Blaškić (1981) and Aljinović (1984)



investigations, already draw attention to the probable counterclockwise rotation of the Istria peninsula, Kvarner and Lika. Based upon hereinabove publications it is obvious that the rotation of Istria is more likely the consequence of subthrusting of the Adriatic Platform under the Dinaric Carbonate Platform along NW-SE directed reverse faults and thrusts. The boundary of subthrusting is not uniform but takes wider belt of the southwest margin of the Dinaric Carbonate Platform. After Aljinović, Blašković and Romandić Istria is a part of microplate, the rotation axis of which (constructed upon figure 11 from Romandić's article) should be somewhere in the area of middle Tilment river stream. Southeastern boundary is geophysically identified lineament traversing the Outer Dinarides at the prolongation of the line Susak island - Jablanac town by the Velebit channel. The coexistence kinematics of the NW-SE directed reverse faults and thrusts with equably directed strike slip faults can be, according to the recent dynamics, an interesting subject of future investigations. The Del Ben et al. (1991) construction gives only partial answer to that question. When reconstructing paleogeographic conditions possible rotation of Istria and herewith decrease of the subthrusting dimensions from southeast toward northwest should already be incorporated.

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THE KARST OF POSTOJNA AND SURROUNDINGS. ITS GEOLOGICAL AND SPELEOLOGICAL PROPERTIES

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The Pivka basin

The Pivka basin (Fig.1) is a large flysch and karst plain (approximately 150 km^2) in the levels between 500 m a.s.l. and 600 m a.s.l. It is surrounded from all sides by higher (800 m to 1300 m) karst plateaus: Nanos and Hrušica on the West, Javorniki and Snežnik on the East, Vremščica on the South. Together with the Postojnska vrata (Postojna gap) Pivka is the lowest pass over the Alpine-Dinaric mountains, yielding the easiest transition between Adriatic and Panonian basin.

The central part of the Pivka basin and low borderland belongs mostly to the basin of upper Pivka river. Its karst springs are in the most SW part near Knežak and Zagorje, and then all along the foot of Javornik till Prestranek, where the river leaves limestone territory and enters the flysch one. At the end of its 26 km long periodical surface stream it sinks together with Nanoščica in Postojna Cave near town Postojna. It continues its underground course below the Postojna Karst towards Planinsko polje and there from to the sources of Ljubljanica. Only the high waters from Javorniki pour out to the Pivka; all the rest flow underground, directly towards the Planinsko polje. In the northern part of Pivka basin there are several sinking brooks, encompassing about 15% of the basin area only. They flow underground through the Nanos towards west, reappearing on the

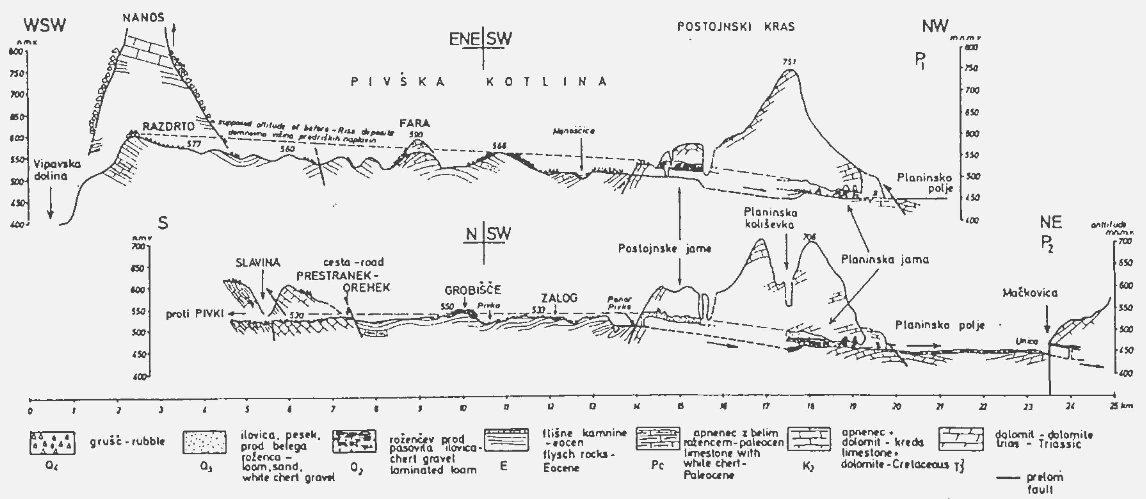

Fig.1: The Pivka Basin, the Postojna Karst, Polje of Planina and among them lying Postojna Cave System (Gospodarič, 1976)

surface again at Vipava, and therefore draining to Soča and the Adriatic. About 3% of the total Pivka territory (the Sajevščica basin) sinks in a short blind valley and flows through the Karst to the Adriatic sea. Therefore, an interesting water division between the Adriatic and the Black sea there is in Postojna basin.

The basin is tectonically, fluvially and karstically shaped. At the foot of the tectonically risen karst plateaus, covered with conical hills and minor depressions typical pedimental flats are found. Karstification brought about the uvalas and other depresions of similar size formation, while the whole karst surface is pitted with dolines.

The limestones of the upper Pivka are overthrusted on flysch and so the ground water is very close to the surface. Dolines in that area become flooded several times and small periodical lakes appear there in.

The Postojna Karst

The area between the Pivka Valley and Planinsko Polje was labelled the Postojna Karst (Fig. 2) by Kossmat as early as 1897. The Postojna Karst is built up entirely of Lower and Upper Cretaceous carbonate rocks. To the north and east the Postojna Karst borders with the Predjama overthrust of Triassic dolomite on Cretaceous limestones, and to the west with impervious Eocene flysch sediments of the Pivka Valley, which enabled the development of the surface water net. The southern boundary lies approximately along the Rakek - Postojna railway line. The system of the Postojna Caves is in Turonian and Senonian limestones (Gospodarič, 1976) and was caved by the Pivka River on its subsurface way from the Pivka Valley to the Planinsko Polje. The cave system is subdivided into six units (the underground Pivka, the Postojna Cave, the Otok Cave (Otoška jama), the Magdalena Cave, the Black Cave (Črna jama), and the Pivka Cave) and its total length amounts to about 20000 m. The depth of the caves, measured between the highest elevation point in the Postojna Cave and Magdalena Cave respectively (562 m) and the lowest elevation point (447 m) in the Pivka Cave amounts to 115 m.

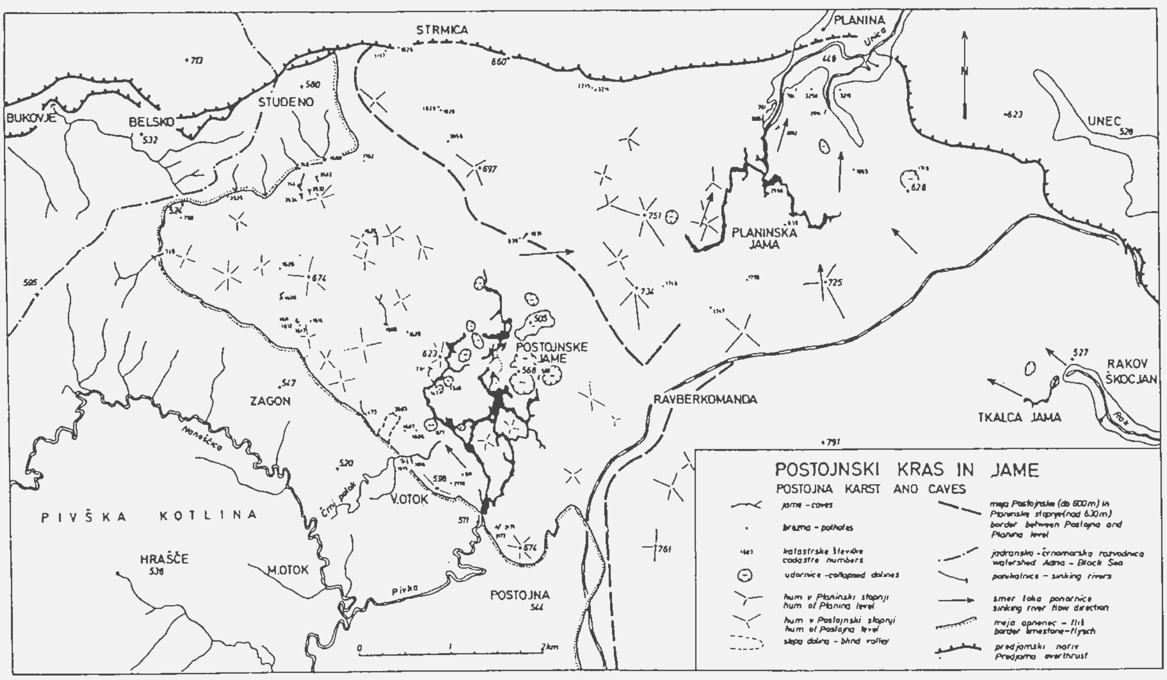

Fig.2: Postojna Karst and caves, simplified morphological sketch (Gospodarič, 1976)

On the geological map (sheet Postojna 1:100 000; Buser et al., 1967), Turonian-Senonian strata are represented together.

According to Gospodarič (1976), the boundary between Turonian and Senonian beds is marked by the first appearance of the foraminifer *Keramosphaerina tergestina* (Stache) and by different lithological composition of the limestone (cf. Šebela, 1994). However, according to Buser (1965), the *Keramosphaerina*-bearing beds in the Slovene Dinarides belong to the upper part of the Campanian and Santonian. The same conclusion was reached by Drobne (1979) for the region NW of Postojna.

Geological data about the Postojna Cave system

Turonian

Turonian strata contain rudists, mostly radiolitids. The lower part of the Turonian is represented by well-bedded, grey coloured limestones with chert (Fig. 3), and the upper part by massive grey limestones (cf. Šebela, 1994).

In the Postojna Cave, the chert-bearing horizon is about 60 m thick, and the massive limestone about 100 m. According to Gospodarič (1976), the total thickness of the Turonian is approximately 300 m. Almost all cavities and passages of the Postojna Cave, including both the dry and the temporarily flooded ones, as well as those with permanent water streams, are formed in the Turonian rocks. The easternmost passage, called Pisani rov (Fig. 4), extends down even into the lower, well-bedded part of the Turonian. The chert - bearing limestone is visible in the passages near Velika Gora. The chert occurs as irregular lenses or in beds several decimetres thick, which are strongly folded, as is also the limestone. The passages in chert - bearing limestone are smaller than the ones in pure limestone. The limestone is heavily dissected by numerous vertical joints and fissures, due to tectonic processes.

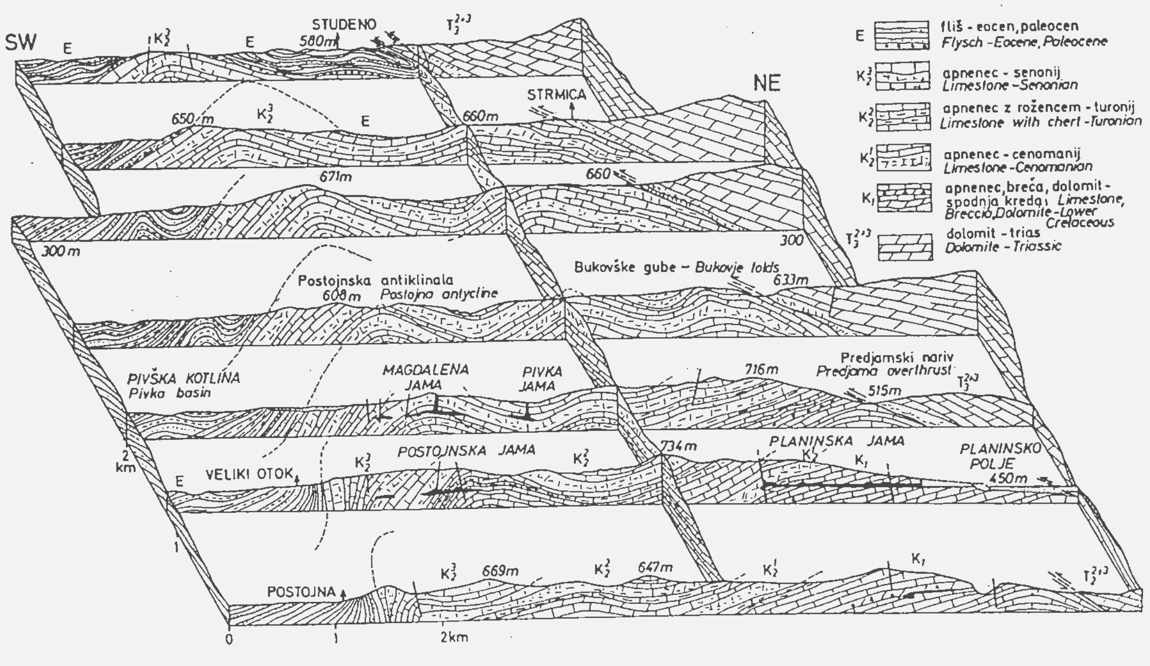

Fig.3: The Postojna Karst, geological sections with Postojna Cave System drawn in (Gospodarič, 1976)

Senonian

The transition between Turonian and Senonian limestone in the Postojna Cave is gradual. The lower part consists of thick-bedded, brown-grey, grainy limestone with numerous specimens of the foraminifer *Keramosphaerina tergestina.* A particulary rich locality is situated in the limestone in the Dance Hall (Plesna dvorana; Gospodarič, 1976). The youngest levels of the thick-bedded limestone belong to the Maastrichtian, which has been proven by *Hippurites giordanii* Pirona. It was found in the limestone above the Postojna Cave system. The total thickness of the Senonian limestone is estimated at least 500 m (Gospodarič, 1976), though it is difficult to be reliably determined, as the rocks were partly eroded before being covered by Eocene flysch.

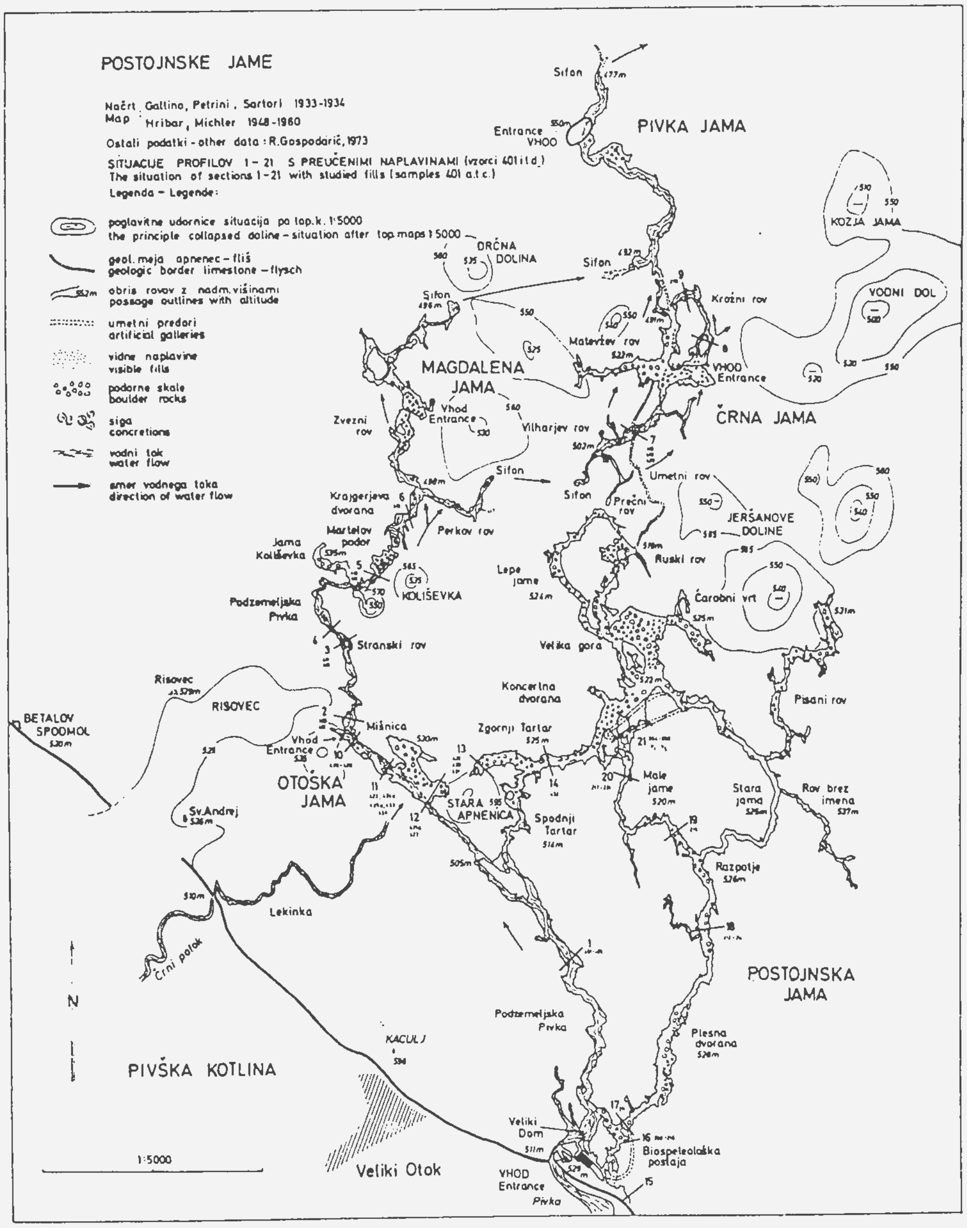

Fig.4. The Caves of Postojna; ground plan and the situation of collapse dolines (Gospodarič, 1976)

Cave deposits

In the dry passages of the Postojna Cave, Gospodarič (1976) distinguished three types of deposits (Fig. 5, 6): (1) The Riss alluvial deposits of white chert and weathered flysch gravels, and with sands, clay, and limonite. There are no calcite flowstones (stalactites/stalagmites); (2) The Lower Wurm banded alluvial deposits consisting of sand, clay, and a few gravels. They were deposited along all the dry channels as longer or smaller heaps between the present-day cave entrance and the Russian Passage (Ruski rov). These deposits are sometimes overlain by red clay, and always by younger calcite flowstone; (3) The Upper Wurm waterlaid flysch clay is sandwiched between two flowstones of calcite. In this deposit, most of the cave-bear bones were found. It contains talus debris (scree) and younger stalactite (dripstone).

The majority of the sediments in the Postojna Cave system is allochthonous. They were eroded by sink hole rivers on the surface of the Pivka Valley and its surroundings.

According to Brodar (1966), the evolution of the Postojna Cave can be subdivided into four phases:

(1) erosional phase in the Upper Pliocene or Lower Pleistocene;
(2) accumulation phase in the Lower or Middle Pleistocene;
(3) erosional phase in the Middle Pleistocene; and
(4) accumulation phase in the Upper Pleistocene.

Paleolithic finds

In the surroundings of Postojna there are a number of Palaeolithic sites. In Betalov Spodmol, near the Veliki Otok village, several colonization phases of the Neanderthal man with Mousterian culture have been found. In the Otok Cave (Otoška jama) there are Wurm artefacts.

In the Wurm ice age, the Postojna cave was a hunting station. In the creek near the biospeleological station numerous bones of the cave bear, cave lion, hyaena, and wolf have been found (Brodar, 1966). Rakovec (1954) also described the remains of *Hippopotamus* from the

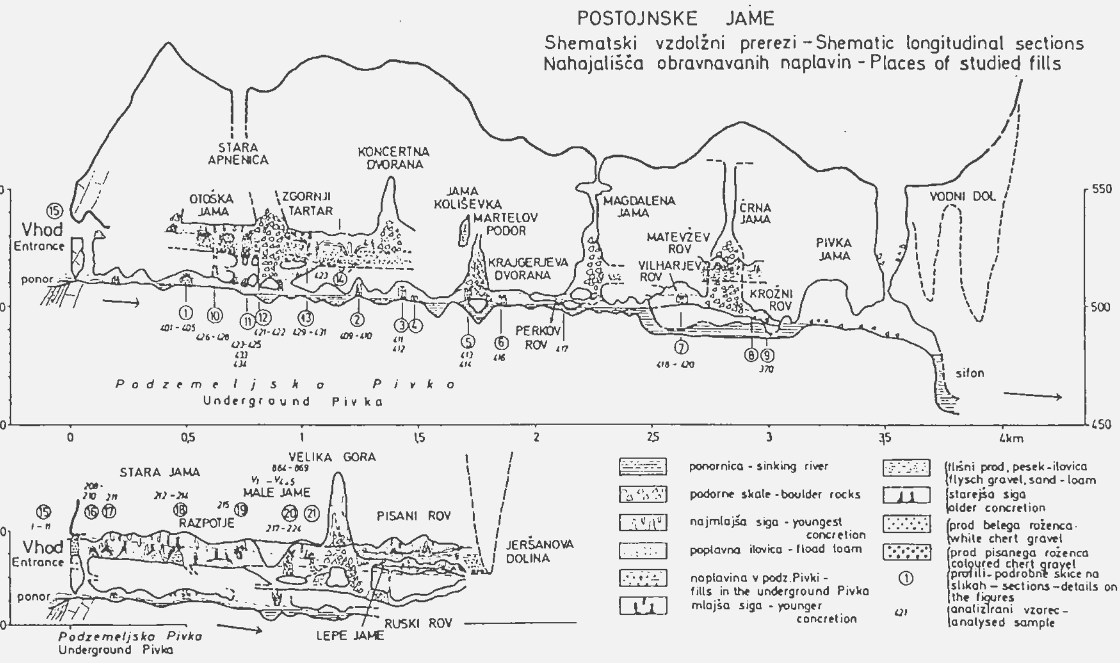

Fig. 5. The Caves of Postojna: schematical longitudinal sections of surface and principal galleries with sediment finding-places (Gospodarič, 1976)

Pleistocene deposits. In the Risovec Cave, near Postojna, paleolithic tools and bones of beaver, elk, and rhinoceros have been found (S. Brodar, 1966).

All these finds, together with the Pleistocene fauna, proves that man inhabited the Pivka Valley at least in the Mindel-Riss interglacial.

Tectonic characteristics

For the Postojna Cave area, the Postojna anticline and, partly, the Studena anticline are particularly important, in both the structural and speleological respect. The underground network of dry and watered passages of the Postojna Cave system crosses the southwestern limb of the Postojna anticline. All touristically attractive parts of the Postojna Cave and underground Pivka passages, from the Perkov rov (Perko Passage) to the Magdalene Cave, are concentrated here.

The crest of the anticline strikes NW-SE and is built of thin-bedded limestones with chert. It is composed of numerous smaller folds, in contrast to well-bedded limestones without chert, which form folds with larger radii of curvature.

In the area of the Postojna Cave, the anticline is divided into two branches. The one crosses the Artificial Passage (Umetni rov) between the Black Cave (Črna jama) and Postojna Cave, as well as the Pisani rov system. The other, stronger one, crosses the Magdalena Cave, Perko Passage, Pretty Caves (Lepe jame), and the beginning of the Pisani rov.

Joints and fissures in the Postojna anticline are much more numerous in the hinge region than in the limbs of the anticline. Two main systems, one striking NW-SE and the other striking SW-NE, and an additional one, striking N-S, are developed (Gospodarič, 1976).

Phases	The Caves of Postojna		Planinska jama		Time
	The Underground Pivka	dry galleries	water channels	dry galleries	
10 9	the bottom deepening into the rock and sediment flood loam, black Mn cover	sinter, 8 000 b. p. concretions collapse, soil subsidence, sediments washing off	deepening of the bottom into the rock till 450 m. at spring, rocky levels, black Mn cover	sinter, concretions collapse, soil subsidence, sediments washing off	Holocene
8	sinter.	sinter, 12 000 b. p.	sinter	sinter	Postglacial
7	allothonous sediments discharge till 3 m/s	breakdown rocks, flood loam and sand	syphons origin, discharge among sediments	flood loam	Upper Würm
6	ponors at 510 m	sinter, 40 000 b. p.	sinter	sinter	Midle Würm
5	ponors at 515 m ?	breakdown rocks, younger laminated loam flysch sand, gravel ponors at 525 m.	younger laminated loam, limestone gravel, Plan. koliševka formation	younger laminated loam	Lower Würm
4		sinter, red loam	sinter, 80 000 b. p.	sinter, 80 000 b. p.	Riss-Würm
3		rubble, ice wedges, white chert gravel, ponors at 530 m.	?	white chert gravel, recent galleries in the rock	Riss
2		?	older laminated loam	older laminated loam	Middle Quaternary
1		coloured chert particles and gravel ponors at 530 m. ?	coloured chert gravel, springs at 460 m.		

Legend
- erosion
- allothonous accumulation
- autothonous accumulation

Fig.6. Development Phases of the Postojna Cave system (Gospodarič, 1976)

From 1991 to 1994 very detailed research in Postojna Cave and its surface from tectonical and lithological point of view was made by Šebela (1989, 1992, 1994).

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5.	1960	17.	1974	29.	1988
6.	1961	18.	1975	30.	1989
7.	1963	19.	1976	31.	1990
8.	1866	20.	1977	32.	1991
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10.	1967	22.	1980	34.	1993
11.	1968	23.	1981	35.	1994
12.	1969	24.	1982	36.	1995

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1956		1,2,3,4	1970		1,2,3,4	1985	32	1,2,3,4
1957		1,2,3,4	1971		1,2,3,4	1986	33	1,2,3,4
1958		1,2,3,4	1972		1,2,3,4	1987	34	1,2,3,4
1959		1,2,3,4	1973		1,2,3,4	1988	35	1,2,3,4
1960		1,2,3,4	1974/75		1,2,3,4	1989	36	1,2,3,4
1961		1,2,3,4	1976		1,2,3,4	1990	37	1,2,3,4
1962		1,2,3,4	1977		1,2,3,4	1991	38	1,2,3,4
1963		1,2,3,4	1978	25	1,2,3,4	1992	39	1,2,3,4
1964		1,2,3,4	1979	26	1,2,3,4	1993	40	1,2,3,4
1965		1,2,3,4	1980	27	1,2,3,4	1994	41	1,2,3,4
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7	1961	19	1976	33	1990
8	1965	20	1977	34	1991
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FIELD BOOK

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BIOTA AND ABIOTA AT THE K/T BOUNDARY IN THE DOLENJA VAS SECTIONS, SLOVENIA

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Introduction

Carbonate beds of the shallow marine environment in the surroundings of the Dolenja Vas village are situated in the Trieste-Komen structural unit. The K/T boundary can be followed in three belts, the first along the SW border of the Vipava valley, the second along its center across Sopada, and the third one in the south, from Padriciano across Lipica to Vremski Britof. In these belts the youngest Cretaceous beds are exposed, and in all but not in the latter also the overlying Paleocene beds (Fig. 1). The territory represents the extreme northwestern region of the extension of the foraminifera *Rhapydionina liburnica* as an indicator of the restricted shelf. This isolated part of the platform was surrounded from north and northeast by a deeper marine depression (Dolenec & Pavšič, 1995), in the south by land (Drobne & Pavlovec, 1991, Delvalle & Buser, 1991), whereas in the southwest pelagic deposits of the shelf slope and basin occur, according to data from boreholes (Premec-Fuček, 1996, this volume).

The considered territory is in the wider sense a part of the Adriatic Carbonate Platform, this is of Adriaticum according to Herak (1986, 1989, 1991), or of the Outer Dinarides according to Placer (1996, this volume). With respect to related Paleogene foraminiferal fauna that can be traced in Dalmatia (Island of Brač, Jelaska & Ogorelec, 1983), on the Apulia, in Greece (Klokova, Tripoliza) (Fleury, 1980; Mavrikas, 1993), the area belongs to connected parts of the same Adria promontory, the intercontinent with a long history of naming and subdivisions (Channell et al., 1979; Cati et al., 1989; Finetti et al., 1989; Herak, 1991).

The present geological position of the considered area is complex. After the deposition of Senonian beds, and even more of Eocene beds, the Adria interplate was shifted from the 30th to the 46th parallel owing the collision of the African plate to European plate. In this process especially in SW Slovenia, along the contact with Dinarides that were thrusted in the direction from NE to SW, on the Adriatic Carbonate Platform very large quantities of gelogical data were lost, covered by overthrusts, or destroyed in the dynamics of evolution (Dercourt et al., 1985; Hottinger, 1988; Dolenec et al., 1995; Marton et al., 1995).

The remainder of the Cretaceous-Tertiary boundary on the Adriatic Platform was utilized for interdisciplinary investigations of biota and abiota with 24 collaborators from 7 countries. The obtained results are presented at this congress (Figs. 2-12).

This paper was realized by the collaboration of K. Drobne (biostratigraphy), B. Ogorelec (lithology, microfacies, partly geochemistry), T. Dolenec (stable isotopes), E. Marton (paleomagnetism), L. Palinkaš (geochemistry of Hg).

Biota

According to paleontological data the carbonate beds are subdivided into the Cretaceous part, the brecciated interval at the Cretaceous/Tertiary boundary, and the Paleocene part (Figs. 2, 3, 4).

Cretaceous unit

The terminal part of Cretaceous beds is characterized by a high diversity of species - rudists, foraminifers and algae. At Dolenja Vas sections 4 rudist genera with 11 species were determined (Pleničar in Drobne et al., 1988, 1995; Pleničar et al., 1992): *Radiolitella* aff. *maestrichtiana, Biradiolites baylei, Bournonia judaica, B. quadripinnae, B. problematica, B. parva, B. retrolata, B. quadrata, Apricardia*. sp. (Pl. 1, fig. 4). With the rudists, and even more often separately from them occur foraminifers. Among the characteristic Mediterranean forms are the most abundant

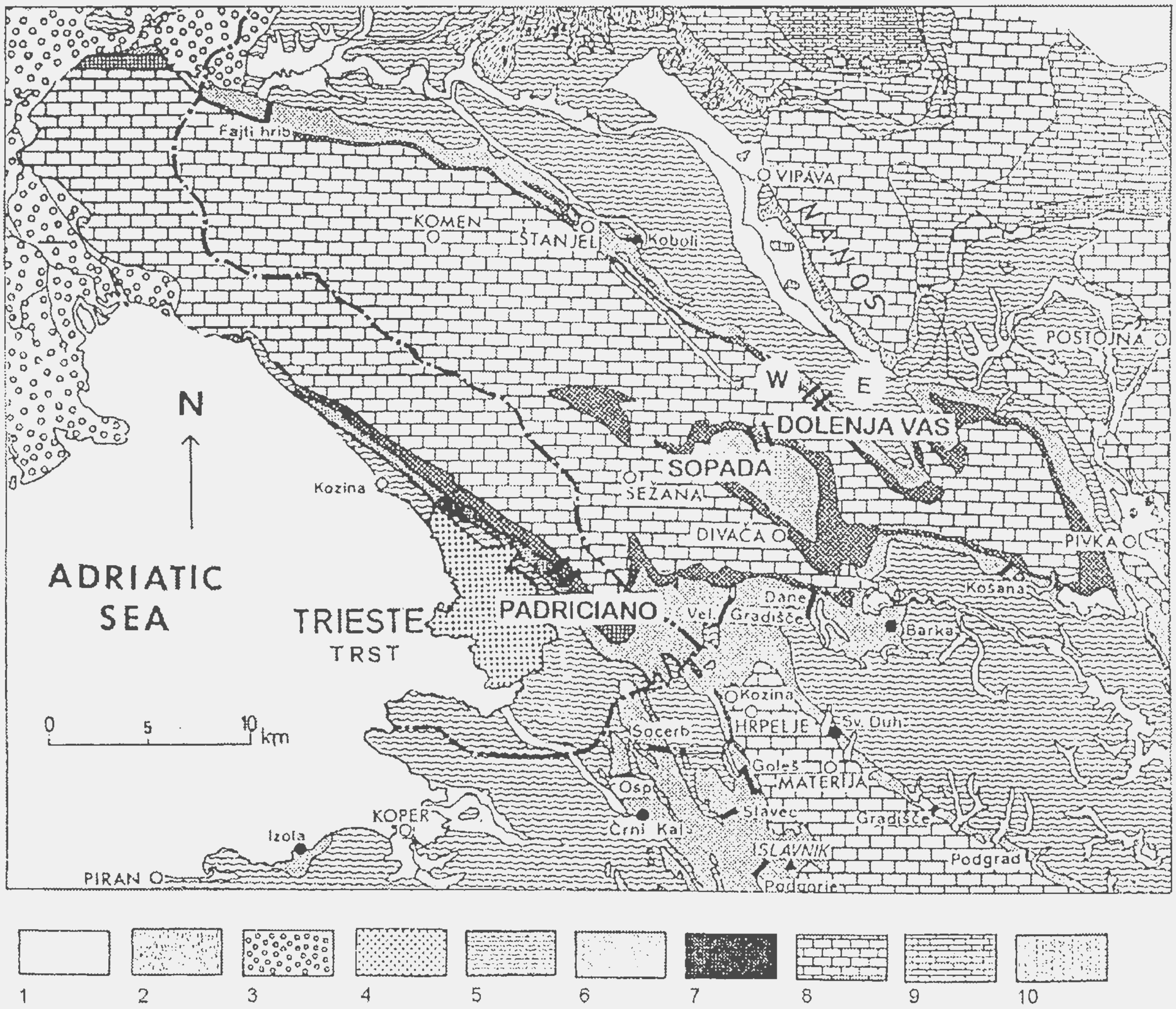

Fig. 1. General geologic map of Karst area (after Drobne ,1977; accomplished by F. Cucchi, cf. Pugliese et al., 1995).
Legend : 1 - Alluvium, 2 - Rubble, 3 - Quaternary teracces, 4 - Pliocene clay, 5 - Paleogene flysch, 6 - Alv.-Numm. Lms, Miliolids and Kozina beds, 7 - Vreme beds (Maastrichtian), 8 - Cretaceous, 9 - Jurassic, 10 - Triassic. K/T sections : Padriciano, Sopada, Dolenja Vas.

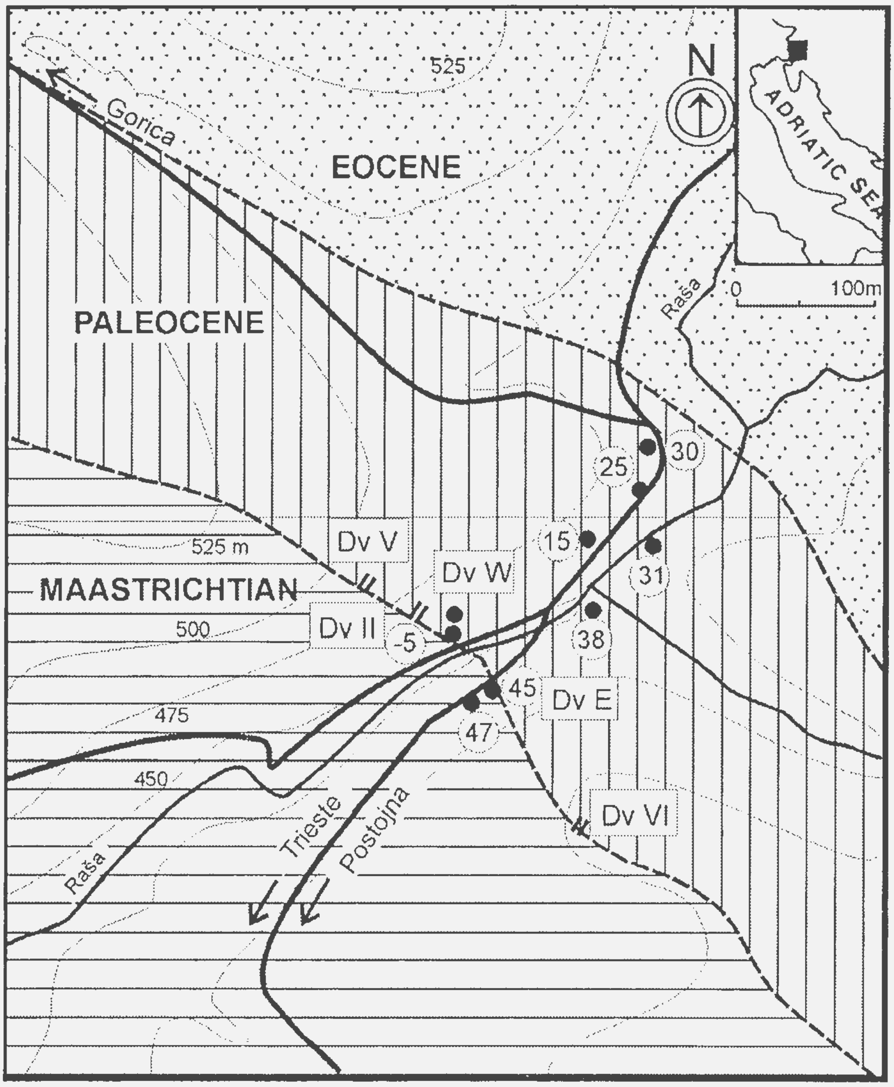

Fig. 2. Location map of the Dolenja Vas sections with the position of the Cretaceous/Tertiary boundary (Geological map simplified after Buser, Grad & Pleničar, 1967; cf. Drobne et al., 1995).

Rhapydionina liburnica with the micro- and megalospheric generations (fA, fB), Cuneolina ketini, *C. cylindrica, Cuneolina* sp., *Bolivinopsis* sp.1, B. sp. 2 , "*Dargenioella*" sp., *Nummoloculina* sp., *Laffitteina menguadi, Fleuryana adriatica, Pseudochrysalidina* sp., *Gyroconulina* sp. Locally very abundant are miliolids with massive tests, polymorphinids and discorbids (Drobne et al. 1994) (Pl. 1, figs. 3,4).

Most characteristic of the central part of the Tethys and the Mediterranean are *Rhapydionina liburnica* and *Fleuryana adriatica* (De Castro et al., 1994). The marine connection with Near East provided *Cuneolina ketini* and *C. cylindrica,* as well as *Gyroconulina* sp.; the latter was established in the central and southern belt of Cretaceous/Tertiary boundaries (Sopada, Padriciano) (Pugliese et al. 1995). The genus *Laffitteina* could be considered cosmopolitan, as it is known from Near East to the Atlantic Ocean in the Pyrenees (Fleury et al., 1985). Among the algae occur, according to determinations by F. Barattolo (cf. Drobne et al., 1989; cf. Pugliese et al., 1995), Charophyta, *Thaumatoporella* sp., *Aeolissacus barattoloi* as Mediterranean forms, and *Acroporella chiapasis* as transatlantic species.

Breccia interval

In the breccia complex appear in clasts the Cretaceous forms, and in the matrix the elements or overgrowths of *Paronipora* sp., frequently also tiny discorbids accumulated in small depressions in the sea bottom. During the entire deposition of breccia indications of marine environment with the elements of the subtidal manifested, as the shrinkage pores (Pl. 1, fig. 2).

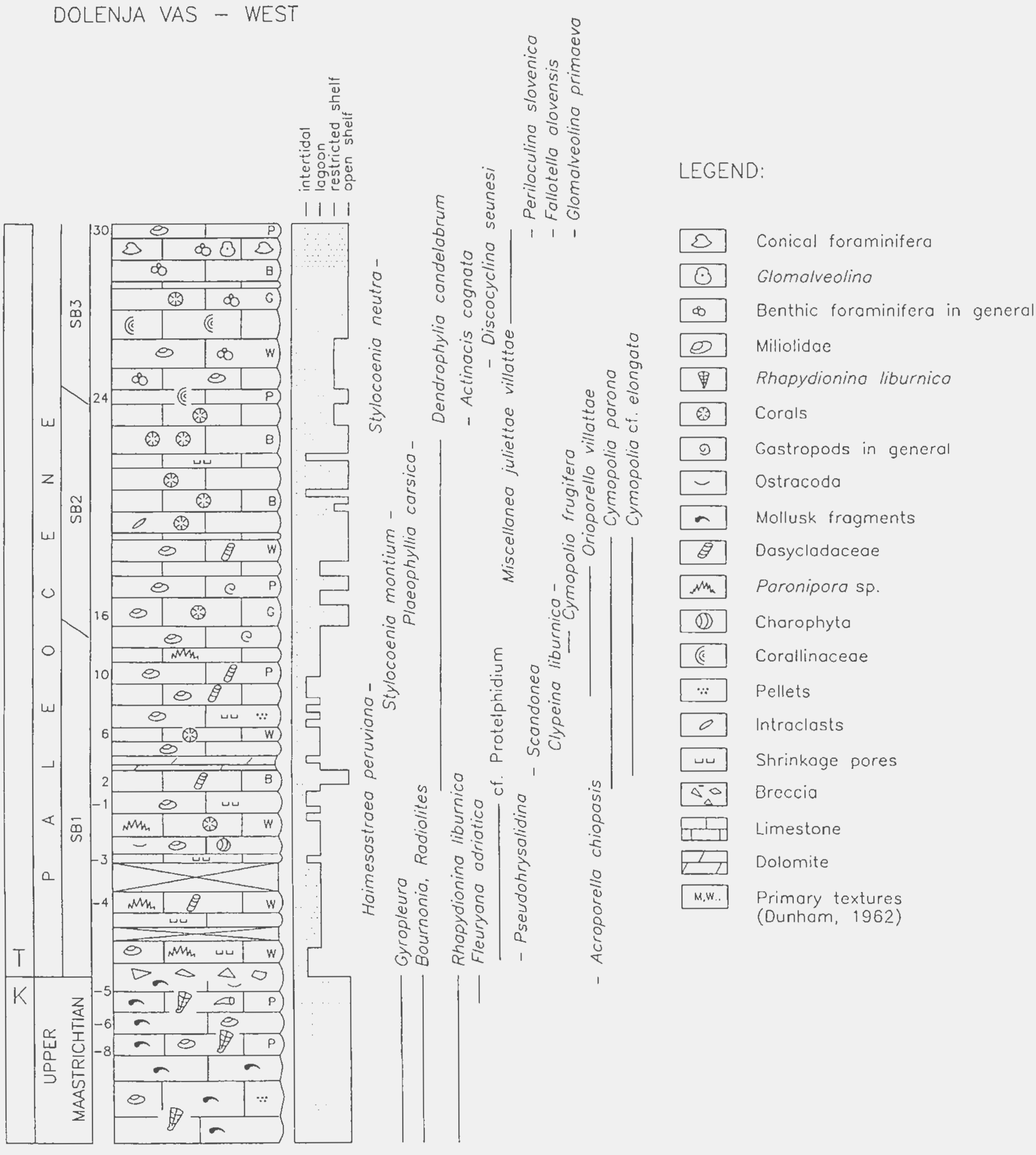

Fig. 3. Stratigraphical column of the Dolenja Vas section - W. Lithology, depositional environment, biota (Algae, Foraminifera, Corals) and shallow benthic zones (SB, Serra - Kiel et al., in print) (amended after Ogorelec and Drobne, in Jurkovšek et al., 1996)

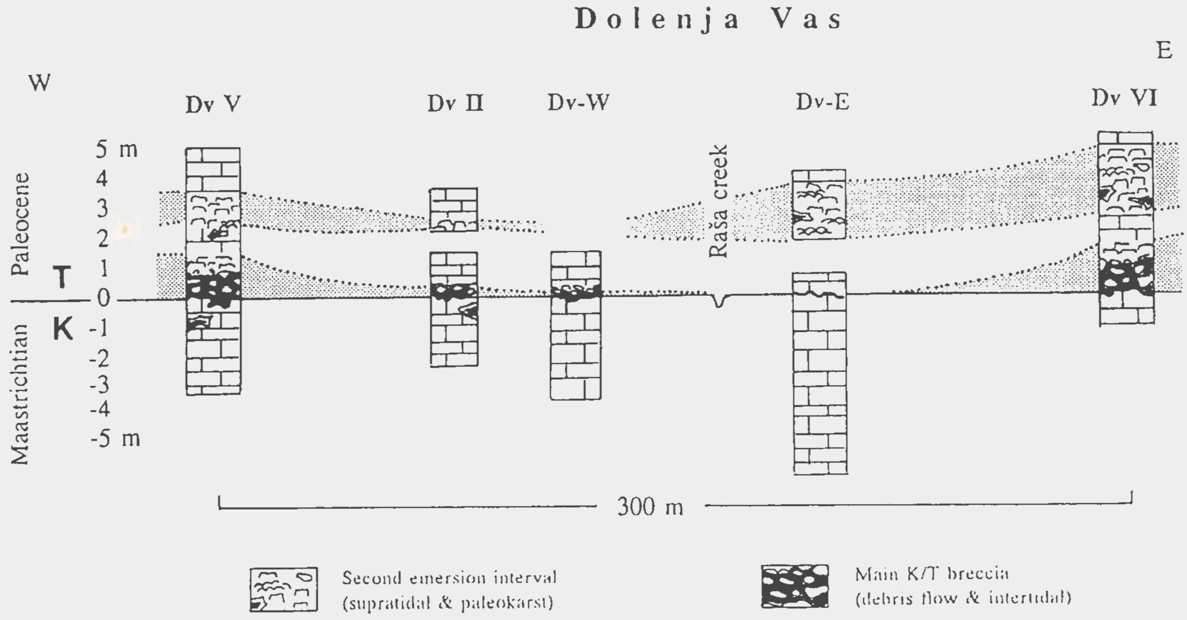

Fig. 4. Shematic presentation of K/T emersion events in 5 sections at Dolenja Vas.

Paleocene unit

The breccia (debris flow, according to Hansen et al, 1995) is overlain by Paleocene beds of dark to light brown silty limestones of highly diverse sedimentary textures (Pl. 1, fig. 1). The fossil inventory is very modest. It is represented by small miliolids, discorbids, seldom also plankton, as a guest in this environment. Prominent among foraminifers is *Protelphidium* sp. It can be considered by its large size and rounded peripheral margin as ancestor of *P. hofkeri* from Thanetian formation. *P. hofkeri* was assigned to the zone P4 in the Selandian Stage, Reculver Silts (Banner & Culver, 1978). In the assemblage occur also *Pseudochrysalidina* sp., *Scandonea* sp., small miliolids and polymorphinids, and in bioturbation fillings also *Paronipora* elements.

Discussion of age of biota

For numerous genera and species from the Cretaceous carbonate beds there is no doubt they belong to the upper part of Maastrichtian. Lj. Šribar and M. Pleničar (1990) established in the SW Slovenia the *Rhapydionina liburnica* zone. It is of shallow marine environment that consists of a parallel zone with orbitoids in a more open shelf.

Hansen and others (1995) proved with the magnetic susceptibility curve in the Dv W section the terminal part of Maastrichtian. Marton detected in all analyzed samples the Ch 29R, for the Cretaceous and Paleogene part of the beds (Marton et al. 1995).

The time of deposition of the breccia remains open. Evidently, first the disintegration of the platform surface was needed, followed by transport of material. The highly varying thicknes of breccia at small distances (Fig. 4) and repeating occurrence speak in favor of differentiation of the sea bottom during deposition. Increased mercury in the carbonate rocks sequence (Fig. 12) and iridium in the breccia bed (debris flow) suggests the association of formation of breccia with the impact of a bolid (Hansen et al. 1995, Palinkaš et al. 1996, this volume).

The age of Paleocene beds was determined indirectly. Positive proof for Paleocene is the appearance of genus *Protelphidium* sp., and negative proof the disappearance of a large number of

Cretaceous macro- and microfauna. As species that survived from the Cretaceous the algae *Aeo. barattoloi* and *A. chiapasis* are present. Also triangular form of *Pseudochrysalidina* sp. survived across the K/T boundary, and it occurs in the Lower Paleocene beds (Fleury, 1980; cf. Pugliese et al., 1995). After the paleontological data the sequences of beds above the K/T boundary could be attributed to the SB 1, SB 2, SB 3 shallow benthic zones, that is from the Danian to Thanetian stage (Serra-Kiel et al., in print) .

The development of Paleocene beds from Maastrichtian to Thanetian at Dolenja Vas with selected genera and species is shown in Fig. 3, that was prepared for the recently issued monography on the geology of the southern part of the Trieste-Komen plateau (Jurkovšek et al. 1996). Details from the biota of Paleocene time are given in the description of the Padriciano section on the platform SW of Dolenja Vas, about 20 km away (Brazzatti et al. 1996, this volume).

Lithology and microfacies

The Cretaceous-Paleogene limestone transition at Dolenja Vas can be observed in six sections at the distance of 300 metres (Fig. 4). The four sections, having a few metres of thickness, follow each other under and above the boundary and are located in the forest W of the Raša creek. The other two sections outcrop along the road and in the crest in the eastern part of the study area.

The Maastrichtian limestone is moderately thick-bedded (10 to 80 cm) and light olive gray in colour. According to its texture limestone is a gently washed biomicrite and pelbiomicrite of the wackestone - packstone type, deposited on a very shallow and relatively well aerated platform. The influence of the open pelagic environment is indicated by calcispheres. Carbonate content varies from 96 to 99 % of $CaCO^3$. Valves of pachyodont pelecypods are often fragmented and were subjected to intensive endolithisation.

The rock just below the K/T boundary is somewhat darker. It is still biomicrite to pelbiomicrite. The influence of more restricted environment with some freshwater influence is indicated by ostracods and characeans. The content of organic matter in comparison to the rock below reaches up to 1.5 %. This rock is characterised by intensive bioturbation in the sediment surface during deposition, and by pyrite framboids which indicate anoxic conditions in very early diagenesis.

The K/T boundary at Dolenja Vas is marked by a hardground (section Dv-E along the road) or by an up to 0.7 m thick layer of intraformational conglomeratic breccia (section Dv-W). The breccia fragments are up to 10 cm in diameter and show diverse degree of roundness. In the basal part of breccia they consist mostly of biomicritic rudistid limestone of the Maastrichtian age. After Hansen et al. (1995) this breccia is interpreted as "debris flow", whereas in the upper part the breccia has more the characteristics of supratidal flat pebble conglomerate. The matrix itself is biomicritic, containing frequent *Paronipora* colonies and pyrite framboids. *Paronipora* is in some places filling also up to a few cm large corrosion voids, that indicate paleocarstification phases. Such a plastic "supratidal breccia" accompanied by numerous shrinkage pores disiccation cracks, thin stromatolite layers, intensive bioturbation and *Paronipora* colonies occurs at Dolenja Vas not just in the K/T layer but also in the second layer, one or two meters above the boundary (Fig. 4). Hansen et al. (1995) estimated the time of the emersion in the K/T layer on the basis of magnetic susceptibility measurements in Dv-W section at about 40 k.y. (Figs. 8, 10).

Subaerial exposure in the time of K/T events on the same parts of the NW Adriatic Platform is evident also from palynological data. Kedves (in Pugliese et al. 1995) observed reworked old Paleozoic species, mostly *Trachysphaeridium laminaritum*, and a probably Triassic form *Craterisporites* sp. The reworked sporomorphs are concentrated in the lowermost Danian (SB 1) and Thanetian (SB 3) beds. These finds suggest a large subaerially exposed land of Paleozoic and Triassic layers on the background of the area.

According to gypsum crystals and crusts, as well as collophane traces very warm semiaride climate can be conjectured that time on the Adriatic Platform. Traces of phosphate mineral collophane are observed as tiny brown nests in some layers.

Limestone of the Lower Danian age is dark gray to black coloured and contains over 92 % of carbonate. Texturally it is still biomicritic to biopelmicritic (mudstone to packstone, according to the content of fossils and other allochems). Limestone was deposited under very low energy conditions in the littoral lagoonal environment, episodicaly disturbed by inter- and supratidal conditions. Sediment was intensively bioturbated, whereas small planktic foraminifers still show the connection with the open shelf.

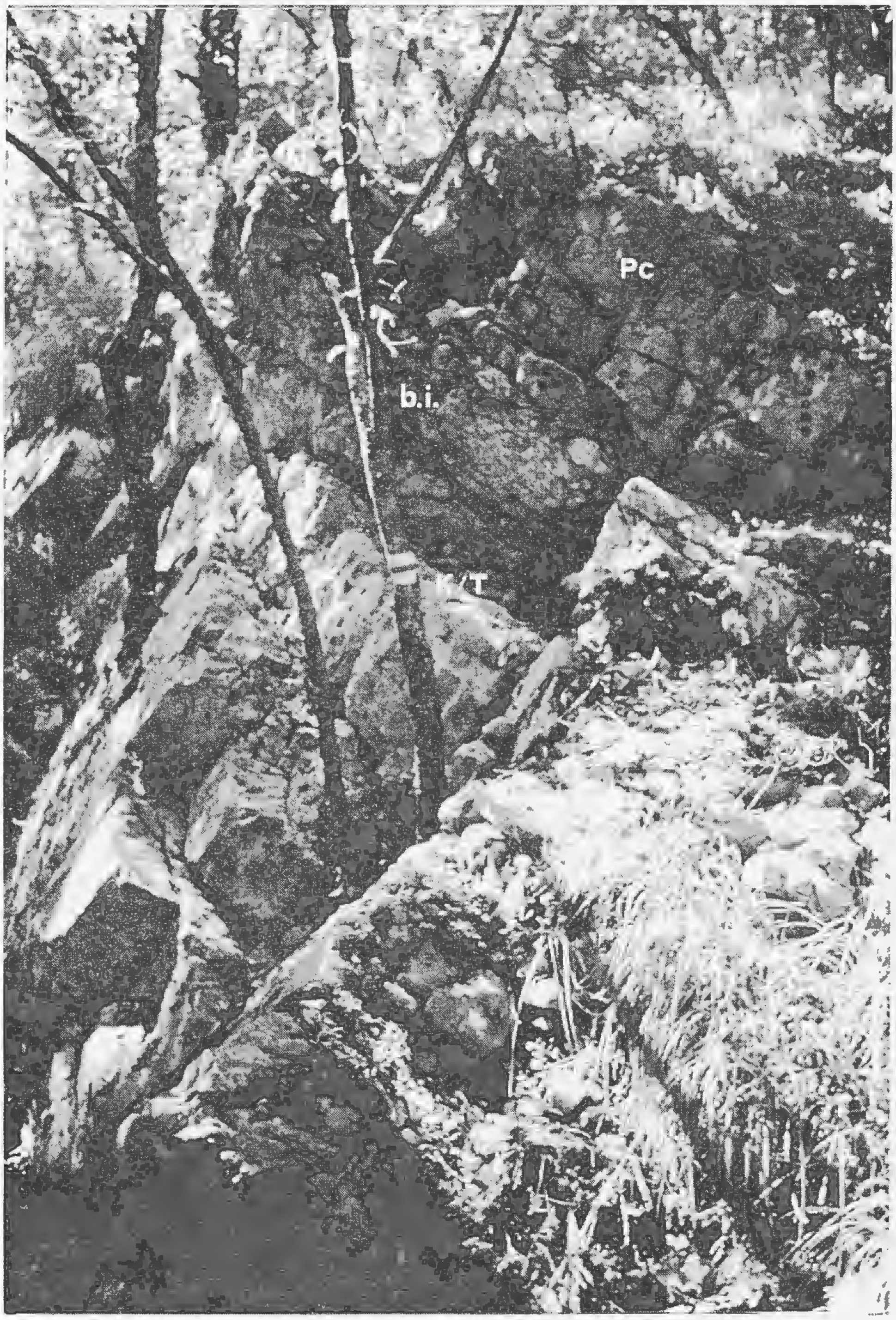

Fig. 5. Dolenja Vas II section, with K/T boundary, breccia (#4), Paleogene beds (#5, #6) and Maastrichtian part below the K/T boundary. Note the boreholes for paleomagnetic analyses. (Photo K. Drobne)

Carbon and oxygen isotopes

The study of carbonate isotopic composition in limestone samples from the K/T boundary in sections Dv - West and Dv II shows the major shift of $\delta^{13}C$ from -0.43 ‰ to -8.15 ‰ (PDB), while $\delta^{18}O$ mostly remains unchanged and varies only in a narrow range from +25.64 ‰ to +26.57 ‰ (SMOW). In terms of amplitude, the $\delta^{13}C$ depletion across the K/T boundary is of around 8 ‰. A rapid drop of $\delta^{13}C$ begins about 80 cm below the K/T boundary in both investigated sections (Figs. 6, 10). This negative excursion of $\delta^{13}C$ is terminated 50 to 120 cm above the K/T boundary, where it returns to positive values. These isotopic anomalies most likely suggest the strong influence of light terrestrial carbon in sedimentary basin at the time of K/T transition that is related to global climatic changes caused by the impact of an extraterrestrial body (Alvarez et al., 1980), followed by the destruction and combustion of terrestrial plants. A negative, but not so large $\delta^{13}C$ excursion of K/T boundary sediments toward lighter values has been reported also from other K/T boundary localities on the carbonate platform (Delvalle & Buser, 1990) and hemipelagic and flysch sediments (Letolle & Renard, 1980; Magaritz, 1989; Keller & Lindinger, 1989; Dolenec & Pavšič, 1995).

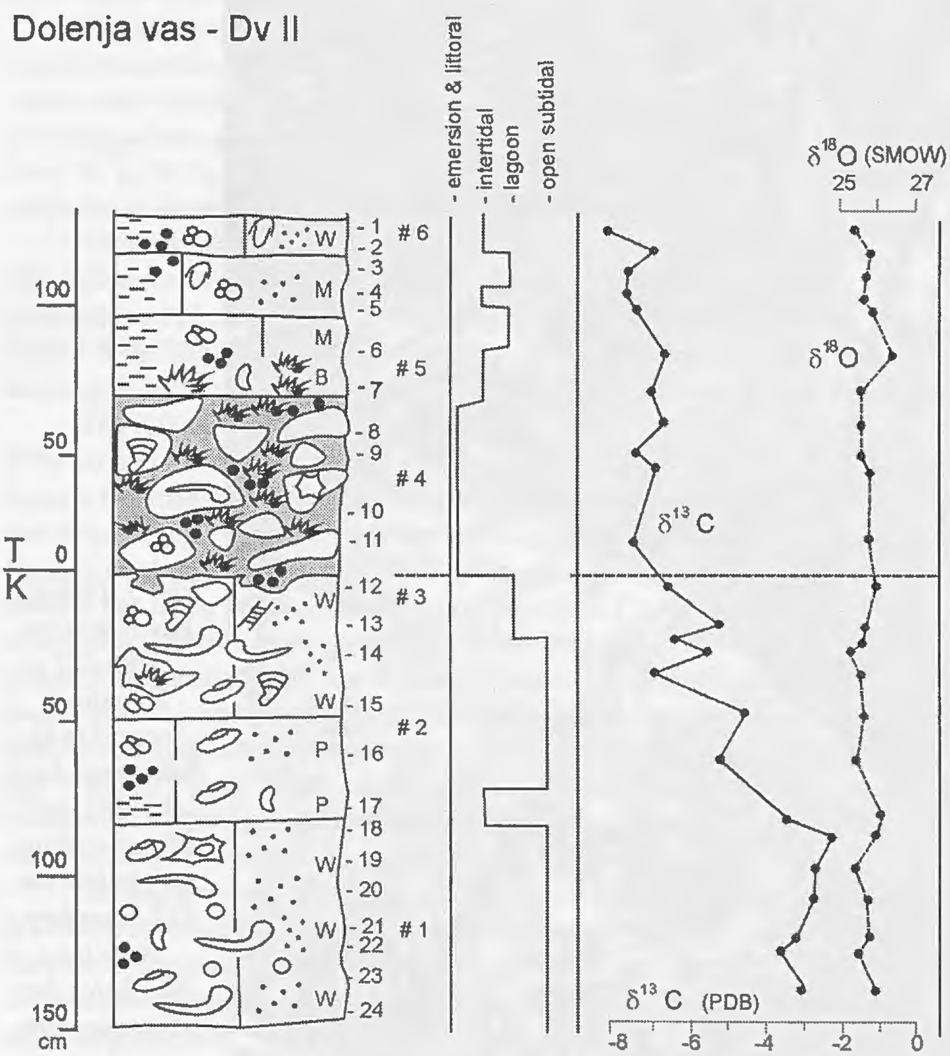

Fig. 6. Dolenja Vas II section, lithology, microfacies, depositional environment, $\delta^{13}C$ and $\delta^{18}O$ of carbonate. Legend see Fig. 10.

Geochemistry

Preliminary geochemical analyses of 8 samples in the section Dv - W were focused on a three meter interval of the K/T transition. Samples were analysed on 32 elements, and 6 of them included also determination of rare earth elements. According to the high carbonate content in

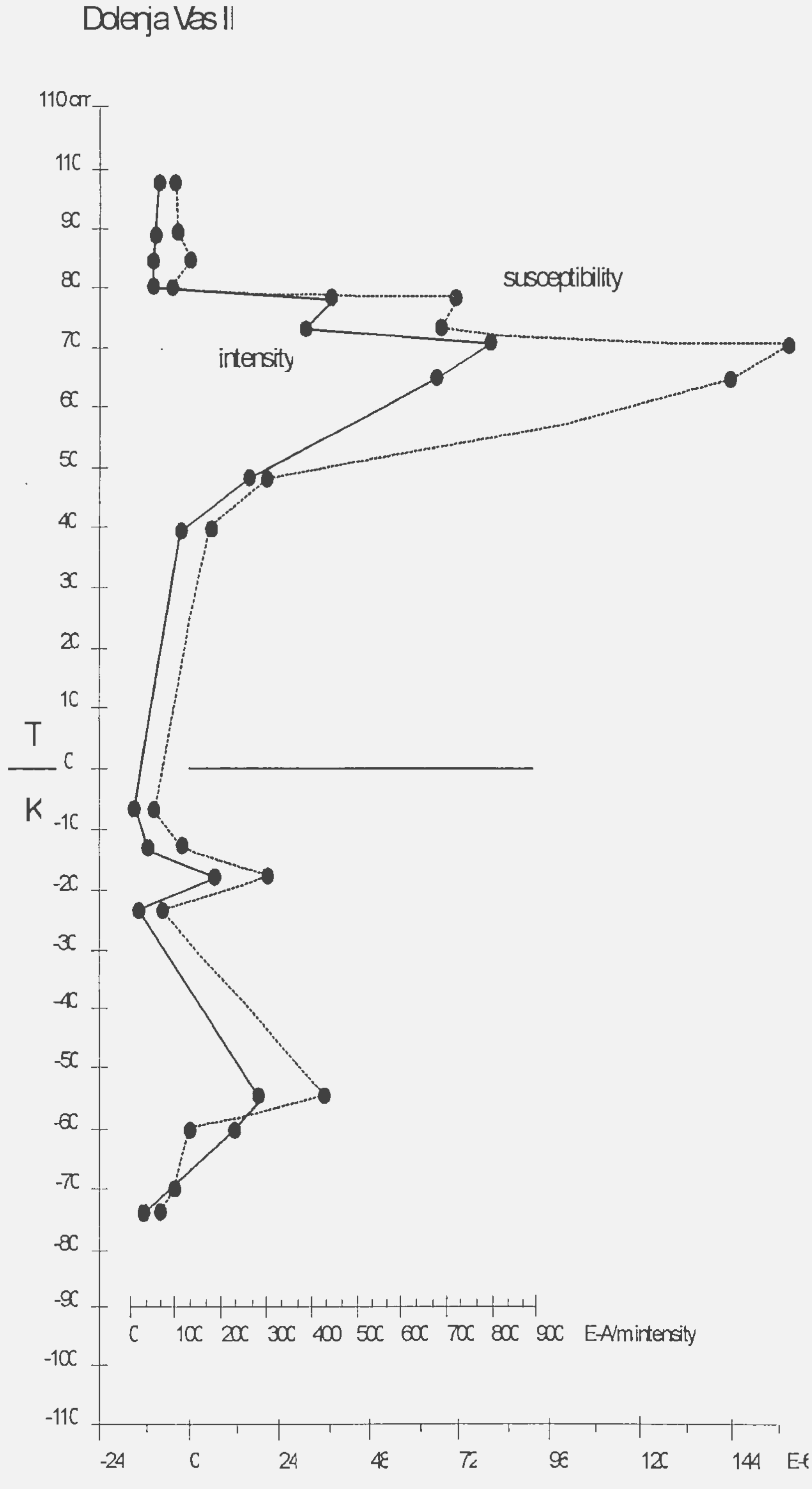

Fig. 7. Susceptibility and intensity of remanence in Dolenja Vas II section.

the rock (over 54 % of CaO) no special distinction can be observed below and above the K/T boundary as previously expected. Neverthless there is a two- to threefold increase of Ga, Co, Ni, V, Sm and Zr contents 60 cm below the K/T boundary (Ba 50-450 ppb, Ni 3-12 ppm, Co 6-32 ppm, V 10-85 ppm, Sm 8-25 ppb and Zr 10-45 ppm). Rare earth element content of all investigated limestone samples is below or around 0.1 ppb, while of some other incompatible elements (Os, Rh, Pb, Pd) the amount is also below 1 ppb, except for Re (1-3 ppb).

The content of iridium is in investigated samples lower than 0.2 ppb. Inspite of all that somewhat higher content of Ir can be expected in the limestone of the K/T boundary since Hansen et al. (1995) observed appreciable higher values (5.8 ppb Ir) in the carbon fraction of the K/T breccia. Therefore, additional detailed analyses are planned.

The 39 rock samples were collected along the eastern and western Dolenja Vas sections (Dv - E and Dv - W) at an irregular distance from the K/T boundary (Fig. 12) (Palinkaš et al., this volume). The concentration of Hg spans between 6 and 290 µg/kg. The maximum was achieved in the uppermost Cretaceous level of Dv - E section with the Paleocene limestone. The matrix of K/T breccia itself contains even higher concentrations, 428 µg/kg Hg. The Hg anomalies in the Dv - W section are less expressive. The natural impact of Hg into environment is via volcanic activity, thermal fluids and degassing of the Earth's mantle.

The data of the activity of natural radionuclides in the section Dv - W (19 samples) show the variation from 12 - 47 Bq/kg (Giacomich in Ogorelec et al., 1995). The Maastrichtian limestone shows relatively higher values than those above the K/T boundary. The studied data are lower in comparison to those obtained in the Padriciano section where they vary from 23 to 97 Bq/kg. The measurements are related to the activity per mass unit of each sample. They concern the γ radiations from ^{210}Pb and ^{214}Bi in hypothesized secular equilibrium with ^{226}Ra and ^{238}U.

Fig. 8. Dolenja Vas - West section, the top 2m of Cretaceous unit with K/T boundary. In the upper part of the section note the breccia interval (b.i.) and Paleocene unit (Pc). (Photo K. Drobne)

Paleomagnetism

In the years 1993 - 95, 84 paleomagnetic samples were collected from the Dolenja Vas sections close and across the K/T boundary. In all, Dolenja Vas II, West and East section it was only the samples collected at and close to the K/T boundary that possessed meaningful paleomagnetic signal. All these samples had reversed polarity, 18 of them practically free of overprint, while 7 additional samples had slight, but unremovable overprint of normal polarity. Thus, the polarity observed at and close to the K/T boundary at Dolenja Vas corresponds to the reversed polarity zone observed elsewhere for the corresponding time interval.

Concerning the magnetic susceptibility and the intensity of the remanent magnetization, it is extremely weak, except at and close to the K/T boundary, where peaks are observed.

The paleomagnetic mean direction for Dolenja Vas after tectonic correction, is consistent with those observed for several localities in the same area: mean paleomagnetic direction for localities Razdrto, Dolenje-Štjak, Dolenja Vas (Marton et al., 1995), Volčjigrad, Kazlje, Brestovica (Jurkovšek et al. 1996) show remarkable consistency (with positive fold test) after tectonic correction: they all show moderate - up to 28°- clockwise rotation.

Conclusions

With the interdisciplinary studies of the K/T transition in the Dolenja Vas sections the following conclusions can be made:

Lithologically the rocks are solid, hard, at about 0.80 to 0.50 m below the K/T boundary, and disintegrated in the uppermost part of the Cretaceous unit across the breccia interval and also in the lowest Paleocene unit.

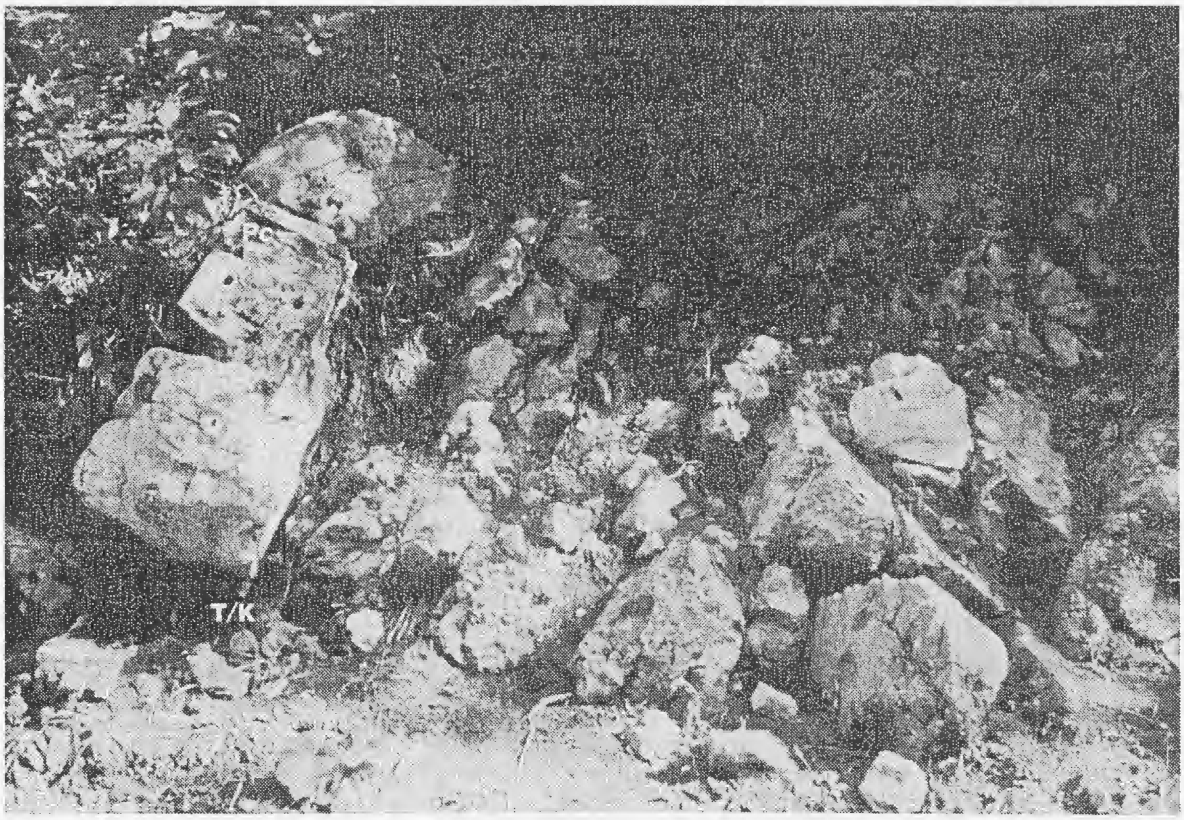

Fig. 9. Dolenja Vas - East section, the top 2m of Cretaceous unit with K/T boundary, without breccia interval, overlain by Paleocene unit (Pc). (Photo K. Drobne)

Microfacial analyses document a shallow depositional environment at the end of Maastrichtian time, and supratidal to very shallow conditions during the sedimentation of Paleocene breccia and lowermost limestone.

Paleontological studies reveal a high diversity of species (rudists and foraminifera) of Maastrichtian age in the hard, solid rocks, and a gradual decrease in presence of biota upsection to the K/T surface. The first appearance of new species is sporadical at different distances from the top of breccia interval. As a rule there occur small dasyclydaceans, discorbids and *Protelphidium* sp.

The carbon isotope curve from carbonate shows an intensive up to $\delta^{13}C = -8‰$ negative shift that expresses an instable environment across the K/T transition. An increase of trace elements characterize the layer below the top of Cretaceous unit. The highest value of Hg is recorded on the K/T surface. An enrichment of iridium is observed in the breccia interval. On the basis of

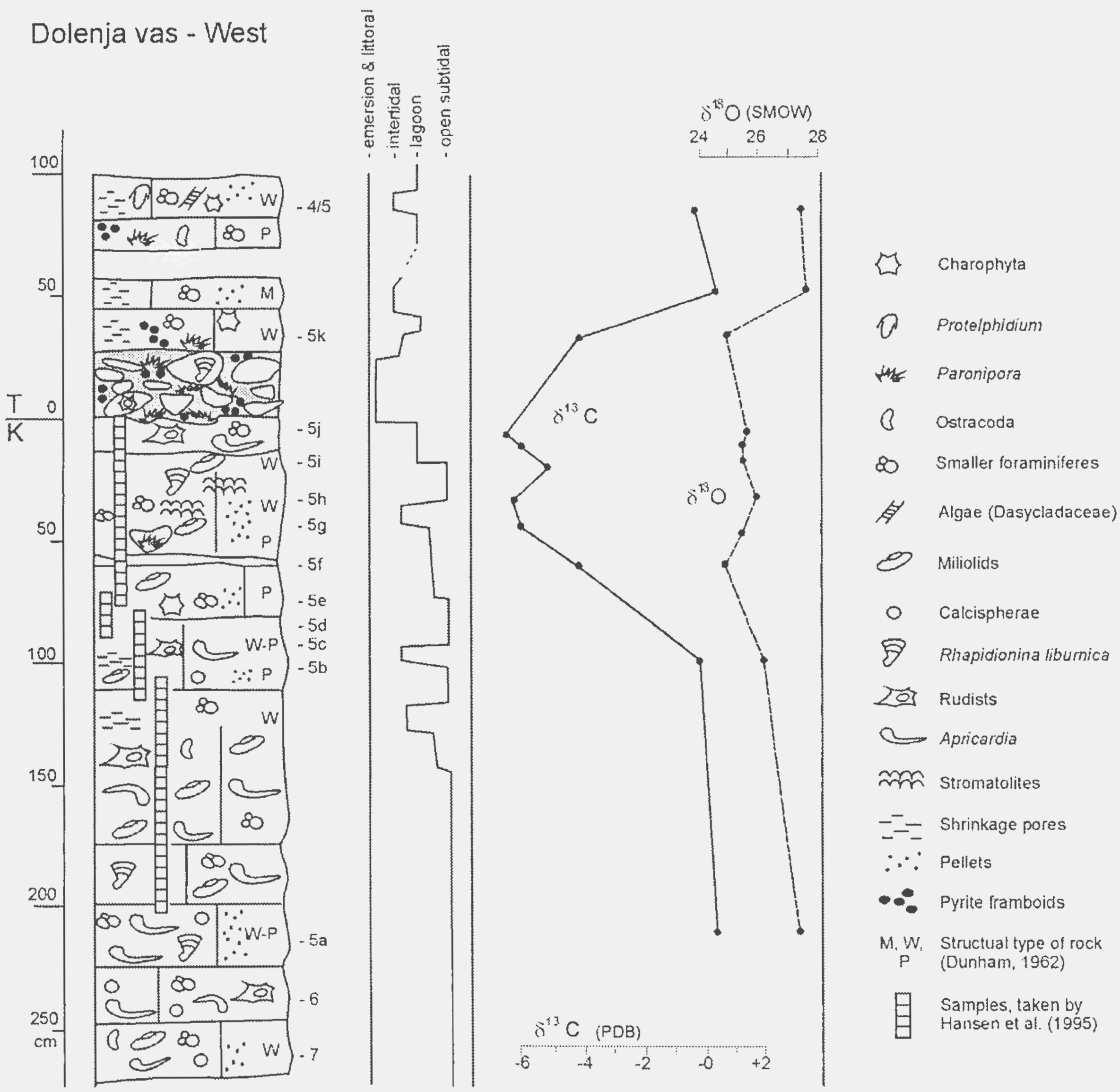

Fig. 10. Dolenja Vas - West section, lithology, microfacies, depositional environment, $\delta^{13}C$ and $\delta^{18}O$ values of carbonate.

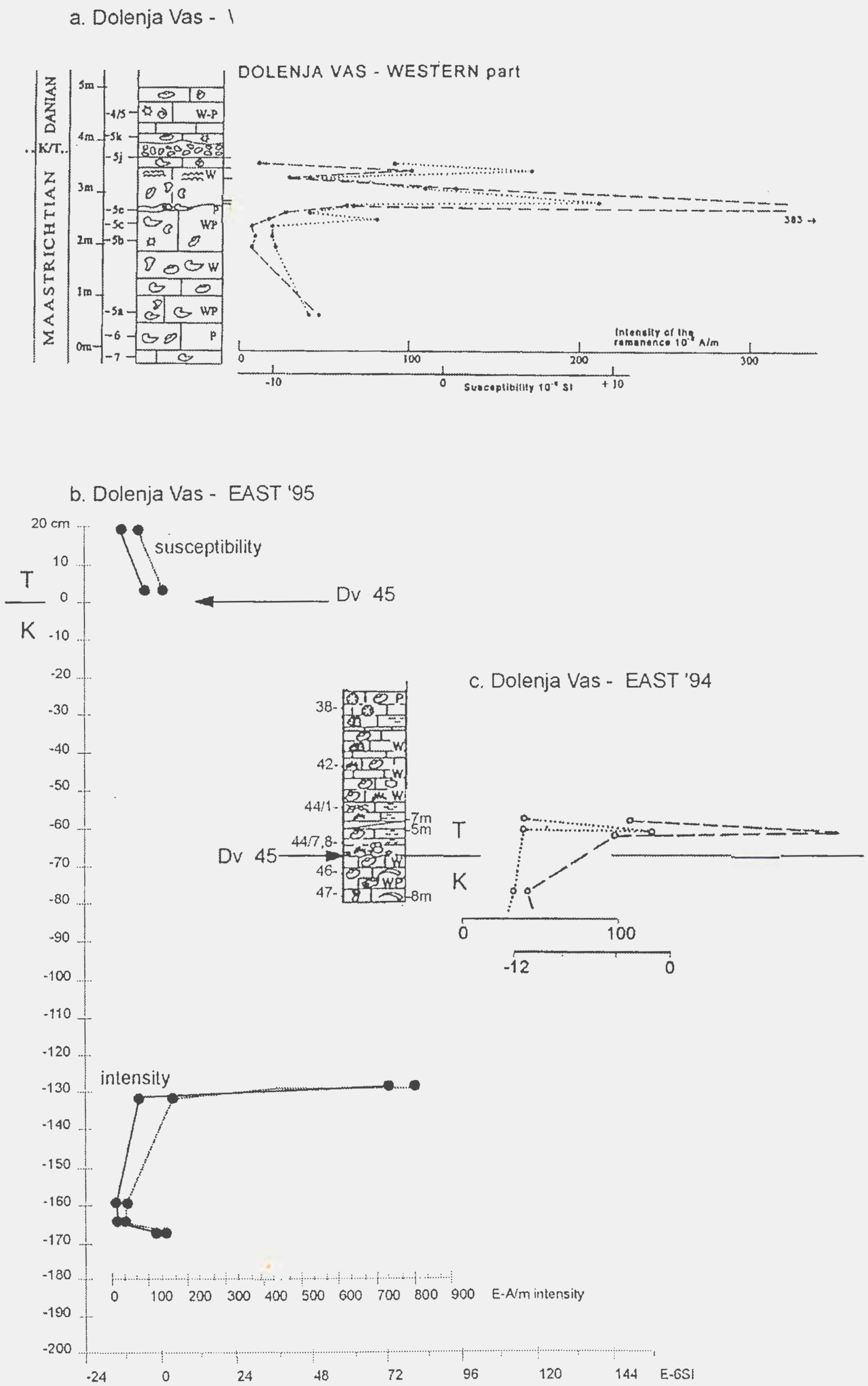

Fig. 11. Susceptibility and intensity of remanence in Dolenja Vas - West and Dv - East sections (a: sampled in 1994, b: 1995).

isotopes long-term events can be inferred, while higher values of Hg suggest more episodic events at the K/T boundary.

The duration of breccia interval could be estimated in a time span from 40 to 200 k.y. with respect to the magnetic susceptibility curve and the established Ch 29R for the entire carbonate sequence, below and above the breccia.

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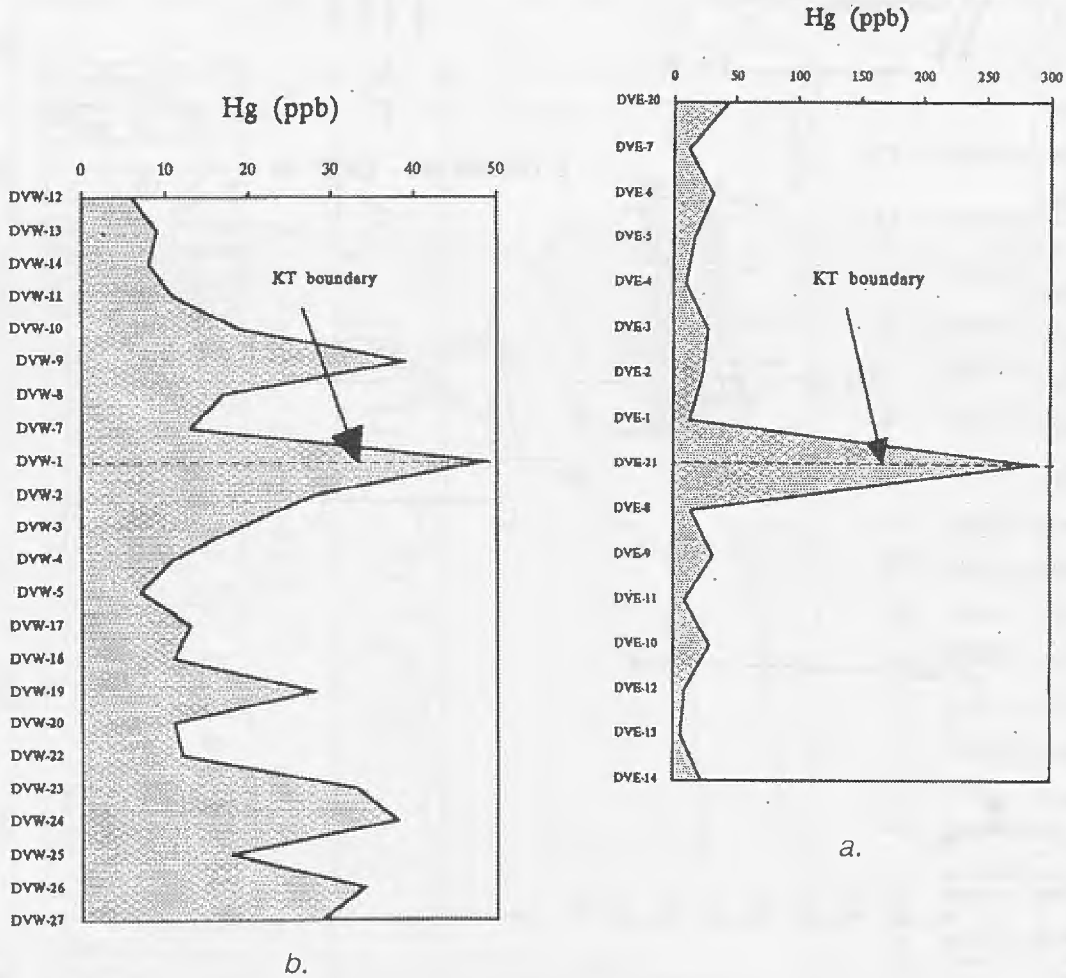

Fig. 12 a, b. Content of Hg (ppb) in the sections of Dolenja Vas. Sample number is given on vertical axes. For sample distance from K/T boundary see Tables in Palinkaš et al. 1996, this volume. (a: Dolenja Vas - East, b: Dolenja Vas - West).

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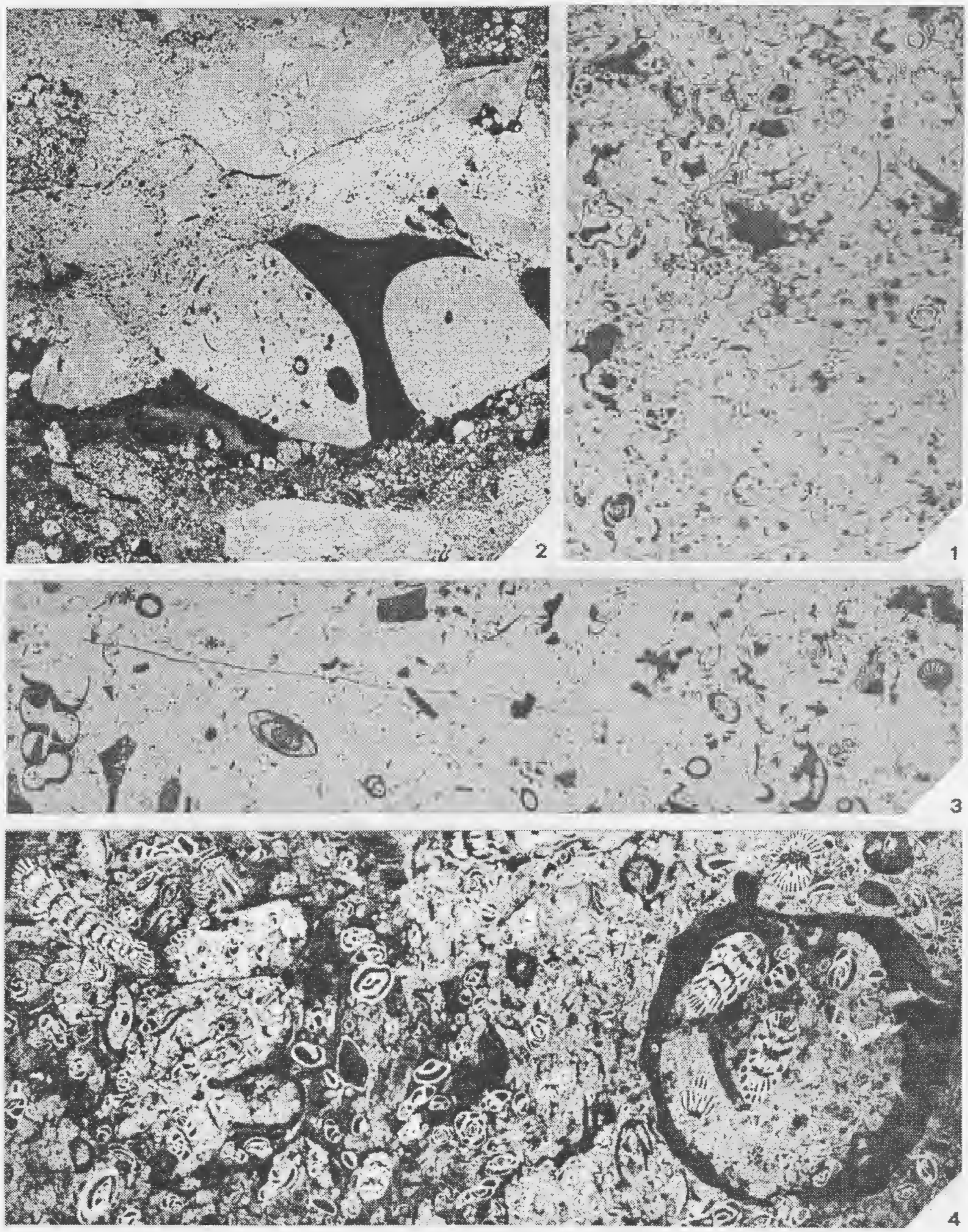
Plate 1

Fig. 1. Paleocene biomicritic limestone including foraminifers *Scandonea* sp., *Pseudochrysalidina* sp.(arrow). Shrinkage pores are filled by A and B generations of rim cement. Dv II/1, x 10.

Fig. 2. K/T breccia partly with rounded clasts of Cretaceous limestone, and Paleocene clasts. Matrix is micritic with *Paronipora* partly sparitic, voids are filled by sparite. Dv W/K/T-10981, x 5

Fig. 3. Micritic limestone with dasycladaceans, foraminifers *Laffitteina menguadi*, gastropods. Dv V/Rh 1, x 10

Fig. 4. Biomicritic limestone with *Rhapydionina liburnica*, dissolved mollusc shell filled by sparitic calcite, Dv W/9-10999, x 10. all in incident light, coll. K. Drobne, photographs by M. Zaplatil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ŠKRBINA (KOMEN LIMESTONE) THE FIRST PELAGIC EPISODE (CENOMANIAN - TURONIAN TRANSGRESSION)

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Introduction

A peculiarity of the carbonate succession, occurring in the central part of the Trieste - Komen plateau, is dark coloured laminated and platy limestone with chert, known as Komen limestone (Fig. 1, 2; Pl. 1, Fig. 1). At the end of the past century some horizons with excellently preserved fish skeletons were found. Gorjanović-Kramberger (1885) determined 17 fish species and this work made the Komen limestone famous in geologic literature.

Recently, the Komen limestone is quoted as evidence of the Second Cretaceous oceanic anoxic event (OAE 2; Jenkyns, 1991). However, until the present, no complex study has been done yet but only some partial interpretations of the sedimentary environment (Buser, 1973; Ogorelec et al., 1987; Šribar, 1995; Jurkovšek et al., 1996). In our opinion the Second Cretaceous oceanic anoxic event (OAE 2) and global Cenomanian-Turonian sea level rise (Haq et al., 1987) can only

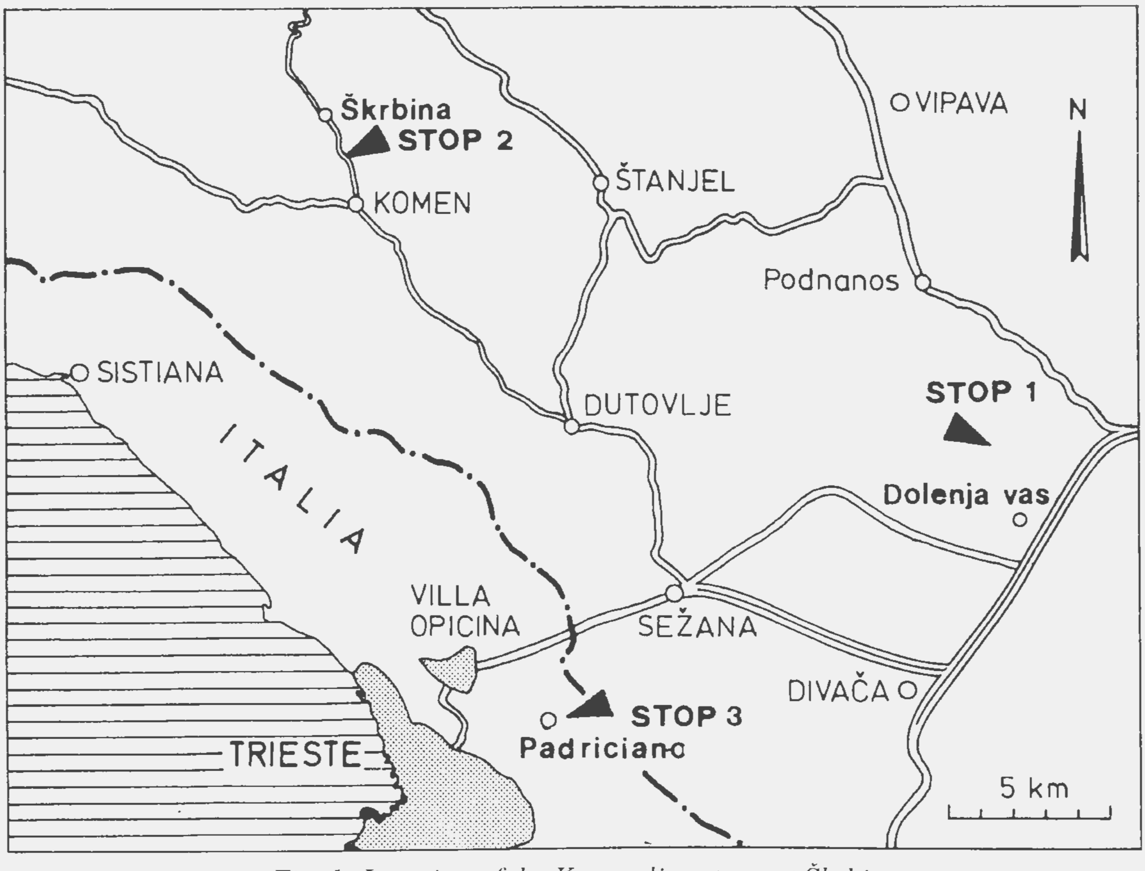

Fig. 1: Location of the Komen limestone at Škrbina

be related to the older part of the Komen limestone of the central part of the Trieste-Komen plateau.

Lithology and depositional environment

According to its texture the Komen limestone is most commonly biomicrite or biopelmicrite (mudstone - wackestone). Sparse and rather uncharacteristic benthic fauna, as well as the absence of bioturbation indicate, that fairly anoxic conditions predominated in the sedimentary environment. Pyrite pygmentation, dispersed organic matter and well preserved fish skeletons indicate the presence of anoxic physiological regime as well.

Within some levels - mainly in the basal parts of the Komen limestone (Fig. 1), sheets of laminite (Pl. 1, Fig. 4) and sometimes also stromatolite or flat pebble supratidal conglomerate occur. These lithologic varieties indicate the episodic shallow littoral environment. Some strata of fine-grained conglomerate show the characteristics of tempestites with graded bedding structure, formed by accumulation of plasticlasts - particles of not completely consolidated carbonate mud (Pl. 1, Fig. 3). Some sheets of laminites contain numerous pelagic fossils - calcispheres, some saccocomas, and ammonites which undoubtedly indicate episodic and intensive connection with the open sea (Pl. 1, Fig. 2; Pl. 3, Figs. 1-3). In the upper part of the lower sequence of the Komen limestone, calcispheres are frequent, and the laminated limestone is interbedded with calcispheral limestone.

Locally, concretions and thinner sheets of cherts also occur in the Komen limestone. The chert is of gray to black colour and of micro- to cryptocristalline texture. The primary rock texture is partially preserved. It was probably formed during early diagenesis due to alternating pH conditions in the littoral lagoonal environment.

Although the Komen limestone is bituminous, the C_{org} values of the rock are relatively low, ranging from 0,4 to 2 %.

Comparison with similar lithologic units and global eustatic events

Similar facies, as observed in the Komen limestone, also occurs in the Santonian - Campanian Lipica Formation (Fig. 1), named the Tomaj limestone (Jurkovšek et al., 1996). From the genetic point of view and according to the fossil content it can be compared to the Komen limestone. It will probably be ranged into single lithostratigraphic unit in future. Pleničar (1960) has already noticed that the "Komen shists are not stratigraphic horizon but a special facial form of Senonian, Turonian and Lower Cretaceous sediments". Recently fish skeletons and ammonites were also collected in the Tomaj limestone (Jurkovšek & Kolar-Jurkovšek, 1996; Summesberger et al, 1996).

From the lithologic column (Fig. 2) it is evident that the bituminous limestone facies of the Trieste-Komen plateau occurs in different statigraphic levels. The first level is encountered in the surroundings of the Komen village and can be defined as a part of the Upper Cenomanian beds. From the stratigraphic point of view it is related to the global eustatic sea level rise and can be correlated to the anoxic event of Mediterranean (OAE 2) or the Bonarelli level (Jenkyns, 1991; Montanari et al., 1995). The Komen limestone was assumingly formed due to the upwelling of anoxic water in bordering parts of the carbonate platform. Up to hundred times higher thickness of these strata in the Trieste-Komen plateau compared to the thickness of the main Bonarelli level (Jenkyns, 1991) can be explained by essentially greater sedimentation rate on the carbonate platform if compared with sedimentation in the basin.

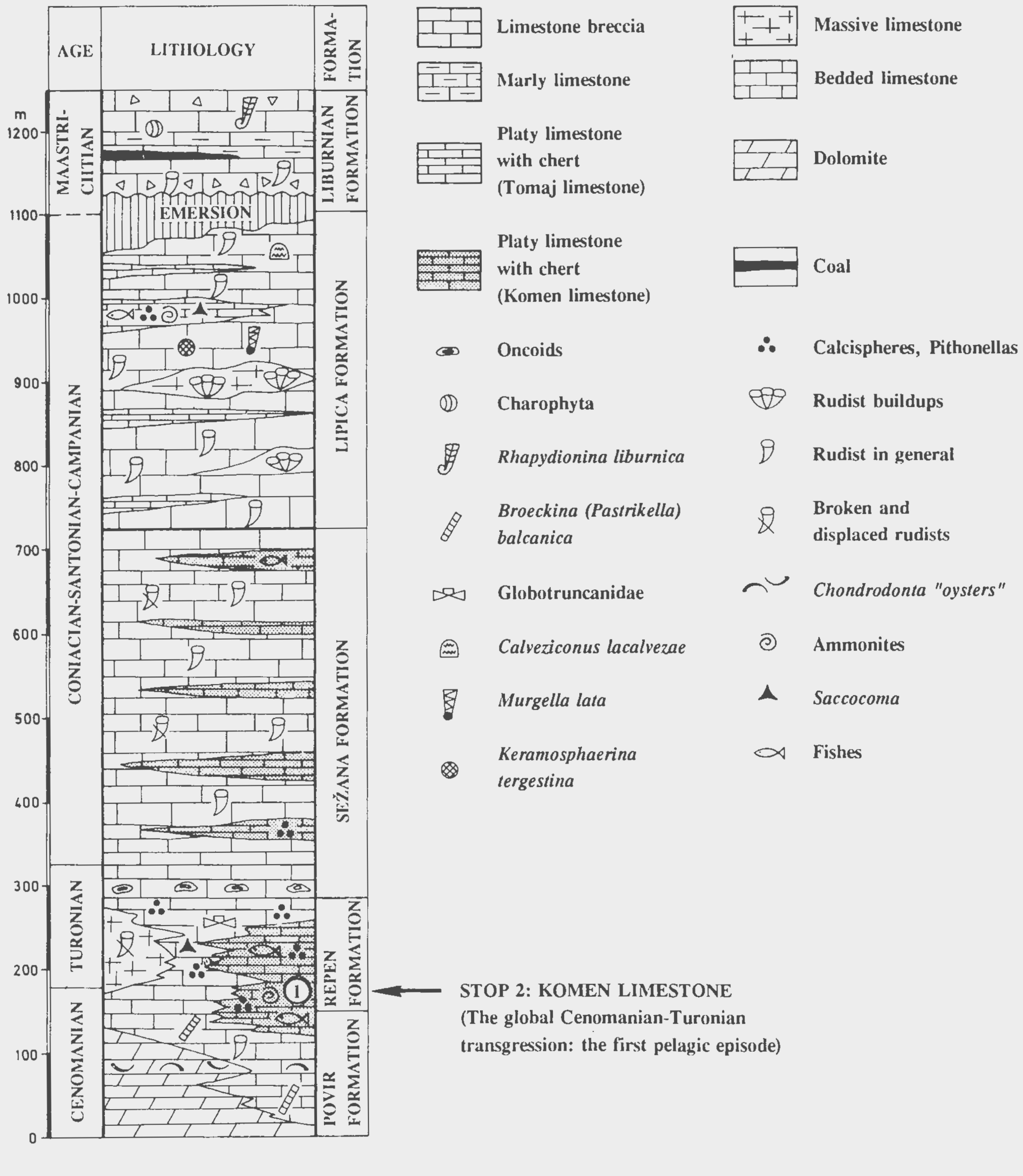

Fig. 2. Shematic stratigraphic column of Cenomanian to Maastrichtian succession in Trieste-Komen area and position of the Komen limestone.

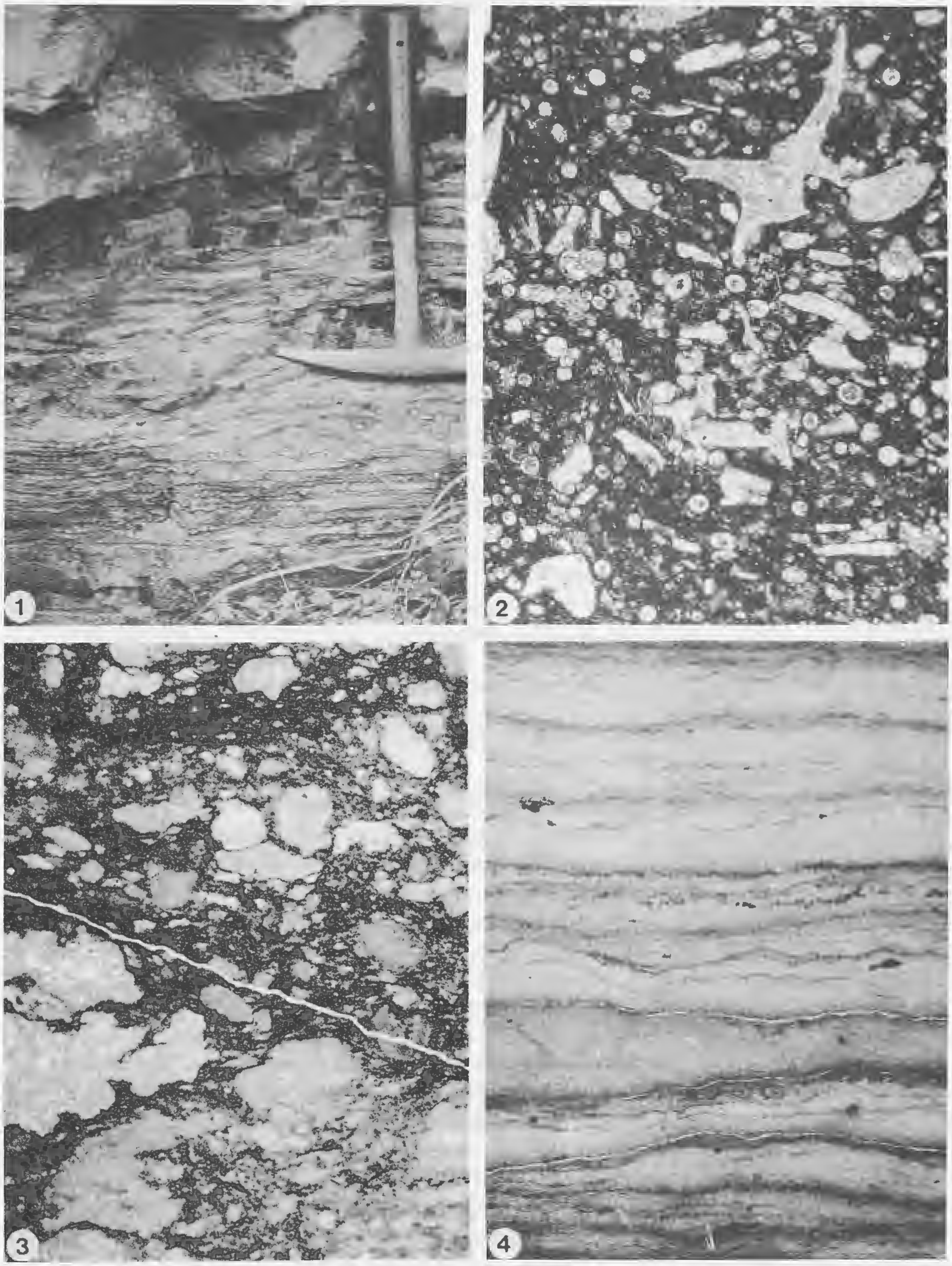

Plate 1

Fig. 1: Platy Komen limestone in Škrbina quarry.

Fig. 2: Calcispheral wackestone with some *Saccocoma*. Škrbina, 80x.

Fig. 3: Intramicritic limestone - detail from the pebble conglomerate. Škrbina, 20x.

Fig. 4: Laminated micritic limestone with disseminated organic matter. Škrbina, 30x.

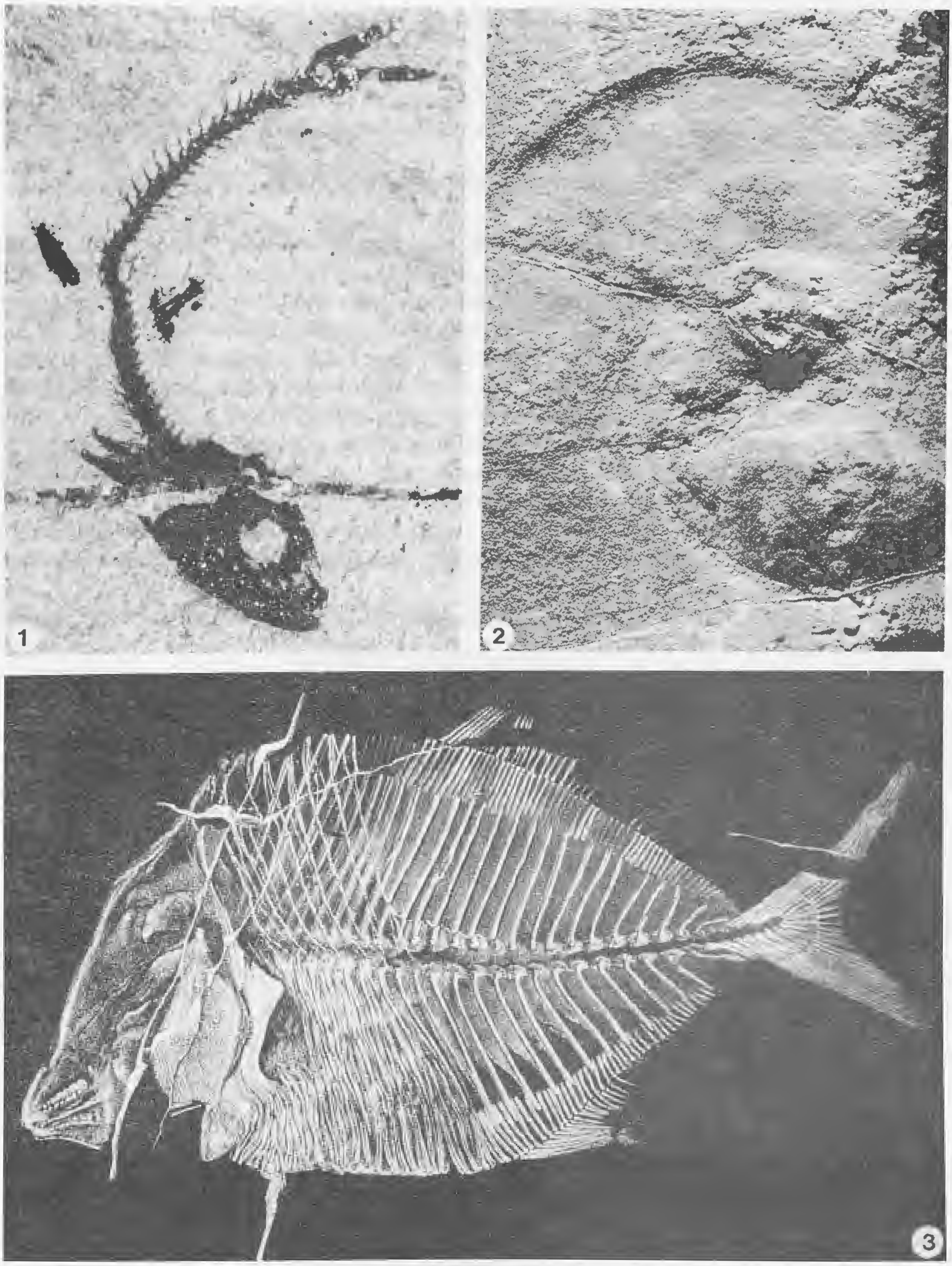

Plate 2

Fig. 1: Clypeidae. Gabrovica near Komen. Sample BJ 1587, 5x.

Fig. 2: Ammonoidea. Gabrovica near Komen. Sample BJ 1586, natural size.

Fig. 3: Well preserved fish skeleton of *Coelodus vetteri* Gorjanović-Kramberger. Komen; length of the sample 23.5 cm (from Gorjanović-Kramberger, 1895).

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PADRICIANO SECTION (KARST OF TRIESTE, ITALY)

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Introduction

The Padriciano area is located in the southwestern part of the Trieste Karst anticline and presents a monoclinal asset with southwestward dip of 15°-40° (Fig. 1). The stratigraphic sequence here outcropping spans from late Maastricthian to early Eocene (Cucchi et al., 1988; Caffau et al., 1995). The excursion focuses on the sequence from late Maastricthian to late

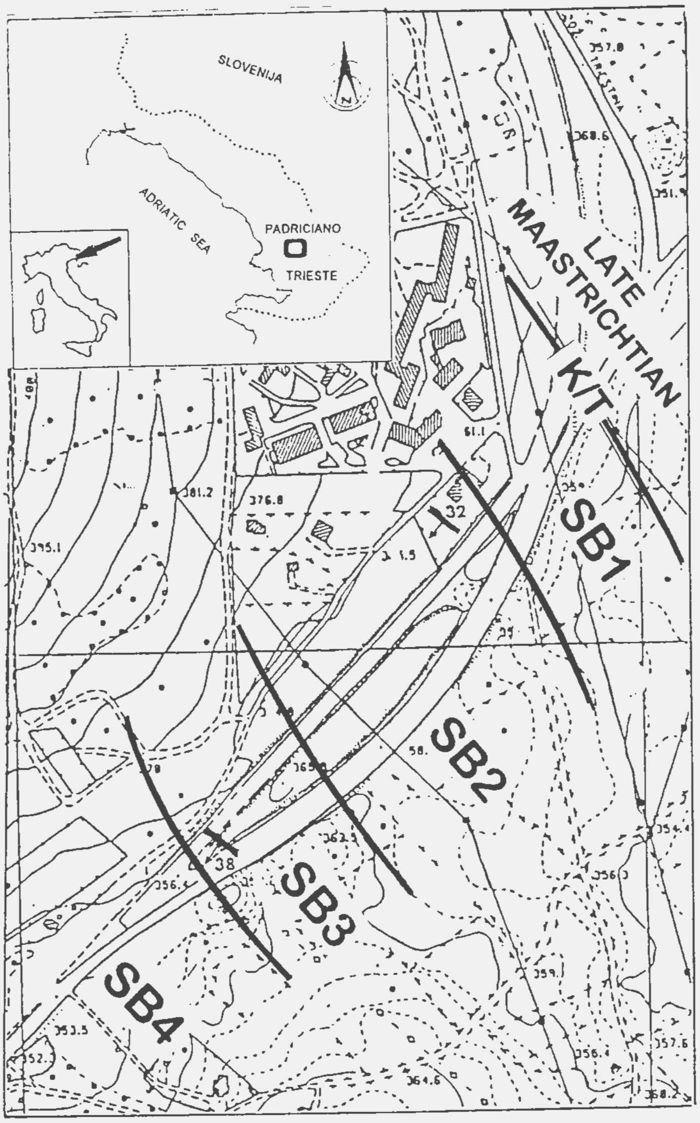


Figure 1 - Simplified geological map of the Padriciano area.

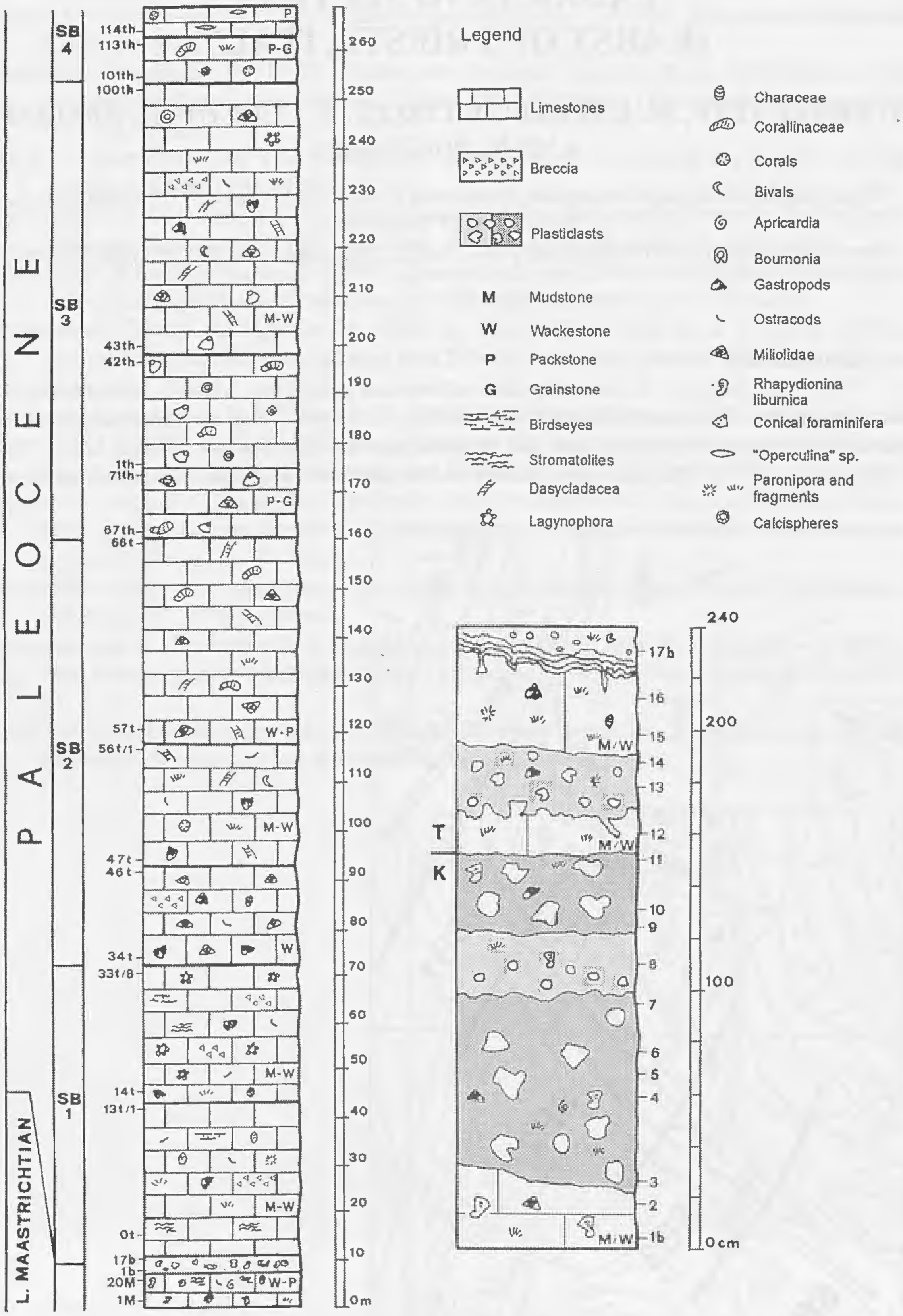


Figure 2 - Stratigraphic column of the studied Padriciano section and of the "breccia" level corresponding to the K/T boundary. The most indicative samples are reported.

Thanetian *p.p.* evidenciating the K/T boundary and the Shallow Benthic biozones proposed by Serra-Kiel et al. (in press).

The Padriciano section examined is 270 m thick and is described below (from the bottom to the top). The part of the section corresponding to the Paleocene beds is subdivided from the biostratigraphical point of view following the previously cited SB biozonation (Fig. 2, 3).

Late Maastrichtian

The late Maastricthian beds are constituted by grey and brown-grey limestones and, at the top, by a level of "breccia", which will be described separately in the K/T section. This part of section is 4 m thick and represents the uppermost part of very thick rudist limestones, which in the Trieste Karst range from late Cenomanian to late Maastrichtian. It presents a faint bedding period and, in the upper part, three rudist horizons, represented by whole and fragmented displaced specimens of *Bournonia excavata* (d'Orbigny), *Bournonia parva, Bournonia* n. sp., *Bournonia* sp. and *Apricardia* sp. Above the last rudist layer plane-parallel laminations are present. Topward, a muddy matrix containing abundant characean girogonites, thin-shelled gastropods and nonionids is present. The most common microfacies are wackestones with abundant *Rhapydionina liburnica* (Stache), *Fleuryana adriatica* De Castro, Drobne & Gušič, *Cuneolina ketini* Inan, *Cuneolina cylindrica* Henson, *Dargenioella* sp., *Pseudochrysalidina* sp., *Bolivinopsis* sp. 1, *Bolivinopsis* sp. 2, *Gyroconulina* sp. 1, Textulariidae, Miliolidae, *Thaumatoporella* sp., ostracods and calcispheres; scattered angulose clasts are also present.

The Maastrichtian limestones indicate subtidal lagoon settings characterized by high bottom-energy episodes (levels of displaced rudists, laminations); furthermore, they reveal a fresh water influence (presence of Characeae) in the upper part.

K/T boundary (observation point)

In the literature (Caffau et al., 1995; Dolenec et al., 1995; Hansen et al., 1995; Ogorelec et al., 1995; Pugliese & Drobne, 1995; Pugliese et al., 1995) the previously cited "breccia level" corresponds to the K/T boundary. In the Padriciano area, this level seems to be discontinuous and, in the examined section, is 2.40 m thick. On the basis of recent data, it is composed by a repetition of deposition in a subtidal environment followed by limited exposure and later brecciation and reworking by a transgressive event. Three shallowing episodes are observed in the breccia body, overlying a 30 cm thick mudstone-wackestone facies (samples 1b and 2b), sometimes with a nodular texture (containing nonionids, rare *Rhapydionina liburnica* (Stache), *Fleuryana adriatica* De Castro, Drobne, Gušič, *Paronipora* and gastropods), topped by an irregular erosive surface.

The first episode (3b to 8b samples) consists of breccias with subrounded bioclasts (rudists and gastropods) and subordinate mm-cm clasts ("plasticlasts"), composed of wackestone and packstone sometimes with *Paronipora*, in a bioclastic grainstone matrix containing Maastrichtian taxa, such as *Rhapydionina liburnica* (Stache) and *Cuneolina ketini* Inan. At the top of the brecciated body a thin mudstone-wackestone layer, similar in composition samples 1 and 2, is capped by an erosive surface.

The second one (9b to 11b samples) shows breccias with rounded mm-cm clasts ("plasticlasts"), very similar to samples 3b to 8b. These are overlain by a wackestone - packstone with *Paronipora* and rare small gastropods, with also discorbids very similar to those Danian in age (sample 12b).

The last transgressive event is composed of breccias with clasts coming from the underlying level (sample 12b) in a mudstone matrix. At the top of the breccias crinkled and wavy stromatolites are found, testifying a supratidal depositional environment.

In both types of matrix, very abundant disarticulated *Paronipora* occur. The clasts show both isopacous and meniscus cements found around the *Paronipora* fragments and mud particles, together with abundant irregular fenestrae, calling for an early cementation in a vadose environment with short exposure to subaerial diagenesis.

On the basis of the paleontological data, the "breccia" of the Padriciano section can effectively indicate the K/T boundary. On the basis of paleontological data, the K/T boundary might be placed between the samples 11b and 12b. Actually, the samples 3b to 11b may be late Maastrichtian in age in relation to the occurrence of *Rhapydionina liburnica* (Stache) and *Cuneolina ketini* Inan in the matrix, if the autochthony of these taxa is verified. The samples 12b to 17b may be considered Danian in age in relation to the presence of discorbids in the matrix, together with the disappearance of Maastrichtian taxa.

The existence of the K/T boundary might be confirmed by Hansen et al. (1995), who evidenciated an iridium anomaly (0.6 ppb Ir in the carbon fraction and 0.9 ppb in the untreated sample) in the matrix of the upper part of the "breccia" level. Furthermore, Dolenec in Dolenec et al. (1995) supports the identification of the K/T boundary in the "breccia" evidenciating an extreme depletion of the $\delta^{13}C$ (-9.80%.) values due to a strong influence of light terrestrial carbon. This author suggests that this anomaly, which is also present in other localities, may be related to global climatic change, together with the destruction and combustion of terrestrial plants, which followed the impact of an extraterrestrial body (Alvarez et al., 1980). In addition, studies in progress show close to the K/T boundary a small peak of susceptibility and intensity of remanent magnetization (Marton, 1995, personal communication) and the lowest values (21 Bq/Kg) of the activity of natural radionuclides (Giacomich in Ogorelec et al., 1995).

The origin of this "breccia" is still under discussion. Ogorelec et al. (1995) consider this breccia very similar to that of Dolenja Vas section and define it as an "intraformational plastic breccia and supratidal flat pebble conglomerate". Dolenec et al. (1995) and Hansen et al. (1995) interpret it as an intertidal breccia and a debris flow, respectively.

On the basis of new data, the "breccia" level may be originated in a subtidal shallow lagoon and supratidal environment. However, short emersion phases (duration of at least 40 ky) have been already recognized by Hansen et al. (1995) in the breccia of Dolenja Vas.

Paleocene

SB 1 biozone

This biozone is evidenciated by the identification of *Protelphidium* sp. The beds, belonging to SB 1 biozone and overlying the "breccia" level, are constituted by two parts, which are described below (from bottom to top).

The lower part consists of grey and blackish very fossiliferous limestones with a decimetric bedding period and thickness of 33 m. Repeated levels of stromatolites, monogenic breccia with mm-cm whitish clasts, plane-parallel laminations, fenestral fabrics and birdseyes are present in all the interval; possible paleosoils are found in the middle-upper part of the unit. The most common microfacies are mudstones and wackestones with very abundant disarticulated *Paronipora* fragments, gastropods, ostracods, small Miliolidae, Discorbidae and, subordinately, by *Protelphidium* sp., Polymorphinidae, characean girogonites and calcispheres.

The upper part mainly consists of dark-grey and grey-brown fossiliferous (gastropods and Characeae) limestones with a decimetric bedding period and thickness of 31 m. Repeated levels of blackish limestones and sporadic ones of monogenic breccia, with whitish clasts, plane-parallel laminations, fenestral fabrics and stromatolites are present. The most common microfacies are mudstones and wackestones with *Lagynophora* sp., characean girogonites, Discorbidae, rare ostracods, calcispheres and disarticulated *Paronipora*. Scattered specimens of probable planktonic foraminifers are present.

Notwithstanding the absence of biostratigraphic markers, the upper part is also included in SB 1 biozone since it is overlain by beds belonging to SB 2 biozone.

The beds of the SB 1 biozone testify settings which vary from peritidal settings (lower part) to fresh and brackish ones (second unit). The former consist of shallow restricted lagoon (dark-grey limestones), intertidal and supratidal settings, (laminations, fenestral fabrics, stromatolites overlain by *Paronipora*, birdseyes, breccia paleosoils); furthermore, the frequent occurrence of Characeae testify a diffused fresh water influence. The latter are represented by restricted lagoon settings (presence of Characeae, Discorbidae, gastropods and ostracods) with intertidal/supratidal episodes (stromatolites, laminations, fenestral fabrics, birdseyes, breccia), which are affected by anoxic phases (blackish limestones) probably related to stagnation and eutrophication.

SB 2 biozone

The SB 2 biozone is defined by the finding of *Pseudonummoluculina* sp. 1; In the Padriciano section, it is characterized by three parts which are described below (from bottom to top).

The lower part consists of light-grey and brown limestones with decimetric bedding period and thickness of about 22 m. Sporadic levels of monogenic breccia, plane-parallel laminations and stromatolites are present. The corresponding microfacies are mainly constituted by mudstones with Discorbidae, characean girogonites, gastropods and ostracods, and by wackestones and subordinate packstones with abundant Miliolidae, *Pseudonummoloculina* sp. 1, *Scandonea* sp., *Pseudochrysalidina* sp. and rare Textulariidae. Among these taxa, the occurrence of some specimens of *Scandonea* sp. has to be underlined, in that it is a marker of SB 1 biozone.

The middle part is constituted by dark-grey fossiliferous (gastropods, corals, sea-urchins) limestones with decimetric bedding period and thickness of 27 m. Lenses of monogenic breccia and thin levels of black limestones are present. The microfacies mainly consist of mudstones and wackestones with abundant *Paronipora* fragments, Discorbidae, *Spirolina* sp., Dasycladaceae (*Cymopolia* sp.), ostracods and calcispheres.

The upper part consists of light-grey fossiliferous (Miliolidae and encrusting corallinacean algae) limestones with decimetric-metric bedding period and thickness of about 46 m. The microfacies are mainly characterized by wackestones and packstones with abundant Miliolidae and Corallinaceae, and displaced *Cymopolia* sp.

Notwithstanding the absence of biostratigraphic markers, the middle and upper parts might also pertain to SB 2 biozone, since they are comprehended by the lower part (SB 1 biozone) and the overlying beds which belong to the SB 3 biozone. Furthermore, following Barattolo (in Pugliese et al., 1995) the presence of *Cymopolia* sp. might furtherly confirm the pertinence of the middle part to SB 2 biozone.

The beds of SB 2 biozone testify an environmental evolution characterized by restricted lagoon (mudstone with Discorbidae, characean girogonites and ostracods) and open lagoon settings (wackestones and packstones with Miliolidae, *Pseudonummoloculina* sp. 1, etc.) with some intertidal episode (breccia, laminations, stromatolites), in the lower part, by restricted lagoon (presence of Dasycladaceae and Discorbidae) in the middle part, and high bottom-energy marine coastal ones (presence of encrusting algae) in the upper part.

SB 3 biozone

The SB 3 biozone is evidenciated by the presence of the first agglutinated conical foraminifers (*Fallotella alavensis* Mangin) and the porcellanaceous ones with inner structure (*Periloculina slovenica* Drobne). In the Padriciano section, this zone comprehends two parts which are described below (from bottom to top):

The lower part consists of light-grey limestones with very abundant foraminifers (Miliolidae and conical forms), metric bedding period and total thickness of about 41 m. The most common microfacies are packstones and subordinate grainstones, with abundant Miliolidae, *Fallotella alavensis* Mangin, *Fallotella kochanskae* Hottinger & Drobne, *Coskinon rajkae* Hottinger & Drobne, *Idalina sinyarica* Grimsdale, *Periloculina slovenica* Drobne, *Cribrobulimina carniolica* Hottinger & Drobne, Corallinaceae and, subordinately, *Broeckinella arabica* Henson, *Pseudonummoloculina* sp. 2 and calcispheres.

The upper part is represented by dark-grey fossiliferous (Dasycladaceae) limestones, which are interbedded by monogenic breccia levels, in the upper part. The bedding period varies from decimetric to metric; the thickness of the interval is about 68 m. The most common microfacies are constituted by mudstones and wackestones with abundant Dasycladaceae (*Cymopolia* sp. and, subordinately, *Clypeina* sp.), rare Miliolidae, *Periloculina slovenica* Drobne, *Idalina sinyarica* Grimsdale, displaced conical foraminifers, gastropods and scattered *Lagynophora* and *Paronipora* fragments.

The beds belonging to SB 3 biozone testify an environmental evolution which varies from marine coastal settings (presence of the previously described rich foraminiferal fauna and algae), in the lower part, to more or less restricted ones (presence of Dasycladaceae), with evident displacement of taxa coming from nearby brackish and supratidal areas (*Lagynophora* and *Paronipora* occurrence, respectively), in the upper part.

SB 4 Biozone

The SB 4 biozone is characterized by the occurrence of porcellanaceous foraminifers, such as *Glomoalveolina dachelensis* Schwager, *Glomoalveolina levis* Hottinger, *Pseudolacazina donatae* (Drobne), *Lacazina blumenthali* Reichel & Sigal and *Hottingerina lukasi* Drobne. In the Padriciano section, the beds belonging to this zone comprehend two parts, which are described below (from bottom to top).

The lower part is represented by recrystallized grey limestones (lowermost part) and dark-grey limestones, with decimetric bedding period and thickness of 9 m. The microfacies are mostly constituted by mudstones and wackestones which contain abundant Corallinaceae, *Ethelia alba* and *Distichoplax biserialis* Dietrich, in the lowermost part, and Dasycladaceae, *Hottingerina lukasi* Drobne, *Glomoalveolina* sp., Miliolidae, corals, sea-urchin fragments and *Paronipora* clasts, in the remaining part.

The upper part consists of light-grey limestones with metric bedding period and thickness of few meters. The corresponding microfacies are packstones with *Lacazina blumenthali* Reichel & Sigal, *Pseudolacazina donatae* (Drobne), *Glomoalveolina dachelensis* Schwager, *Saudia labyrinthica* Grimsdale, *Pentellina* sp. and "*Operculina*" spp. *Pentellina* sp., which occur in this biozone, is normally recorded in SB 3 biozone.

The limestones belonging to the SB 4 biozone define high bottom-energy marine coastal settings in relation to the occurrence of the previously described rich foraminiferal fauna and corallinacean algae. Furthermore, reef structures are due to the corals as reported by Turnšek in Pugliese et al. (1995).

Final considerations

The study of the Padriciano section evidenciates some biostratigraphic, chronostratigraphic and paleoecological results.

Within the Paleocene beds four (1 to 4) Shallow Benthic biozones are identified: SB 1 biozone is defined by the occurrence of *Protelphidium* sp.; SB 2 biozone is indicated by the occurrence of *Pseudonummoloculina* sp. 1.; SB 3 biozone is characterized by the presence of the conical agglutinated foraminifers and *Periloculina slovenica* Drobne; SB 4 biozone is evidenciated by the occurrence of *Hottingerina lukasi* Drobne, *Pseudolacazina donatae* Drobne, *Lacazina blumenthali* Reichel & Sigal and *Glomoalveolina dachelenensis* Schwager and by first *Assilina*.

From the chronostratigraphic point of view, the previously defined biozones may be ascribed to the Danian (SB 1), early Thanetian (SB 3) and late Thanetian (SB 4), meanwhile the precise chronostratigraphical attribution of the SB 2 biozone is under discussion.

Thus, the stratigraphic sequence studied records an environmental evolution from late Maastrichtian to late Thanetian. The Maastrichtian beds indicate restricted lagoon settings. In correspondence of the K/T boundary, which may placed at the boundary between the lower and upper part of the "breccia level", the paleoenvironment varies from shallow subtidal lagoon, with some

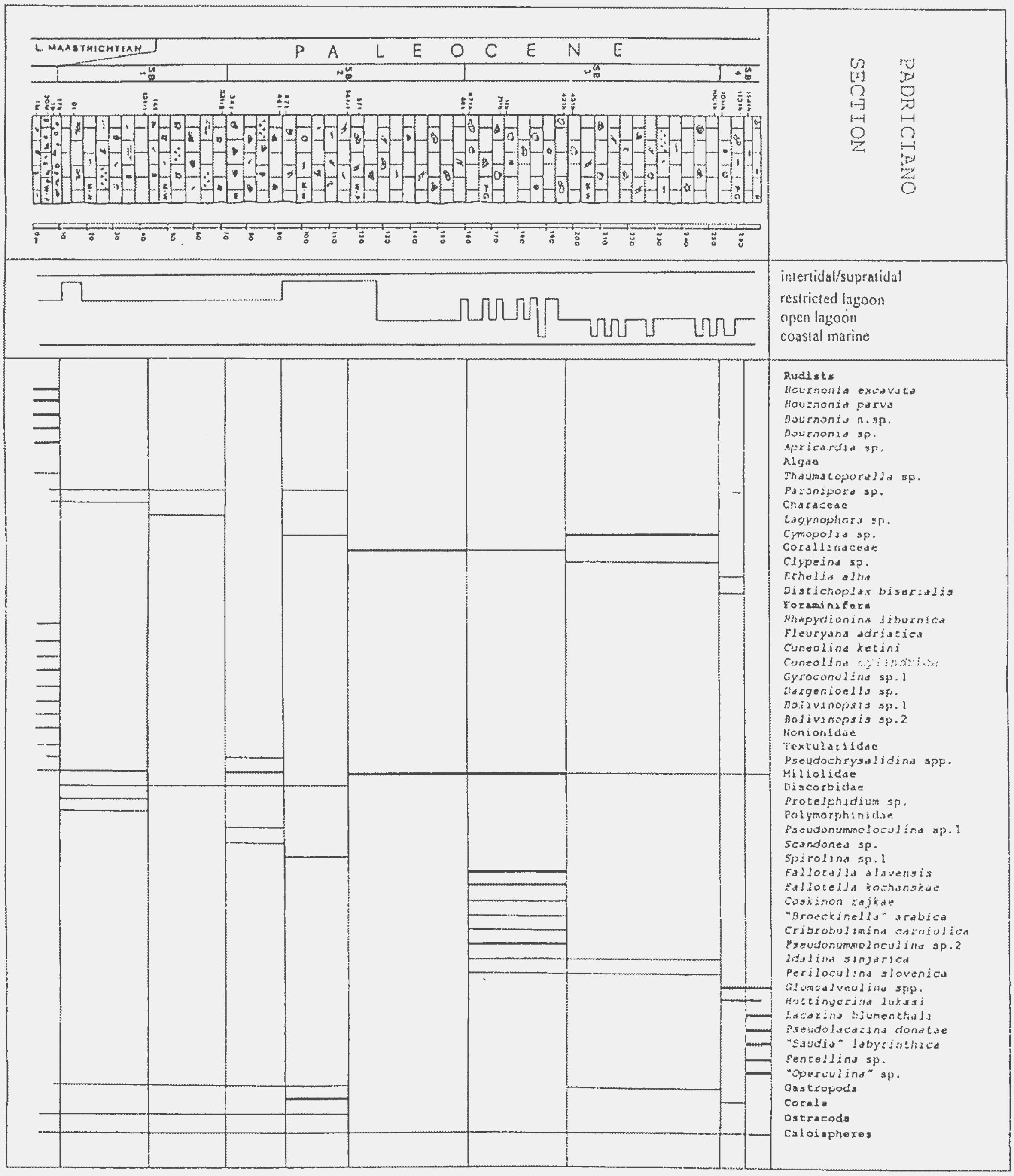
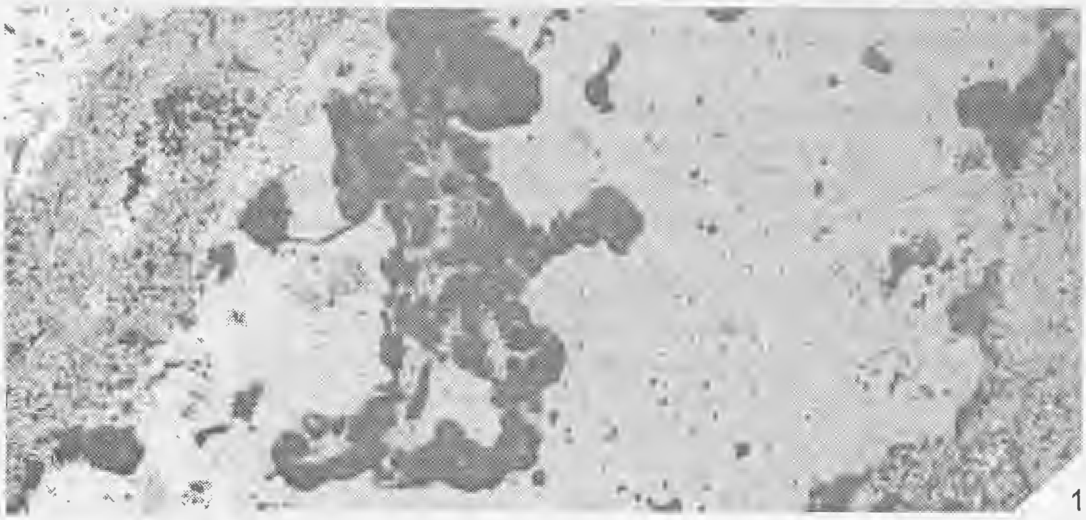


Figure 3 - The taxa found in the Padriciano section reported in order of appearance.

3

2



1

Plate 1
Fig. 1: "breccia" level (sample 5b): plasticlast with *Paronipora* in grainstone matrix (10x)
Fig. 2: "breccia" level (sample 7b): plasticlast in a matrix containing *Rhapydionina liburnica* (10x).
Fig. 3: "breccia" level (sample 17b): stromatolite at the top of the breccia (10x)
Photographs by Igor Lapajne

intertidal episodes (lower part), to supratidal (upper part). The Paleocene beds may testify on the whole a transgressive trend from restricted lagoon and intertidal/supratidal settings (SB 1 and SB 2 *partim* biozones) to coastal marine ones (SB 3 and SB 4 biozones), through open lagoon (lower part of SB 2 biozone) and restricted lagoon episodes (upper part of the SB 3 biozone). Such paleoenvironmental interpretation is also confirmed by the occurrence of sporomorphs, including the possible existence of neighbouring land behind the brackish and marine settings as demonstrated by the finding of reworked Paleozoic taxa (Kedves, in Pugliese et al., 1995).

Within this environmental evolution some biological events have been already identified and discussed by Pugliese et al. (1995):

- the disappearance of rudists and some foraminiferal species, such as *Fleuryana adriatica* De Castro, Drobne & Gušič, *Rhapydionina liburnica* (Stache), *Cuneolina ketini* Inan and *Cuneolina cylindracea* Henson, just before the end of the Maastrichtian probably in relation to environmental changes, as indicated by depletion in $\delta^{13}C$ and other isotopic anomalies highlighted by Dolenec et al. (1995) in nearby localities (Dolenja Vas)
- the renewal of the benthic life after the K/T boundary in the Danian during unsuitable environmental conditions, as indicated by negative values of $\delta^{13}C$ (Ogorelec et al., 1995) and high intensity of remanence (Marton et al., 1995); such environmental conditions allow small discorbids, gastropods and ostracods (opportunistic assemblage) to colonize the substrate;
- the development of the benthic life as demonstrated by continous appearances of new taxa (conical agglutinated and porcellanaceous with inner structure foraminifers, algae, etc.) mainly beginning from the Thanetian in relation to the establishment of suitable conditions in marine settings, as recorded by positive values of $\delta^{13}C$ (Ogorelec et al. 1995).

Further studies will be addressed to complete the stratigraphic framework of the Padriciano section focusing on the Eocene beds up to the drowing by terrigenous turbidites (Flysch).

Acknowledgements: This text is the result of a constant discussion among the researchers who participate to the Alpe-Adria Project "Paleobiological and paleoenvironmental events from late Cretaceous to early Eocene in the Karst region". The Authors of this text particularly thank Prof. T. Dolenec, Prof. E. Marton, Dr. B. Ogorelec and Prof. M. Pleničar. The research is supported by Ministry of the University, Scientific Research and Technology of Italy (60% program).

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LIJAK
MAASTRICHTIAN TO EOCENE

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Introduction

Red marls with rich pelagic microflora and microfauna are developed all across Slovenia. They can be traced from the northern part of the river Soča region across central Slovenia to Kočevje area, and to northeastern Slovenia (Pavšič, 1977; 1994). They occur in the time span from the Santonian to the Upper Paleocene with some interruptions. This lithological unit is especially well known where it includes the Cretaceous/Tertiary boundary. It was named the Podsabotin beds (Drobne & Pavlovec, 1969) after Podsabotin village in the Goriška Brda region where, beside the Lijak section, also the transition from the Cretaceous to Tertiary can be observed (Šribar 1967; Pavšič, 1973, 1979; Perch-Nielsen & Pavšič, 1979).

Description of the section

The section across the red marl developed as the Podsabotin beds is situated on the southern slope of the Trnovski gozd mountain above the Vipava valley. It is well exposed above the village of Loke between Cretaceous limestone and Eocene flysch along the carriage-way above the karst source of Lijak (Fig. 1).

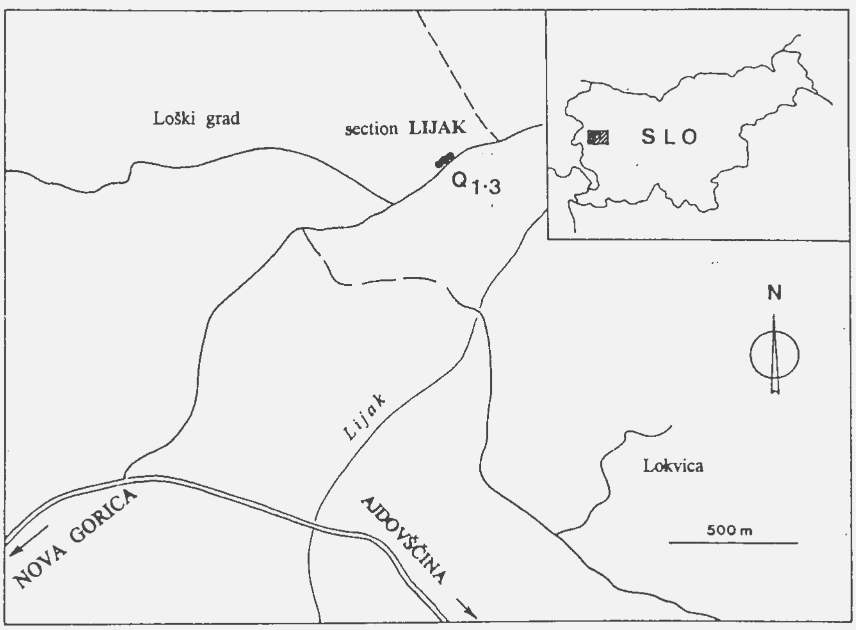

Fig. 1. Situation of the section of Podsabotin beds at Lijak near Nova Gorica.

International workshop POSTOJNA '96: *THE ROLE of IMPACT PROCESSES in the GEOLOGICAL and BIOLOGICAL EVOLUTION of PLANET EARTH*, Eds K. Drobne, Š. Goričan, B. Kotnik, Ljubljana 1996.

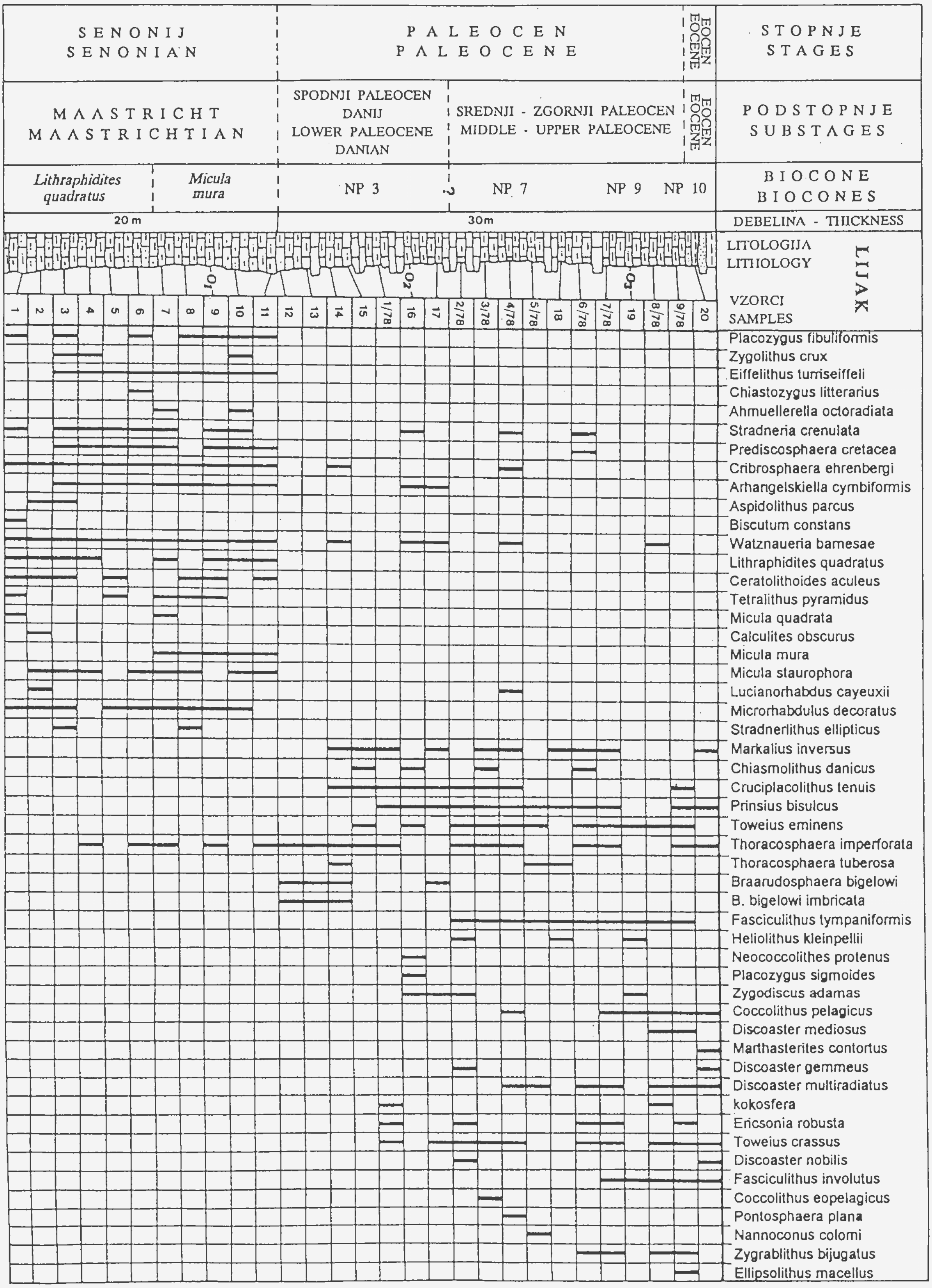

Fig. 2. Distribution of calcareous nannofossils in the Lijak section.

The red marly limestone is overthrust by the Upper Cretaceous limestone. First beds of marl are pale greenish and silicified, and later they turn red with greenish spots in places. About in the middle of the section the colour suddenly changes. The marls become intensely brownish red and considerably softer; layers and lenses of limestone are intercalated. Burrows of different animals can also be found in this part. Upsection, the colour again becomes paler. Marl becomes repeatedly reddish; limestone interlayers are more frequent and thicker. In the terminal part, the red marl beds alternate with layers of yellow marls which passe into sandstone, and later into genuine flysch sequence.

The age is from Maastrichtian to Eocene with a hiatus in the Lower and Middle Paleocene.

In the marl and marly limestone a rich fauna of planktic foraminifers and a fossil nannoflora were determined.

Upper Cretaceous:

Planktic foraminifera:
Heterohelix globulosa (Ehrenberg)
Racemiguembelina fructicosa (Eger)
Pseudotextularia elegans (Rzehak)
Globotruncana arca (Cushman)
Rosita contusa (Cushman)
Globotruncana lapparenti Brotzen
Globotruncanita stuarti (de Lapparent)
Globotruncana falsostuarti Sigal

Nannoplankton see Fig. 2.

Lower Paleocene:

P1 - Planktic foraminifera
Dorothia pupa
Dorothia oxycona
Globigerina triloculinoides Plummer
Morozovella uncinata (Bolli)
Morozovella trinidadensis (Bolli)
Morozovella pseudobulloides (Plummer)

Nannoplankton from biozone NP 3, see Fig. 2.

Middle Paleocene:

P4 - Planktic foraminifera
Dorothia oxicona
Dorothia pupa
Acarinina primitiva (Finlay)
Globigerina linaperta Finlay
Morozovella velascoensis (Cushman)
Planorotalites pseudomenardii (Bolli)
Morozovella angulata (White)
Morozovella aequa (Cushman et Renz)

Nannoplankton from biozone NP 7, see Fig. 2.

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KANAL-LIG
CRETACEOUS/TERTIARY BOUNDARY IN FLYSCH

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Introduction

The K/T transition was traced in several places in the wider surroundings of the Soča Valley. The following sections were examined in detail: Lijak, Podsabotin, Kanalski vrh and Lig (Perch-Nielsen & Pavšič, 1979). Wherever the Paleocene beds overlie clastic Cretaceous beds, the highest Cretaceous biozone with species *Micula mura* was found, but the lowermost Danian biozones could nowhere be established. Deposition starts everywhere in the Middle Danian with the NP3 biozone. The section described in 1979 is not identical with the section which is the object of this paper.

The lowermost Danian was first discovered in the Kanal-Lig section in 1981 (Pavšič). The characteristic tiny species *Neobiscutum parvulum* by which the lowermost Paleocene parts are characterized was determined. The section was not investigated in detail at that time.

Similar relations were established somewhat later (Pavšič, 1985) in the environs of Breginj where similar flysch development is exposed. However, due to unfavorable facies development in this part the calcareous nannoplankton could not be studied in an uninterrupted succession which are extremely rare in the Cretaceous part. In the Cretaceous part, only rare thin sheets of marls which contain very little nannoplankton occur within the prevailingly carbonate sedimentation. Therefore only the somewhat higher part of Danian with NP2 biozone was reliably proved here.

Investigation in the Kanal -Lig section was initiated to determine the exact position of the K/T boundary and to establish whether there have been any systematic changes in elemental content, $\delta^{13}C$ and $\delta^{18}O$ during the K/T boundary transition in flysch sequence of the Soča Valley in Slovenia, related to the considered catastrophic events (Dolenec & Pavšič, 1995).

Description of section

The uninterrupted transition from Cretaceous to Tertiary is exposed between Kanal in the Soča Valley and Lig (Fig. 1).

The entire succession of Upper Cretaceous and Lower Paleocene flysch beds represents a uniform lithological complex of about 500 meters of total thickness. The section was studied in detail at a length of 40 meters at the Cretaceous/Tertiary boundary (Fig. 2). In the section up to 30 cm thick layers of calcitic lithic sandstone alternate with up to 70 cm thick layers of marl. Up to 3,5 meters thick beds of carbonate turbidites which fill the erosion channels are interstratified. The lower part of turbidites is composed of calcareous breccia which gradually passes into coarse grained calcarenite. Grains of calcarenite are angular to subrounded, poorly to medium well sorted; calcarenite is composed of micritic, sparitic and biomicritic grains with predominance of micritic grains. The main component of calcarenites are fragments of pelecypod valves among which fragments of rudistids and inocerami can be recognized, as well as fragments of echinoderm plates.

Foraminifers (globotruncanas, globigerinas, miliolids, textulariids and orbitoids) are also abundant. Grains of chert and muscovite are rare. Calcarenites appear also within the marly-sandy flysch as independent, up to 15 cm thick layers with developed grading and parallel lamination.

The calcareous breccias are composed of poorly rounded fragments of older, mainly Cretaceous limestones. The fragments do not surpass 10 cm size, measuring in average about 2 cm. Fragments of micritic limestones prevail. Beside intraclasts, frequent fragments of pelecypod valves and echinoderms occur; orbitoids and fragments of red algae are rare.

The marl : sandstone ratio is about 70 : 30 in the marly-sandy flysch. Layers of calcitic lithic sandstones are from a few to 30 cm thick. The sandstone consists of 20 to 40 % of quartz and up to 30 % of rock fragments; 3 % of grains belong to extrusive rocks with altered diabase texture. Grains of chert, plagioclase, chlorite, muscovite and zircon rarely occur. Several percents of grains belong to clasts of micrite and sparite.

Marls in the lower part of the section are of gray color and above, 20 m above the K/T boundary, they turn red. Marls occur in 5 to 70 cm thick, partly shaly beds. Three samples af marl were examined by X-ray diffraction. Their composition is very similar; they consist of calcite,

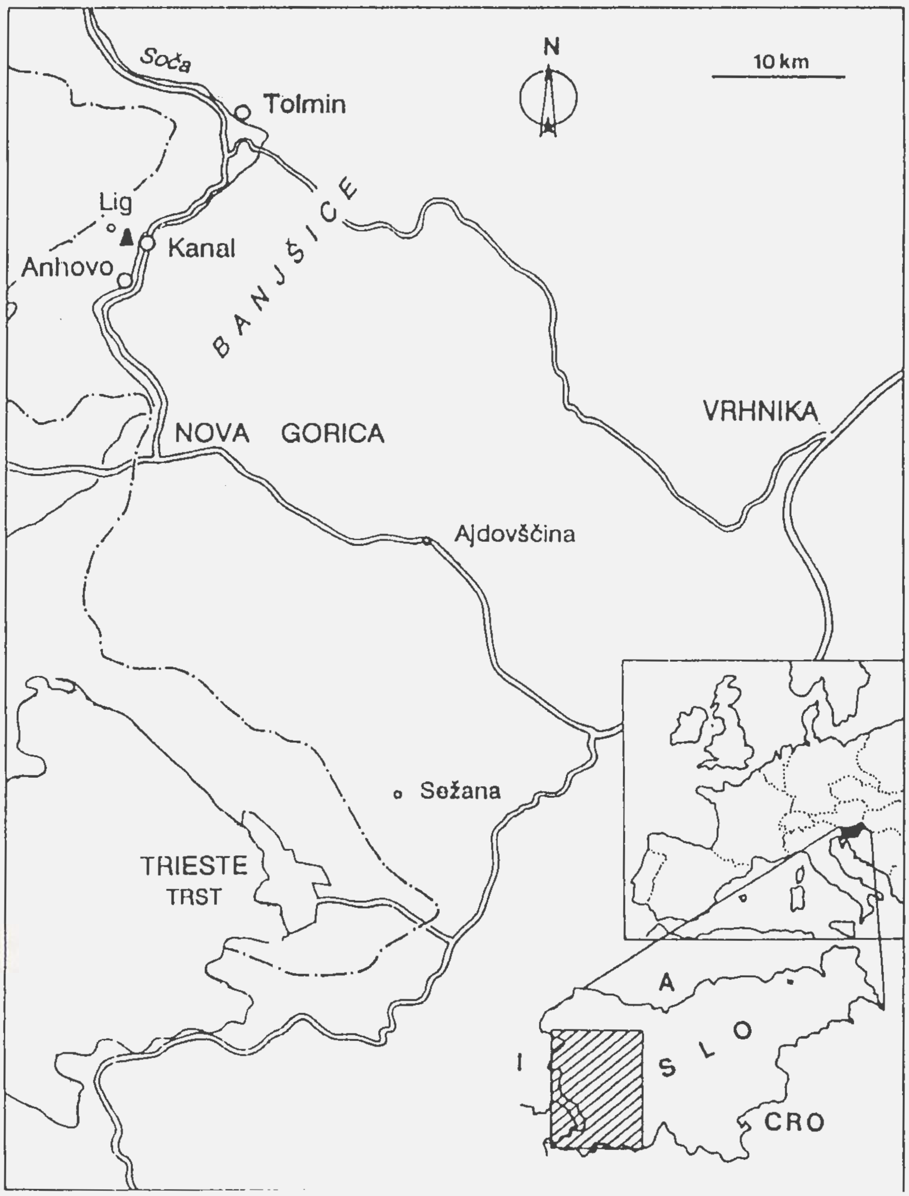

Fig. 1: Location sketch map of section Kanal - Lig (Pavšič, Dolenec & Horvat, 1995)

quartz, muscovite, chlorite, and traces of pyrite, analcime and dolomite. Calcite amounts to 15-25%. Interesting are inclusions of harder marly limestone which appear only in the Cretaceous part, whereas they disappear at the boundary (Fig. 2).

Six washed concentrates of marl samples were examined for planktic foraminifers. Very scarce poorly preserved fauna was found only in one sample (10 m above the boundary): *Globigerina triloculinoides* (Plummmer), *Morozovella pseudobulloides* (Plummer), and *Globigerina edita* (Subbotina). Principal stratigraphic data on the Cretaceous to Tertiary transition were obtained with calcareous nannoplankton. The state of preservation and abundance of nannoplankton varies much from sample to sample, and it is on average rather poor. The figure 3 shows the abundance of nannoplankton in individual samples within the about 75 meters thick interval.

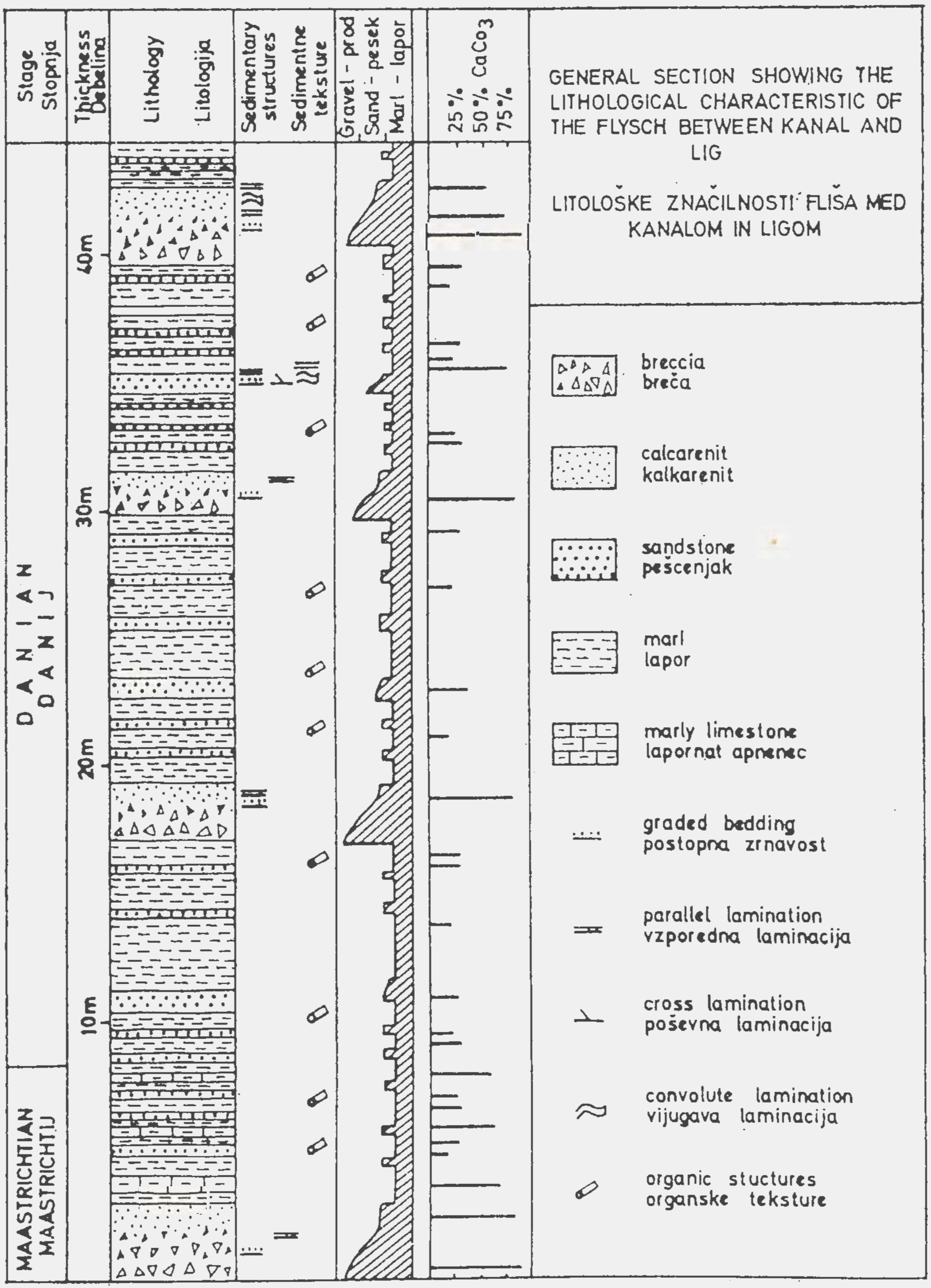

Fig. 2: Section showing the lithological characteristics of the flysch between Kanal and Lig (Pavšič & Horvat, 1988)

Comparison of thickness of individual parts of NP1, or entire NP1, indicates that the flysch development in Slovenia (Pavšič & Horvat, 1988) is by its great thickness hardly comparable to normal pelagic developments elsewhere in the world. The thickness is at least several times greater than the average thicknesses, in places up to ten times. If we compare the present thickness from the El Kef section with ours, we can see that the thickness of the Neobiscutum parvulum subzone is in the relation 1:20. In other sections, as those of Caravaca, Zumaya, or Gubbio, the differences in thickness are even higher (Perch-Nielsen et al., 1982; Sayve, 1984), (Pavšič & Horvat, 1988).

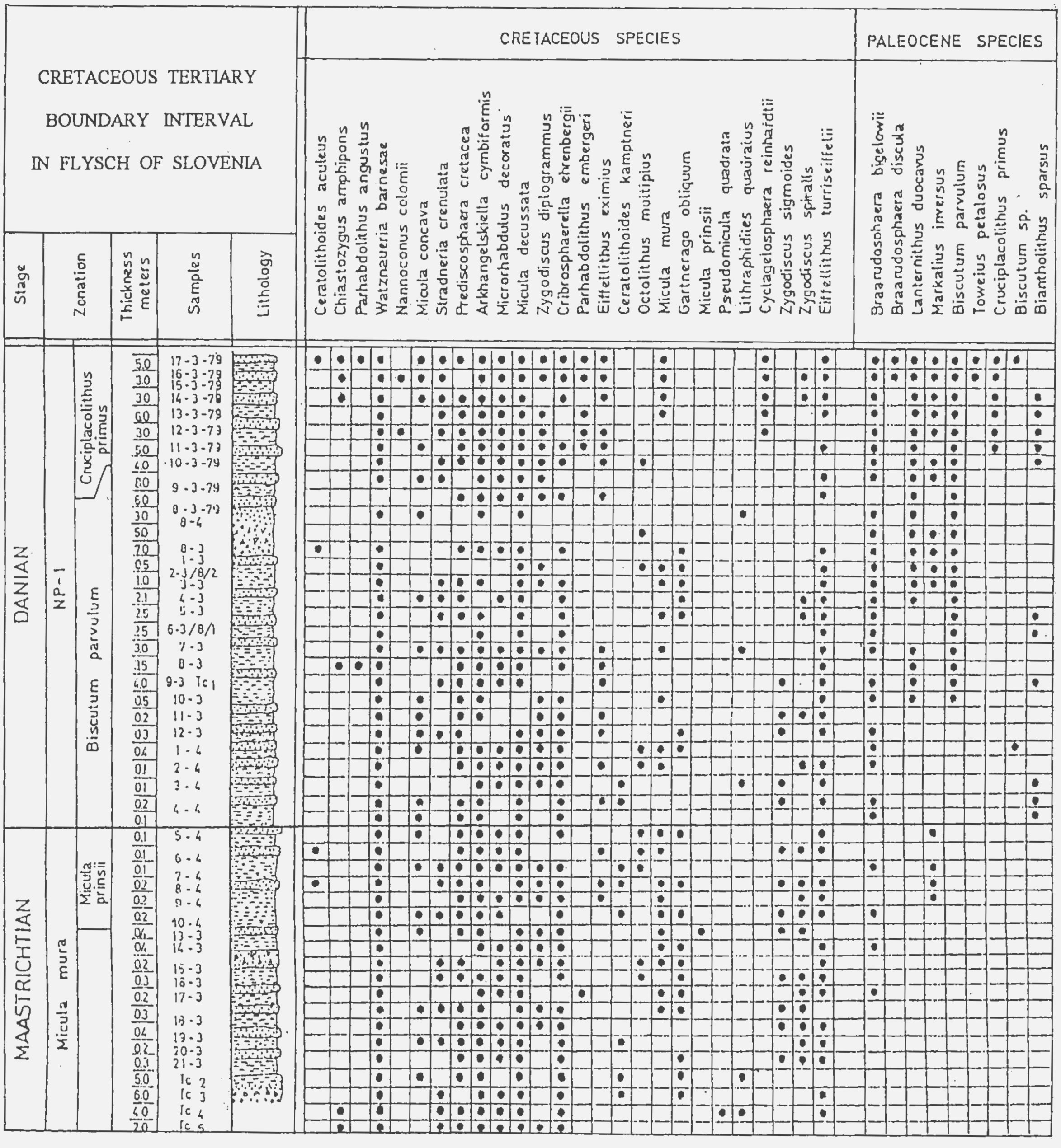

Fig. 3: Distribution of the calcareous nannoplankton in the Kanal-Lig section (Pavšič, Dolenec & Horvat, 1995)

Elemental and stable isotope variations

Elemental concentrations in the investigated K/T boundary strata are high enough to confirm a clear elemental signal which is higher than those of adjacent Cretaceous and Tertiary parts of the sequence. When the elemental data of a clayey layer are normalized to the average of the Creta-

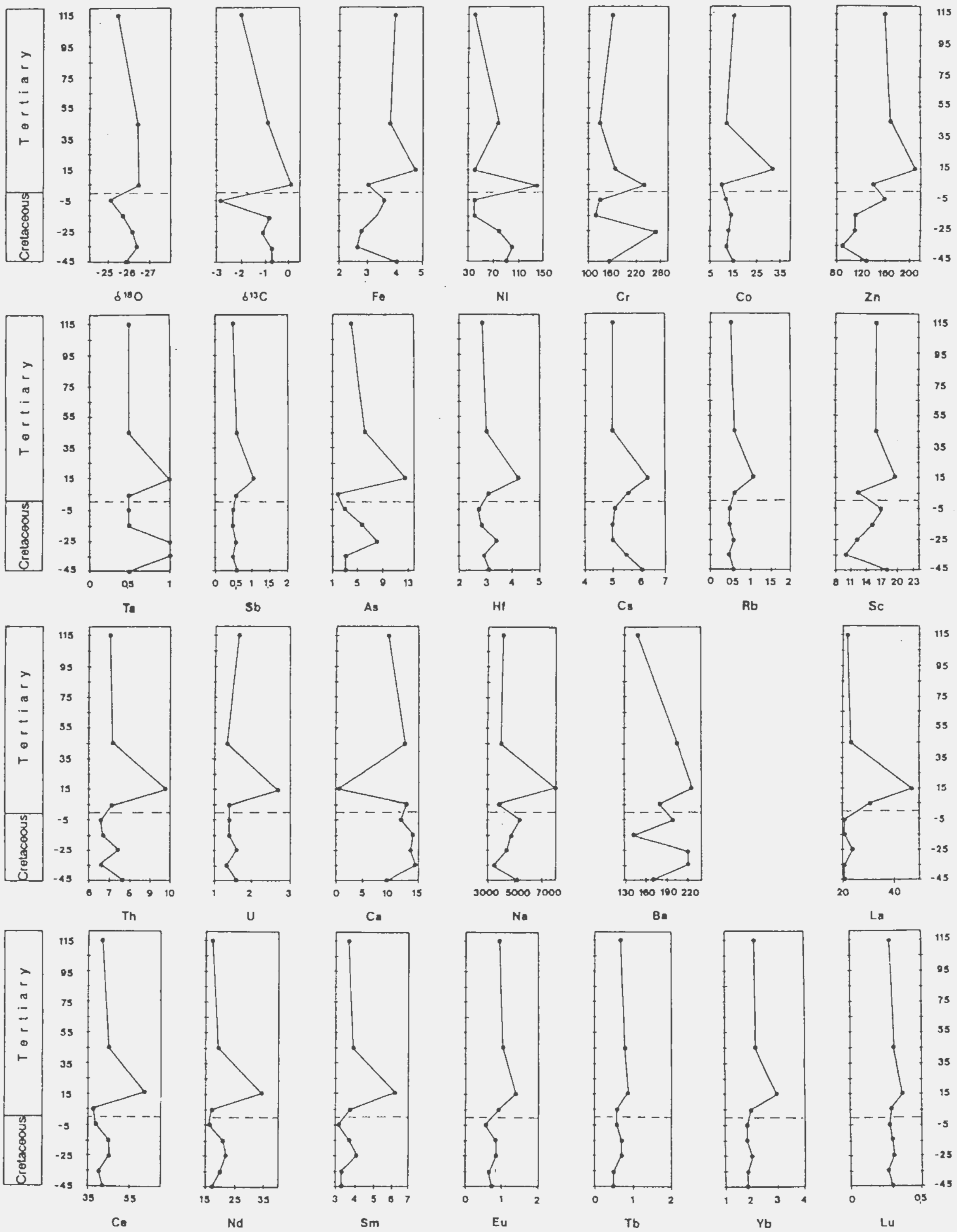

Fig. 4: Elemental and stable isotope variations in the Cretaceous-Tertiary boundary section from the Soča Valley (Dolenec & Pavšič, 1995).

ceous samples, it can be seen that the elements in the clayey layer are enriched by no more than 2.5 times in comparison with the background. The elemental enrichment of this layer is probably due to higher clay mineral contents which also appear to the main carrier-phases of the REE concentration. The REE patterns reflect the sedimentary nature of the analysed samples. Further examination of the data presented here indicates that slightly reducing conditions during deposition of boundary sediments might also have been responsible for the elemental enrichments. This hypothesis is supported by the presence of scarce framboidal pyrite grains in the clayey layer as well as in the clayey boundary marl enriched in Ni and Cr. The relatively weak elemental anomalies can be easily explained by the high sedimentation rate at the time of deposition of boundary sediments.

The carbonate isotopic compositions of the flysch sediments from K/T boundary section show the variation of $\delta^{18}O$ in the range between +25.10‰ and +26.48‰ (SMOW) and of $\delta^{13}C$ between -2.80‰ and +0.16‰ (PDB) (Fig. 4).

It can be supposed that although the post depositional changes slightly altered the original oxygen and carbon isotope composition, the primary palaeoceanographic signal was not completely overprinted.

The depletion in $\delta^{18}O$ content probably reflects slightly higher temperature conditions at the end of Cretaceous followed by the further tendency towards climatic cooling across the K/T boundary. The shift in the carbon isotopic curve at the boundary zone seems to reflect major changes in the carbon cycle and thus changes in biological system, as well as climatic changes. Positive $\delta^{13}C$ excursion in the Lower Paleocene can also be due to the cooling events previously indicated by positive $\delta^{18}O$ shift.

This study has also shown that the decrease in $\delta^{13}C$ values in carbonate at the K/T level in the Soča Valley is similar to the carbon isotopic patterns observed on a global scale at many extinction-related boundaries not only at the K/T transition. A negative $\delta^{13}C$ excursion of about 1.54‰ suggests a flux of isotopicaly light carbon in a depositional environment of the flysch sediments. This flux can be related to destruction and combustion of terrestrial biomass triggered by the impact explosion or by intensive volcanism with subsequent transfer of land plant organic matter into the sedimentary basin. Support for our supposition has come from the carbon isotopic record of the K/T transition limestones from the NW part of the shallow Adriatic Carbonate Platform at Dolenja vas and Sopada in Southern Slovenia (Drobne et al., 1988). Extreme depletion in ^{13}C of this boundary carbonate sequence up to -7‰ and -10‰ (Drobne et al., 1994), which is among the greatest ever measured in the extinction-related boundaries, confirms the strong influence of light terrestrial carbon in the sedimentary basin at the time of K/T transition. Confirmaton of one sharp Ir anomaly in the Italian section Gubbio (Rocchia et al., 1990; Alvarez et al., 1990), which lies about 330 km south-east of Soča Valley and 260 km from Dolenja vas and Sopada, also supports the hypothesized impact scenario (Dolenec & Pavšič, 1995).

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DOBLAR IN THE SOČA VALLEY THE VOLČE LIMESTONE (CAMPANIAN ALLODAPIC LIMESTONE)

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Introduction

The Volče limestone is a specific facies of the Upper Cretaceous age in the Soča (Isonzo) valley. Its age is determined from Upper Turonian to Upper Campanian. The name "Volče limestone" was introduced into the geological literature by Stur (1858) after the village Volče near Tolmin for the platy limestone with chert nodules. He ranged it at that time into the Neocomian Stage of the Lower Cretaceous. On the basis of globotruncanas it was placed into the Upper Cretaceous (Nedela-Devidé, 1957). The thickness of this formation is estimated between 50 and 250 meters. The underlying rock is platy limestone with chert nodules alternating with red and green marl (scaglia) and the overlying sediment is the Maastrichtian flysch.

The Volče limestone is thin bedded and gray in colour. Chert nodules and sheets are abundant. The calcareous beds consist of calcirudite, calcarenite and micrite varieties. Rare marly inter-

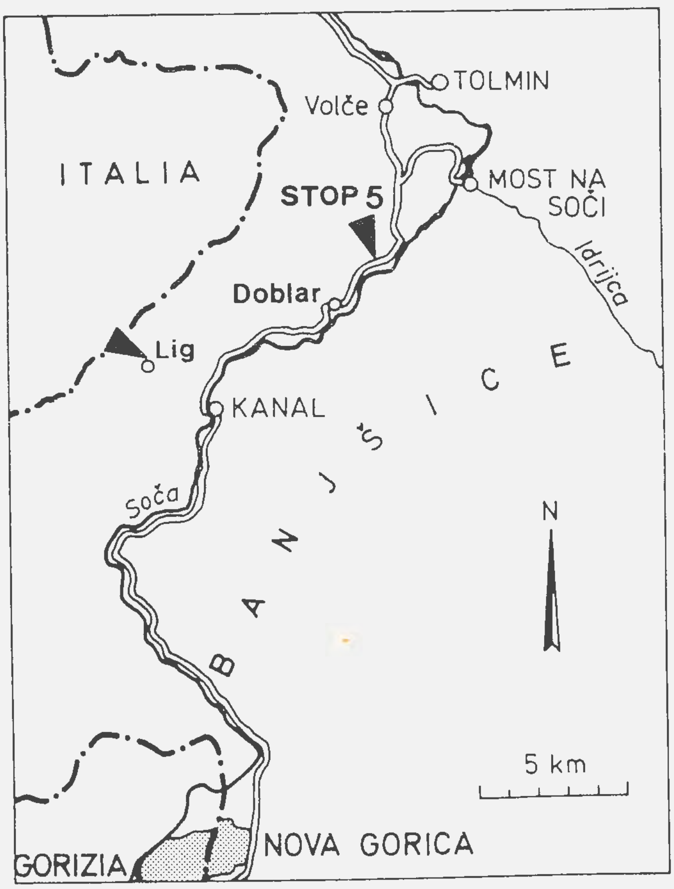

Fig. 1: Location of the Doblar section

calations do not exceed 1,5 cm in thickness. After sedimentological and textural characteristics the Volče limestone could be considered a carbonate turbidite or allodapic limestone (Ogorelec et al, 1976). Its depositional environment was a marginal part of a deeper basin (trench) where autochthonous pelagic sedimentation was often disturbed by turbidite currents. Such a trench (Slovenian trough) existed from the Triassic to Paleocene in the area of Tolmin (Buser, 1989). The transport direction could be suspected from the south, where the extensive Adriatic Carbonate Platform existed.

Description of the section

The entire section is lithologically monotonous. The limestone is thin-layered. Individual layers are from a few cm to 20 cm thick. The calcirudite show graded bedding and alternates rhythmically with calcarenite and micrite layers. A part of grains has been transported as plasticlasts into the basin. The clasts consist mostly of micritic and biomicritic limestone, fossils are planktic foraminifers, mostly globotruncanas. Shell debris, rudist fragments and echinoid plates are also observed. The matrix of calcirudite is micritic.

The calcarenite is moderately to well sorted. The biomicrite is homogenous and contains over 98 % of carbonate. Fossils are nearly all pelagic foraminifers, mostly globotruncanas, and radiolarians. Their quantity usually does not exceed a few per cent with a maximum of 10 % (mudstone). In some biomicritic samples thin parallel lamination is observed.

The chert nodules consist of microcrystalline quartz. They occur rather regularly distributed within the limestone, most commonly in clacarenite layers. Chert is believed to be of late diagetic origin.

In the Volče limestone the following globotruncanas were determined indicating Campanian age: *Globotruncana arca* (Cushman), *G.* cf. *conica* White, *G. fornicata fornicata* Plummer, G. ex gr. *linneiana* (D'Orbigny), *G. linneiana tricarinata* (Quereau), *G. calcarata* (Cushman), *G.* cf. *ventricosa* White, *G. spinea* Kikoine, *G. coronata* Bolli, *G.* cf. *elevata elevata* (Brotzen) and others.

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Plate 1

Fig. 1: Alternation of calcarenite and platy micrite. Chert nodules appear in some beds. Doblar section.

Fig. 2: Allodapic limestone showing a sharp contact of micrite and calcirudite. Natural size.

Fig. 3: Typical layer from the Volče limestone: Bedded chert in between calcarenite and micrite layers. Note the laminar structure of chert. Natural size.

Fig. 4: Micrite including pelagic foraminiferal debris, spicules and fragments of echinoderm plates. 40x.

Fig. 5: *Globotruncana conica* White. Biocalcarenite, Campanian-Maastrichtian. 66x.

SIGHTS OF INTEREST

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EXCURSION 1

Predjama

Predjama with an interesting castle is situated 9 km from Postojna. Close to the road, 2 kilometres from Postojna, there is an important Palaeolithic station called **Betalov spodmol**. In the years from 1933 to 1939 the excavations were led by F. Anelli and by S. Brodar in the years from 1947 to 1953. They found numerous stone and bone tools and Pleistocene animal remains. In the base there are deposits from the Mindel-Riss interglacial. The oldest culture is Tayacian - Premoustérian, followed by Levallois-Moustérian (Riss - Würm), Moustérian (the first Würm stadial), the late Moustérian (the middle of the Würm), Upper Palaeolithic - Gravettian (the second Würm stadial), Epigravettian (late glacial), and then Neolithic, Eneolithic, the Bronze age and Holocene sediments.

The Predjama castle with its museum was set up close to the karst cliff face at the entrance to a complex of subterranean caves and passageways. The oldest part of the castle was built in the cave in the 12th century and it was difficult of access. The existing renaissance castle originates from the 16th century and changed its owners: the Patriarchs of Aquileia or the Habsburgs. The most significant was the brigand knight Erasmus who supported the Hungarian King in his fights against the Austrian Emperor. Erasmus quarrelled with the Austrian King and among others, he killed Marshal Pappenheim on the court. He ran away to the Predjama castle where no one ever took him alive, for through the cave at the back and around the secret passageways he was able, in spite of all the sieges, to obtain supplies of everything he needed. In the 1483 they only managed to kill him with the help of traitors when he was on the latrine. Nowadays the castle as well as the cave represent an attractive sightseeing spot.

Karst

Karst is a countryside that extends from the Bay of Trieste to the Vipava valley denoting a special karst character of a certain landscape. Mainly, Cretaceous and Palaeocene limestones can be found, with various surface and subterranean speleothems (sinkholes, dry valleys, gulfs, caves, etc.). Owing to thinning and goat breeding the land was much more desolate in former times. Recently it has been forested by pine trees and oaks, so that it is mainly overgrown nowadays. Karst was settled already in the early Palaeolithic. In the ancient times there were Roman and other roads from the following historic periods. The railway line Vienna - Trieste cut Karst in the middle of 19th century. Different peoples moved over this region including the Turks who were trying to penetrate into the land and further west. No wonder that very early peoples became acquainted with speleothems. This way some native terms were transferred to professional terminology (dolina, polje, ponor and kras as a natural phenomenon - carso, Karst).

Karst Mediterranean climate is characterized by the strong north wind ("burja") that reaches the speed of even more than 100 kilometres per hour. Heap settlements are built of local stone, mainly limestone. Therefore, many quarries were around the villages in former times. Nowadays, newer types of houses and other building materials prevail while the older buildings were chiefly built of pieces and blocks of rudist or other Cretaceous limestones. Flat limestones were used for roof covering. In broader neighbourhood of Komen they used mainly Cretaceous Komen beds. The above mentioned types of roofs on the churches, houses and other buildings are still preserved in many places. Older houses are characterized by "portons", which means portals at the entrances into closed yards with carved years, initials of owners and other decoration, as crucifixes or ornaments.

In the old times rearing of livestock was developed at Karst as well as sheep breeding, fruit growing and viniculture. One of the most well known wine sort is Karst teran (the refošk vine) and the famous Karst prosciutto ("pršut") is worth tasting.

As there is almost no surface water at Karst, people use cisterns or artificial hollows in which rainwater and dripping water accumulate. In the present, excellent water is as well supplied from the spring at Brestovica, close to the border between Slovenia and Italy.

Due to the shortage of water the locals had to guard water during dry weather to protect it against people from the neighbouring villages. Along the Slovene - Italian border one can follow the dry river bed of the foaming Reka river, that now percolates into the famous **Škocjan caves** near Divača (under UNESCO protection). The river flows 40 kilometres in a rushing torrent through a canyon one hundred meters below the cave's bridges and walkways and comes to the surface as the Timavo river near Monfalcone.

There are many well known villages at Karst, being famous especially for teran and prosciutto (dried ham). These are: Dutovlje, Tomaj, Kostanjevica, Komen and, above all, Štanjel. Some of them were built at the top of the hills which meant a natural protection against besiegers. The first World war raved horribly through Karst. In the severe battles many soldiers were killed, villages burnt and the crops devastated.

Dolenja vas near Senožeče

The village is surrounded by pastures and fields, indicating that cattle breeding and fruit growing are developed. In special basins - ice pits they used to keep ice for the brewery in Senožeče. Up to the year 1935 ice was also taken to Trieste.

In the village there is Mary's Gothic church with frescoes and signatures of pilgrims from the second half of 15th century. The wooden Pieta, which is kept in the parson's house, belongs to the middle of the 15th century. A part of the walls and a defence tower with embrasures in four floors are still preserved.

Tabor

West from Dolenja vas, one can come across a little village, called Tabor. It is a Slovenian name for a defence system. In the Middle age there used to be a castle at the top of the hill that is supposed to have a triple wall. The Mother of God's church is most probably the enlarged onetime castle chapel.

Štanjel

Štanjel is the most significant and the most beautiful fortified settlement in Karst. It has got a strategic position above the transition point to the Vipava valley. The area was settled already in the ancient times, which is proved by the remains from the Hallstadt age with Illyrian population (a necropolis was found). Štanjel has developed on the site of previous Iron Age and Roman posts.

The arrival of the Old Slovenes in the 6th and 7th century brought stirring times to the region. First, Štanjel belonged to the Partriarchs of Aquileia and from the 11th century on the Bishops of Gorica ruled the area. In the time from 1100 to 1200 a fortification was set up on the hill. In the 15th century the region was invaded by Turks many times and after the year 1500 it was taken over by the Habsburgs. The village was surrounded by a wall with many towers. At the beginning of the 16th century Venetians arrived.

The village is characterized by typical Karst stone houses. Some of them have still got preserved stone gutters. Moreover, one can find preserved stone wells, portals, window frames and even stone roof covering. Close to the castle there is a church from the 15th century with a Gothic presbytery, external pillars and walled up Gothic windows. In the following periods, the church has been changed many times. The church tower has got a lemon cap. The relief in the high altar with the picture of the [tanjel castle from the end of the 17th century is especially valuable. The architect Max Fabiani (1865 - 1962) arranged terraced gardens with basins at the east side of Štanjel. However, his plans of bold conception for the arrangement of the whole Štanjel have never come true.

Kobjeglava

The house yards in the lumpy Karst village are mainly closed. The roofs are gentle, covered with the so called "korci" (semicircular tiles), which are weighted with stones so that north wind can not blow them away. The village is surrounded by fields and vineyards, cherry, plum and fig trees. In the St. Michael's church (renovated in the year 1717) there is the picture of Mary by the Slovene painter J. Tominc. In Kobjeglava prosciutto is being produced; they dry it also in private houses.

Lipica

The village is located very close to the Slovene-Italian border. The Archduke Karl II. of Austria founded a stud farm in 1580. They crossed local Karst horses with the Andalusian stallions. Gradually, the famous breed of Lipizzaners ("lipicanci"), beautiful, sturdy and clever horses emerged, that are the pride of the Spanish Riding School of Vienna. The famous Lippizaners are mostly white, while the young ones are black.

Vilenica

Between Sežana and Lokev lies a Karst cave called Vilenica, which is supposed to be the first cave in the world to become a tourist destination. Until the discovery of the Postojna cave it was believed to be the largest and the most fascinatingly moulded cave in Karst. In the length of more than 1000 metres the cave features a number of exceptionally beautiful stalactites and stalagmites. Regretfully, many of them have been carried away. Preserved data from the year 1633 give evidence about the entrance fee income and the entry book indicates over 2000 visitors in the years from 1821 to 1889. The first picture of art is said to be painted in the cave. In 1821 the painter Peter Fendi was awarded the golden medal for the oil painting of Vilenica. Since the year 1986 the

Vilenica cave has been the site of an annual international literary gathering known under the same name.

Lokev

In the village there are characteristic old single or many storeyd houses. Some of them are linked. The portals at the entrance gates to the yards are made of Cretaceous limestone. In the past they bred cattle and sheep and nowadays prosciutto is being manufactured. In the middle of the village there is a well-preserved tower ("tabor") from the year 1485 which served as a defence against the Turks. Being in jeopardy, people hid corn and meat into the tower and defended themselves from there. In the renovated tower one can visit a restaurant and a military museum.

During the Italian occupation Tone Kralj painted the interior of the St. Michael parish church from the 17th century. The content of the paintings is deeply symbolic as for example fascism and persecution of Slovenes, or presentation of some historic figures. Near the church there is the Chapel of God's Mother with a sculpture of Mary. It was built in the middle of the 15th century. The bell of the St. Michael's church that has been removed from the chapel, originates from the 12th century and is one of the oldest bells in Europe. A bronze enamelled crucifix from the period between the 12th and 13th century was made in Limoges, France and is kept in the Lokev parson's house.

Fig. 1. Church in the village Križ near Tomaj. Photo K. Drobne

EXCURSION 2

The Vipava valley

The Vipava valley extends between Razdrto and Gorica. A part of its bottom and the hilly terrain on its south-western fringes consist of Eocene flysch rocks. Quaternary deposits are in the flat part of the valley surface. On the south side the flysch rocks adjoin the Eocene, Palaeocene and Cretaceous limestones. In the north slopes there are mainly Jurassic and Cretaceous limestones, partially with Triassic dolomite.

The main river, Vipava, has a karst spring, but all the way to the outfall into the Soča river (Isonzo) it flows on the surface. Summers in the Vipava valley are mild or sometimes hot, yet in the winter the strong north wind blows, that sometimes turns the cars over at the Veterno polje (Windy field). The major part of the valley is covered by vineyards and fruit trees. The most famous are the Vipava cherries.

Vipava and **Ajdovščina** are the largest places in the valley. The Lanthieri Counts were the owners of the Vipava castle and their summer manor from the 17th century is located on the nearby low hill called Zemono. In Ajdovščina there are the well-known factories of macaroni and fruit juices.

The town of **Nova Gorica** has developed at the utmost western part of the Vipava valley, very close to the Italian Gorizia. Nova Gorica started to grow after the second World war, because the old part of the town (Gorizia) was allocated to Italy. On the hill above the town there is a Franciscan monastery, Kostanjevica, which was heavily damaged during the first World war. As the Bourbon family was exiled from France, they found the refuge here. They are buried in the family vault under the church, together with the last French monarch, Charles X., who died in 1836.

The nearby **Kromberk** castle, which is a specimen of the north-Italian renaissance architecture has developed in a rich museum with archaeological, ethnological, cultural and historic departments with an art gallery.

Sveta gora - Holly mountain (Skalnica 681m) above Gorica is a very popular pilgrimage. The first church there was built in 1544 and was dedicated to Mary. Soon afterwards, the Franciscan monastery was set up. Due to fierce battles in the surroundings, both buildings were entirely destroyed during the first world war. In 1927 they rebuilt the church and used Cretaceous limestone from Nabrežina (Aurisina) near Trieste.

Goriška brda

Goriška brda is a hilly country, extending north-west from Gorica and further to Italy (Colli Goriziani or, shortly called Collio). The highest hills reach up to 300 metres. Towards south they sweep gently down to the marshy plain that is closed by the Colli di Cormons at the other side. Goriška brda consist mainly of Palaeogene flysch rocks. However, in the south and east part there are some Cretaceous and Palaeocene layers of the scaglia type (Podsabotin beds) as well as upper Cretaceous rudist limestones. The country is covered with vineyards and orchards, while woods are scarce. During Venetian and French wars many villages were fortified.

The St. Crucifix's church above **Kojsko** is famous for its late gothic side altar from 1515. In the 15th century there was a defence fortification with four towers. One of them developed in the church tower. The **Šmartno** village is being restored today. The wall with four defence towers is preserved. **Dobrovo** is the administrative centre of Goriška brda. In the castle there is a museum and excellent wines as briški merlot, rebula, tokaj, white and grey pinot, chardonay and cabernet are found in the wine cellar under the village.

Posočje

The area along the Soča river is called Posočje. The river rises in the bosom of the Julian Alps and is extraordinary green. Dr. Julius Kugy from Trieste wrote that it was the most beautiful river in Europe. Besides, its significant feature is a trout that is well known to fishers (*Salmo marmoratus* Cuvier, 1817, - the Slovenian name "soška postrv", the English name "marble trout").

Tolmin

The town of Tolmin is the educational and industrial centre of Posočje. Close at hand there are river beds of the Tolminka river. Both sides of a deep gorge are linked by the Devil's bridge (Hudičev most) and not far away there is the Dante's cave (Zadlaška jama) which extends in the length of 200 metres. The famous Dante Alighieri is said to visit the gorge and the cave when calling the Patriarch of Aquileia.

Kobarid

Kobarid is a very interesting serried settlement at the edge of the Julian Alps. Here one can meet characteristic houses of "Kobarid type". They have wooden passages (which resemble the alpine type of passages); the buildings are set up of stone with gentle roofs (Mediterranean type). In 1976 Kobarid was damaged by the earthquake. The St. Antonio's church with the ossuary of 1014 Italian soldiers, killed in the first World war, is located above Kobarid.

The Kobarid museum was opened in 1990. It has been dedicated to the stormy events in the region during the first World war. The close of military operations on October, 24, 1917, is specially presented. A breakthrough was organized, or the first so called "Blitzkrieg", which was quite unusual for that time. The event was a turning point in the entire world history. With the help of Germans the Austro-Hungarian army broke through the Italian line and penetrated to the Piave river. The events are described in the Hemingway's novel Farewel to Arms. In the year 1993 the museum of Kobarid was proclaimed as a European museum by the European Council commission.

The **Tonovcov castle** near Kobarid is a large, late antique settlement with an excellent natural and artificial protection. Over twenty antique buildings and three churches indicate an important colony and a sacral centre that reached its highest point in the 6th century. Beside the Romanced aborigines the castle was a dwelling place of the East Goths and the Lombards (Dr. Slavko Ciglenečki).

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Front cover: The K/T boundary at Dolenja Vas

Above: Paleocene biomicritic limestone. Bioturbation cavity filled by discorbids, *Paronipora* fragments, Dv VI/3, x 15. Photo B. Ogorelec, coll. K. Drobne.

Center: Location of some K/T boundary sections. • - deep-water, - shallow-water depositional environment

Below: micritic limestone with *Bournonia* aff. *triangulata* Zucchi et Pleničar, clast in breccia, det. by M. Caffau and M. Pleničar, Dv II/9, x 15.

Back cover: Geological map of west Slovenia, part of Geological map of Slovenia, scale 1:500 000, compiled by S. Buser and V. Draksler from data of Geological Survey Ljubljana, 1989. Published by Mladinska knjiga, Copyright Geodetski zavod Slovenije, kartografski oddelek, 1990.

Legend:

Excursion stops:

1st day - carbonate platform

1. Dolenja Vas (K/T boundary)
2. Škrbina (Upper Cretaceous)
3. Padriciano (K/T boundary, Paleocene)

2nd day - basin

4. Lijak (K/T boundary, Paleocene)
5. Lig (K/T boundary)
6. Doblar (Upper Cretaceous)

Key to map symbols:

Quaternary

1 alluvial deposits

Pliocene and Pleistocene

2 clay and sand
3 gravel, sand and clay

Miocene

4 sand, sandstone,conglomerate, marl, clay and limestone

Oligocene

5 marl, clay, sandstone, conglomerate and limestone
6 andesitic tuff

Eocene

7 alternation of marl, mudstone and sandstone (flysch); sandstone and mudstone

Paleocene and Eocene

8 thick-bedded limestone, Alveolina-Nummulites limestone

Paleocene

9 alternation of sandstone, mudstone, marl and breccia (flysch)

Cretaceous

10 carbonate breccia, flysch and red marl
11 rudist limestone
12 thin-bedded Volče Limestone with chert; alternation of thin-bedded limestone and red marl
13 bituminous dolomite and fine-grained limestone
14 alternation of sandstone, mudstone and marl (flysch), chert nodules

Jurassic

15 reef limestone with corals and stromatoporoids, oolite, alternation of dolomite and limestone
16 oolite, fine-grained limestone, bituminous dolomite
17 thin-bedded limestone, mudstone and chert

Triassic

18 thick-bedded limestone and dolomite
19 thin-bedded Bača Dolomite and limestone with chert
20 mudstone, sandstone, breccia, limestone and dolomite
21 dolomite and limestone
22 mudstone, sandstone, tuff, marl, conglomerate and limestone
23 keratophyre, porphyrite, quartz keratophyre and diabase
24 dolomite, limestone, marl and sandstone

Permian

25 quartz sandstone and conglomerate, mudstone and limestone

Permian and Carboniferous

26 shale, quartz sandstone and conglomerate, limestone

Devonian

27 limestone
28 stratigraphical contact
29 fault
30 thrust fault
31 slice

GEOLOGICAL MAP OF WEST SLOVENIA

compiled by Stanko Buser and Vera Draksler
from data of Geological Survey Ljubljana, 1989.

scale 1 : 500 000

Legend

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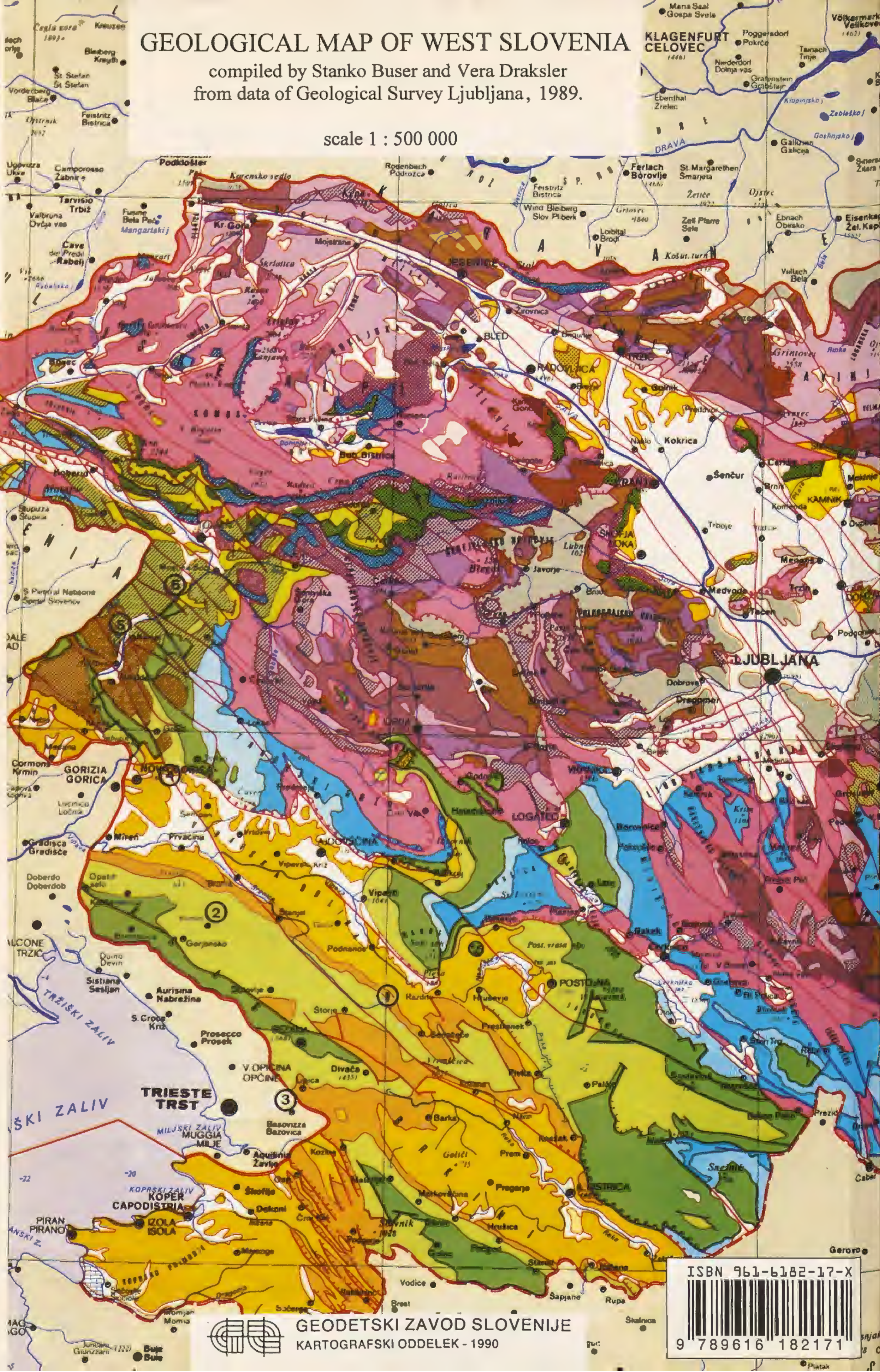

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