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UPPER CRETACEOUS FLORA OF SLOVENIA

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ABSTRACT

Plated and laminated limestones with chert of the Trieste-Komen plateau occur as a special facies within different Upper Cretaceous platform sediments. In the present state of study they are ranged as the Komen and the Tomaj Limestones. In both limestone types many fossil plants were collected. The Slovenian flora differs from all known Upper Cretaceous floras of Europe in the predominance of conifers, while angiosperms are in the minority. In this paper, plants from ten localities are documented that have not been present till now in the map of the Upper Cretaceous floras of Europe.

Key words: flora, Upper Cretaceous, Dinaric carbonate platform, Trieste-Komen plateau, Slovenia

INTRODUCTION

The finds of megaplant fossils of the Upper Cretaceous platy and laminated limestones of the Trieste-Komen plateau have been poorly known. In spite of numerous specimens from the Komen Limestone that have been housed for decades in the Natural History Museum of Slovenia in Ljubljana and in the Museo Civico di Storia Naturale in Trieste (Italy), plant fossils attracted little attention compared with many vertebrate finds, especially fishes and reptiles reported already by Gorjanović-Kramberger (1895). The megaplants of the Santonian-Campanian Tomaj Limestone have not been known until recently. Yet, they were only mentioned in the journal Annales in the paper on the find of the ray *Rhinobatos* (Jurkovšek & Kolar-Jurkovšek, 1995). The Maastrichtian plants of the Liburnian Formation were partly described by Stache (1889).

A new locality appears on the map of the Upper Cretaceous floras of Europe in the very middle of the European continent. Upper Cretaceous plants in Slovenia, widens seriously our knowledge about Cretaceous floras of Europe. This flora differs from all known Upper Cretaceous floras of the region in the predominance of conifers while in other localities of Europe, Africa and Near East in coeval floras the main role belongs to angiosperms, where conifers are in the minority or are completely absent. In the studied collection, the angiosperms are represented by small quantity of small isolated leaves. Slovenian conifers are very special. We still could not find similar species in coeval deposits of Europe. Probably there are new conifer species or even genus in the flora under consideration. Their general habitus recalls more ancient types of conifers.

Unfortunately, the preservation of imprints is not good enough, cuticles are absent. For monographic study more time and material are needed. In spite of this it seems advisable to publish preliminary conclusions of our study: to give preliminary determinations of plants, together with their photographs, to present general review of the Slovenian Upper Cretaceous flora and compare it with coeval floras of the adjacent areas.

Studied megaplant specimens are housed in the collections of the Natural History Museum of Slovenia in Ljubljana, the Museo Civico di Storia Naturale di Trieste (Italy) and the paleontological collection of Bogdan

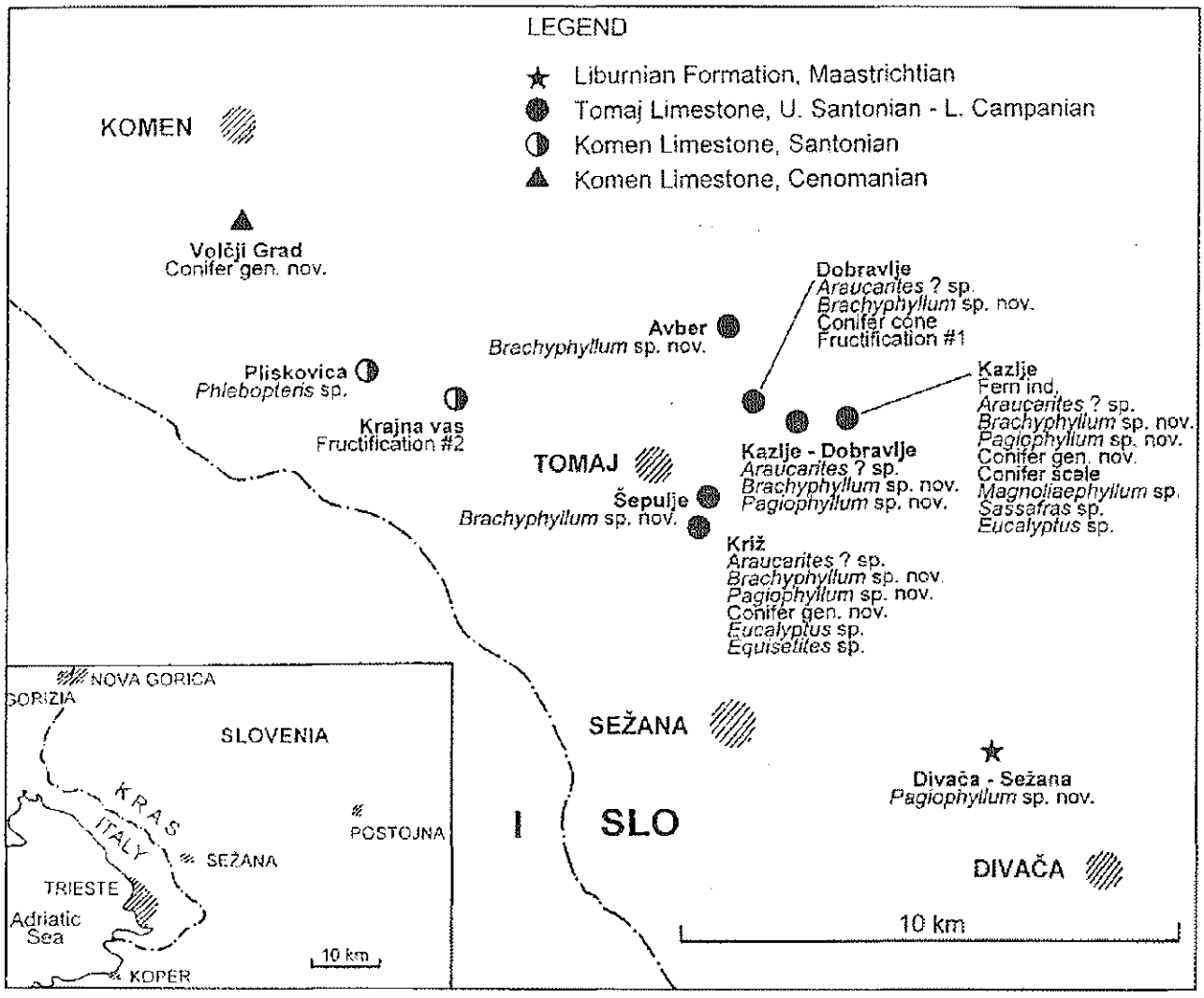

Fig. 1: Geographic sketch map showing distribution of fossil flora at different localities.
Sl. 1: Geografska skica z razširjenostjo fosilne flore v različnih nahajališčih.

Jurkovšek and Tea Kolar-Jurkovšek at Dol pri Ljubljani (Slovenia) that has been in accordance with the current legislation registered with the Ministry of Culture of the Republic of Slovenia and the Natural History Museum of Slovenia.

Abbreviations:

PMS - Prirodoslovni muzej Slovenije / Natural History Museum of Slovenia, Ljubljana

TS - Museo Civico di Storia Naturale di Trieste, Italy,

BJ - Paleontological collection of Bogdan Jurkovšek and Tea Kolar-Jurkovšek, Dol pri Ljubljani.

LATE CRETACEOUS BITUMINOUS LIMESTONES OF THE TRIESTE-KOMEN PLATEAU AND STRATIGRAPHIC POSITION OF THE STUDIED PLANT FOSSILS

Kras in strict tectonic sense can be defined as the Trieste-Komen plateau or the Komen thrust sheet (Fig. 1), but in a wider geotectonic sense Kras belongs to the extensive Outer Dinarides. It is characterised by shallow water platform carbonates and occurrence of black platy and laminated bituminous limestones with chert that locally comprise also plant fossils. They appear within different Upper Cretaceous formations from Cenomanian to Campanian. On the geological map of the southern part of the Trieste-Komen plateau 1 : 50,000 (Jurkovšek *et al.*, 1996) these rocks are incorporated in two members, the Komen and the Tomaj Limestones. The older member is the Komen Limestone that appertains to the Povir, Repen and Sežana Formations; the younger member is the Santonian-Campanian Tomaj Limestone of the Lipica Formation (Fig. 2).

Due to the common lithological similarities of bituminous platy and laminated limestones with chert of various formations, first of all those characteristics that

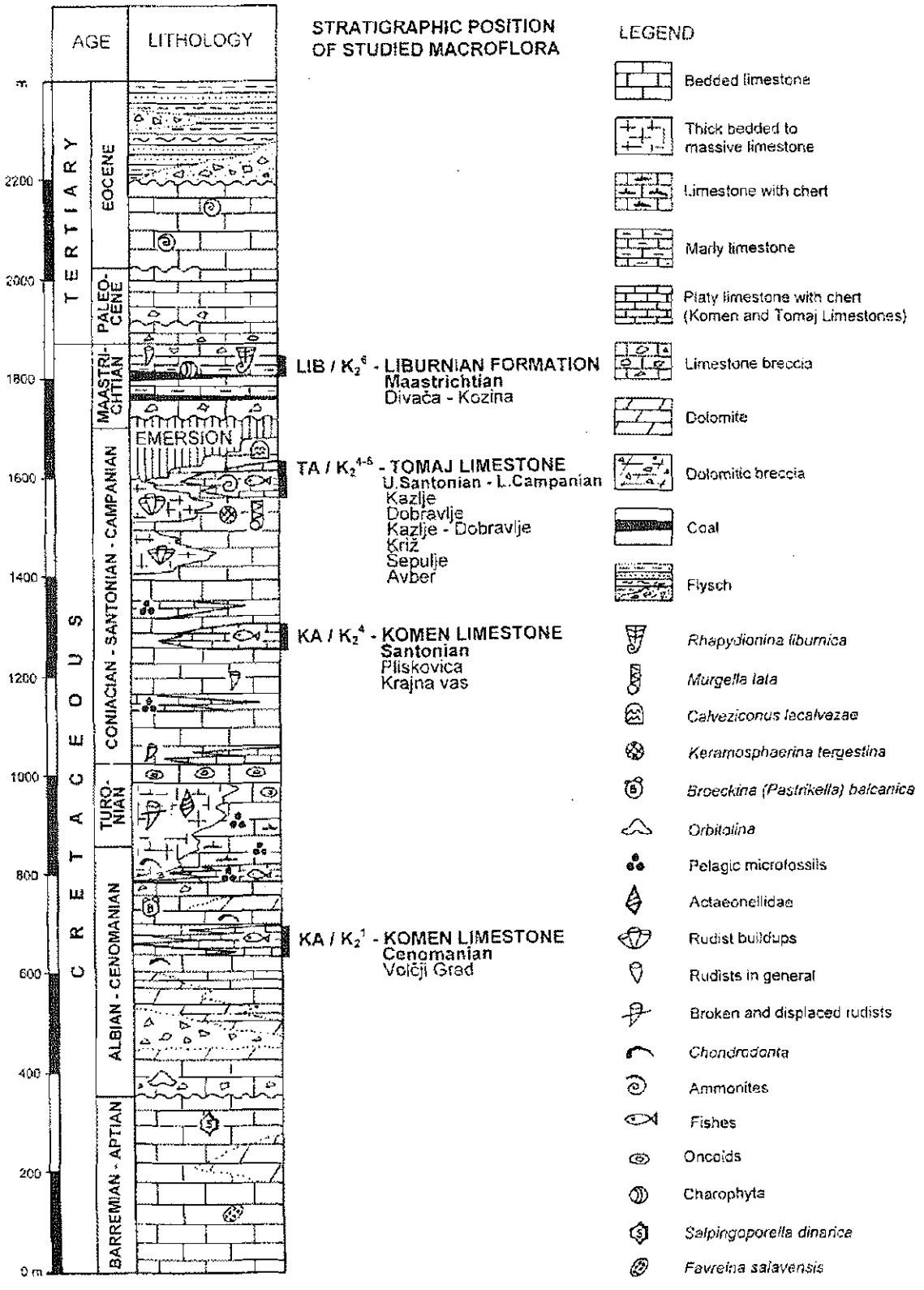

Fig. 2: Stratigraphic column of the Cretaceous beds of the Trieste-Komen plateau with marked positions of studied flora.
Sl. 2: Stratigrafski stolpec kredних plasti Tržaško-komenske planote z označenimi položaji raziskane flore.

point out to different modes and areas of their origin on the carbonate platform were considered during the geological mapping of the northern part of the Trieste-Komen plateau.

Based on the studies of depositional environments and mechanisms of the modern marine carbon rich black shales, Arthur and Sageman (1994) summarised that their deposition can take place in five major modern marine environments:

deep, enclosed basin,
deep borderland basin,
continental slope, zone of "upwelling",
shallow stratified basin,
coastal / intertidal zone.

Šribar (1995) was of the opinion that due to the position on the carbonate platform, only the areas of "upwelling" and coastal intertidal zones were adequate in the case of southwestern Slovenia for the formation of the Upper Cretaceous bituminous limestones.

Komen Limestone (from the vicinity of Komen) has been recently often discussed as evidence for the second oceanic event (OAE 2). Based on comparison of facies on the Dinaric-Adriatic platform and conditions in a wider Mediterranean area, Jenkyns (1991) concluded that during the Cenomanian-Turonian there was a particularly thick column of anoxic water. In the Umbria-Marche basin it resulted in a deposition of the Bonarelli Level. OAE 2 consists of more anoxic events and the main (Bonarelli Level) is preceded by several thinner anoxic levels (Montanari *et al.*, 1995). Oceanic anoxic events influenced the sedimentary conditions of the Dinaric carbonate platform of southwest Slovenia. They were decisive mainly for the deposition of the Komen Limestone within the upper part of the Cenomanian Povir Formation and the Cenomanian-Turonian Repen Formation. Indeed, similar anoxic conditions could exist also in enclosed lagoons where high biological production and oxygen minimum caused a deposition of carbon rich beds.

Precise interpretation of the origin of the Tomaj Limestone remains not fully understood, for the connection with the eustatic sea level rise in this part of Tethys has still not been explained. According to Šribar (1995), the authigen formation of anoxic conditions seems to be likely. Based on the presence of alodapic limestones, a somewhat deeper environment of the deposition of these beds was presumed by Ogorelec and associates (1987). In contrast to the Komen Limestone, there have never been any indications of intertidal conditions in the Tomaj Limestone (Jurkovšek *et al.*, 1996). Pelagic micro- and megafossils with prevailing ammonites indicate a good connection of the sedimentary environment with open sea. Summesberger and associates (1996a, 1996b, 1999) reported on numerous ammonites with preserved body chambers, aptychi partially in situ and their rollmarks, which means that in the water column above the seafloor with anoxic conditions allowed the existence of nektonic and planktonic organisms. At certain levels, a mass mortality with fishes is evidenced and it is connected with mixing of well-stratified water in a lagoon. Based on hitherto knowledge, a strong influence of pelagial on the Tomaj Limestone can be linked also to the sea level rise and the second pelagic episode during the Late Santonian-Campanian that reached its maximum in the Campanian (Haq *et al.*, 1987; Gušić & Jelaska, 1990; Kolar-Jurkovšek *et al.*, 1996). A rich macroflora is present at the studied localities of the Tomaj Limestone and it was derived from the land that as early as in the Late Santonian began to rise up south of the Tomaj lagoon (Pleničar & Jurkovšek, 1997a, 1997b).

Organical-chemical parameters of the Komen and Tomaj Limestones are similar. However, the average value of the organic matter ($C_{org.}$=0.48%) is in general higher in the Tomaj Limestone than in the Komen Limestone. That ranks the Tomaj Limestone to the lowermost range of hydrocarbon potential source rocks (Ogorelec *et al.*, 1996). In comparison with the Komen Limestone it contains more organic matter of marine origin (alginite), while in the Komen Limestone there prevails the organic matter of terrestrial origin (lignin-huminite type).

The studied museal specimens of the Upper Cretaceous flora housed in the Natural History Museum of Slovenia in Ljubljana and the Museo Civico di Storia Naturale di Trieste (Italy) were ranged into different horizons of the Komen Limestone and in the Tomaj Limestone according to the recorded data (Fig. 2). Samples from Volčji Grad were collected in the Komen Limestone of the Povir Formation and are Middle to Late Cenomanian in age. The plant fossils of Pliskovica and Krajna vas were recovered from the Komen Limestone of the Santonian part of the Sežana Formation. All samples including samples from the Paleontological collection of Bogdan Jurkovšek and Tea Kolar-Jurkovšek that were collected in the areas of Kazlje, Dobravlje, Šepulje and Križ are ranged in the Upper Santonian-Campanian Tomaj Limestone of the Lipica Formation. The specimen from the Divača-Sežana motorway section was sampled in the Maastrichtian part of the Liburnian Formation just above a thin coal bed.

PALEONTOLOGICAL PART

Systematic composition of the Upper Cretaceous Flora of Slovenia

Type **Sphenopsida**
Class **Equisetinae**
Order Equisetales
Family Equisetaceae
Equisetites sp.

Type **Pteropsida**
Class **Filices**
Order Filicales
Family Matoniaceae
Phlebopteris sp.

Class **Gymnospermae**
Order Coniferales
Family Araucariaceae
Araucarites ? sp.
Family Araucariaceae ?
Brachyphyllum sp. nov.
Pagiophyllum sp. nov.

Family Taxodiaceae
Sequoia sp.

Family unknown.
Conifer gen. nov.

Conifer cone
Conifer scale

Class **Angiospermae**
Order Magnoliales
Family Magnoliaceae
Magnoliaephyllum sp.

Order Laurales
Family Lauraceae
Sassafras sp.

Order Myrtales
Family Myrtaceae
Eucalyptus sp.

Undeterminable fructifications

Sphenopsida

Only one incomplete specimen with two rests of stems is present in our collection (Pl. 1, Figs. 2a, 2b). Because of its preservation it is impossible to see if there are alternating ribs or not. So determination as *Equisetites* is conditional and it cannot be excluded that these remains belong to such similar genera as *Calamites, Neocalamites* etc.

Filicales

Ferns in our collection are represented by two specimens, one of which is indeterminable. The second one (Pl. 1, Figs. 1a, 1b, 1c) is considered to be *Phlebopteris* without species determination. On photos one can see sterile leaves with very characteristic venetion (Pl. 1, Figs. 1a, 1b) and fertile ones (Pl. 1, Fig. 1c) as well.

Coniferales

Some conifer scales from different localities have been determined as *Araucarites* with the question mark (Pl. 11, Figs. 1-6), but they should certainly be additionally investigated.

Relatively large leafy twigs are the basis of our collection. The majority of them are considered to be *Brachyphyllum* (Pl. 2, Figs. 1-6, Pl. 3, Figs. 1-5) and *Pagiophyllum* (Pl. 4, Figs. 1-6, Pl. 5, Figs. 1-3, Pl. 6, Figs. 1-2). The two above-mentioned genera differ from each other by the relations of the free part of the leaf and its attached part: the first has leaves attached to rachis by all their length. In the second a large part of the leaf is free. In our material there are many intermediate forms, so it is difficult to find a boundary between genera and is merely conditional. Only after monographic study it will be possible to give more exact determinations and to compare Slovenian species with the species from different regions. Nevertheless, at the first stage of the study this is not so important, as both belong to the same group of conifers and can be used as homogenous flora.

The genus *Brachyphyllum* is known from the Upper Cretaceous floras, e.g. from Daralagez in the Transcaucasus and from Lebanon. But it is more widely distributed in the Lower Cretaceous (Portugal, West Kazakhstan, Primorye, India), Jurassic (Yorkshire, Central Europe, France, North Italy, Caucasus, Georgia, less in Central Asia and India) and Triassic (Donbass, Central Asia, Pamirs, Vietnam).

In the Trieste Museum of Natural History there are several very interesting specimens from the locality of Volčji Grad (Pls. 7, 8, 10). They are relatively large twigs compactly covered with leaves or scales as in *Brachyphyllum*. In the upper part, the twigs are dichotomizing several times. In the lower part of rachis places of deciduous twigs are seen. One plant from Križ (Pl. 9, Figs. 1a, 1b, 1c) also belongs to this group. According to the number of dichotomy and thickness of twigs of the second order, these plants can be divided into two groups (two species of a new genus?). Specimens on plates 7, 8 and 9 belong to the former one, specimens on plate 10 to the latter. In our list of fossil species they appear under the name "Conifer gen. nov".

There are seven specimens of this kind in the collection, and five of them were found at a single locality - Volčji Grad. This locality produced only this kind of plant remains.

Conifer twigs resembling the above mentioned plants due to their habitus and size are described and figured from the Cretaceous of Bohemia, Portugal and northern France. But none can be identified with Slovenian remains.

Conifer cone and scales

There are remains of isolated conifer scales and one full conifer cone (Pl. 11) in the Slovenian collection. At this stage of the study we prefer not to determinate them as yet.

Angiosperms

Among 61 specimens of fossil plants in our collection there are only nine small isolated leaves of angiosperms, which could be due to the insufficient material determined only approximately. In our opinion they belong to *Magnoliaephyllum* (Pl. 12, Figs. 1-3), *Sassafras* (Pl. 12, Fig. 10) and *Eucalyptus* (Pl. 12, Figs. 4-8).

Undeterminable fructifications

Two very interesting imprints were found at the localities of Dobravlje (Pl. 12, Fig. 12) and Krajna vas (Pl. 12, Fig. 11). They are probably fructifications. We do not exclude that they belong to Caytoniales, but would rather not determine them as yet.

Thus, among 61 imprints of the Upper Cretaceous plants there are 46 conifers, 9 angiosperms, two ferns and one horsetail and two fructifications of unknown affinity. This means that conifers constitute more than a half of the collection - 77%, angiosperms - 17%. Conifers and angiosperms jointly cover 94% of the entire material (Fig. 3).

Conifers are of an old appearance, including those that have been determined as *Brachyphyllum* and *Pagiophyllum*. Remains that have been determined as "Conifer gen. nov." generally resemble the genus *Voltzia*, which was widely distributed in Europe during the Triassic. In order to compare Slovenian fossils with *Voltzia* we would require not only additional and more abundant material from Slovenia but also a revision of the last genus. This has still not been done.

Local geography and geology. Localities.

Distribution of fossil plants at different localities; the number opposite the species name indicates the number of imprints of the species.

Volčji grad, Cenomanian: Conifer gen. nov. - 5

Pliskovica, Santonian: *Phlebopteris* sp. - 1

Krajna vas, Santonian: Fructification #2 - 1

Avber, Santonian-Campanian: *Brachyphyllum* sp. nov. - 2

Dobravlje, Santonian-Campanian: *Araucarites* ? sp. - 1; *Brachyphyllum* sp. nov. - 6;
Conifer cone - 2; Fructification #1 - 1

Kazlje-Dobravlje, Santonian-Campanian: *Equisetites* sp. - 1; *Araucarites* ? sp. - 1; *Brachyphyllum* sp. nov. - 2; *Pagiophyllum* sp. nov. - 3

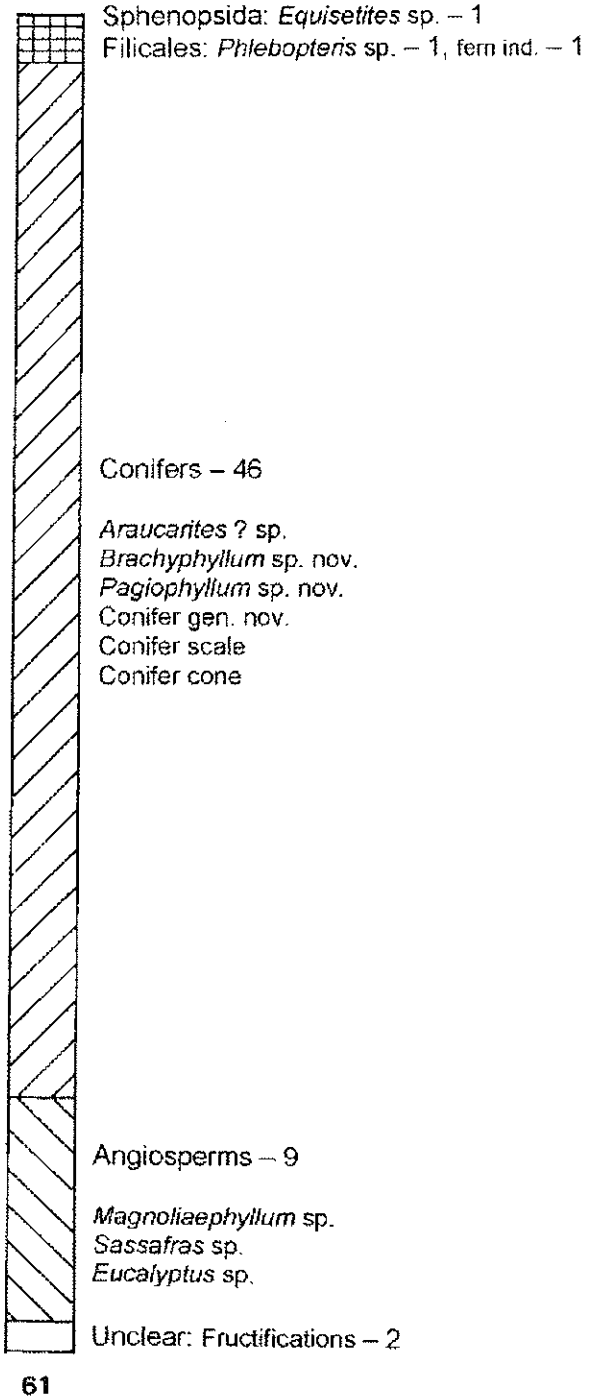

Fig. 3: Relative role of the main fossil plant groups in the Upper Cretaceous floras of the Trieste-Komen plateau. The whole number of imprints is given under the column, the number of imprints of each group is shown by the name of the group.
Sl. 3: Relativna vloga najvažnejših skupin fosilnih rastlin v zgornjekredni flori Tržaško-komenske planote. Celotno število odtisov je podano pod stolpcem, število odtisov vsake skupine je prikazano pri imenu skupine.

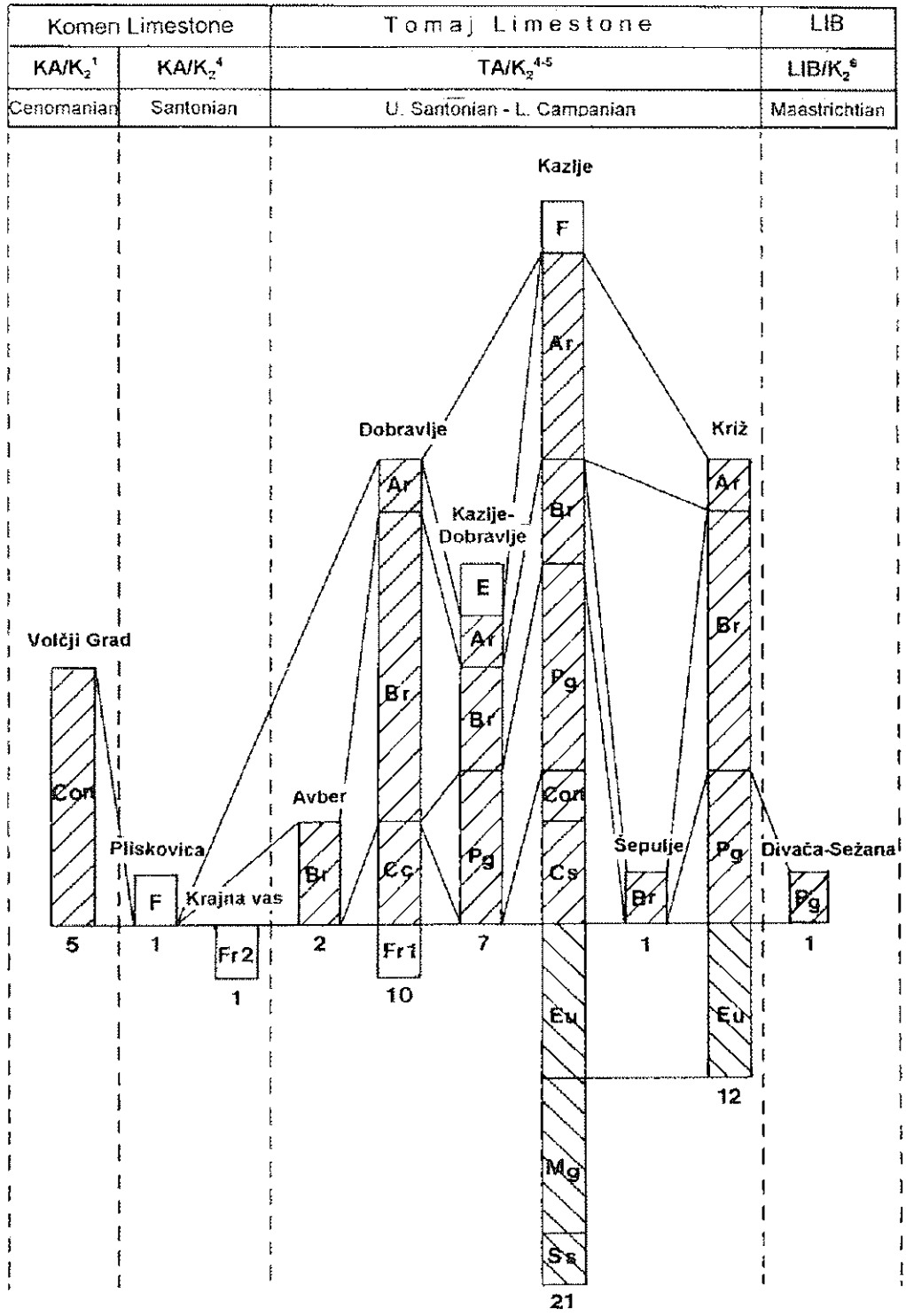

Fig. 4: Systematics of the Upper Cretaceous plants of the Trieste-Komen plateau at different localities, the number of accounted imprints is given under the columns:
Sl. 4: Sistematika zgornjekrednih rastlin Tržaško-komenske planote po nahajališčih, število odtisov je podano pod stolpcem:
E - Equisetites, F- ferns, Ar - Araucarites, Br - Brachyphyllum, Pag - Pagiophyllum, Con - conifer gen. nov., Cc - conifer cone, Cs - conifer scale, Eu - Eucalyptus, Mg - Magnoliaephyllum, Ss - Sassafras, LIB - Liburnian Formation.

Kazlje, Santonian-Campanian: Fern ind. - 1; Araucarites ? sp. - 4; *Brachyphyllum* sp. nov. - 2; Pagiophyllum sp. nov. - 4; Conifer gen. nov. - 1; Conifer scale - 2; Magnoliaephyllum sp. - 3; Sassafras sp. - 1; Eucalyptus sp. - 3

Šepulje, Santonian-Campanian: *Brachyphyllum* sp. nov. - 1

Križ, Santonian-Campanian: *Araucarites* ? sp. - 1; *Brachyphyllum* sp. nov. - 5; *Pagiophyllum* sp. nov. - 2; Conifer gen. nov. - 1; *Eucalyptus* sp. - 3

Divača-Sežana, Maastrichtian: *Pagiophyllum* sp. nov. - 1

In figure 4, distribution of species at different localities is shown graphically.

Comparison with adjacent Cretaceous floras

We still could not have found with certainty any analogues of Slovenian plants in coeval floras. We could not find any similar Upper Cretaceous flora - neither in the Northern Mediterranean (Europe), nor in the Southern Mediterranean (Near East and Northern Africa). No flora has so many conifers (and special ones) and so few other plants (Dobruskina, 1996, 1997).

On the other hand, in adjacent areas, abundant conifers existed in the Triassic (NE Italy, Slovenia, Austria, Switzerland, Germany, France), Jurassic (Italy) and perhaps in the Cretaceous of Northern Italy. According to the finds of the fossili woods, conifer forests were widely distributed in Israel and Lebanon (Dobruskina & Philippe, 1996).

Figure 5 shows Upper Cretaceous localities in Europe and in the Transcaucasus. The nearest to the Trieste-Komen plateau are Hvar (Kerner, 1895) and Friuli (Pinna, 1993). In spite of the insufficient data about age and composition of these two floras, it is possible to say that they do differ from Slovenian flora. From Lesina 6 ferns, 9 cycadophytes, 6 conifers and 5 angiosperms were figured. Neither plants themselves nor relations between the main plant groups are the same as in Slovenia. From "Vernasso nel Friuli" only several small imprints of conifers - different from Slovenian - were figured.

Regarding the still unstudied flora of Gruenbach in Niederoesterreich there are, according to the list in Guidebook (Summesberger, 1997) five ferns, two gymnosperms and 25 angiosperms. This is quite common for the majority of the Upper Cretaceous floras in Europe but different from Slovenian.

The most famous and abundant among the Upper Cretaceous floras of Europe is the Cenomanian flora of Bohemia and Moravia. It was first described as early as in 1881-1887 by Velenovsky. Now it is being intensively studied. Only the list of references covers three pages (if we have all of them) and consists of 14 publications of Velenovsky (including Velenovsky & Vinclar) and at least of 26 publications of other paleobotanists (Bayer, Heer, Elkund, Hlustik, Knobloch, Kvacek Z., Kvacek J., Nemejc). But in spite of the abundance of publications, localities and specimens, there has still been no updated review of the Bohemian Upper Cretaceous flora. It is difficult to determine the dominant plant group, because there are many ferns, many cycadophites, enough conifers, and many angiosperms. Amongst conifers we did not find forms similar to the Slovenian representatives of this group.

It seems that more features that are common with ours may be in the flora of Daralagez (Transcaucasus), but very few plants have been figured and briefly described (Palibin, 1937). In his conclusions, Palibin refers to the abundance of conifer forests and leafy forests in the Upper Cretaceous of Daralagez. At the same time he emphasises a great similarity of Daralagez flora to the Bohemian flora. One specimen - determined by Palibin as *Widdringtonites* - slightly resembles our "conifer gen. nov", but is much smaller.

Another similar twig (and again much smaller) was figured by Teixeira (1948) from Portugal as *Sphenolepidium*. In general, the Upper Cretaceous flora of Portugal is not similar to ours, for it consists mainly of angiosperms.

Lower Cretaceous conifers from Northern Italy were figured in the large volume of G. Pinna with reference to Bozzi L. La flora cretacea di Vernasso nel Friuli - Bulletino della Societa Geologica Italiana, vol.10, Roma, 1891. More up-to-date information on plants and localities is still not at hand.

In Northern Italy, rich conifer flora is known from the Lower Jurassic of Grey Limestone of Veneto - Vecentino and Veronese - not far from just mentioned region (Wesley, 1956, 1958).

Conifers (chiefly, genus *Voltzia*) predominated in many Triassic floras of Central Europe (Dobruskina, 1993, 1994): Carnian Alps (Raibl), Karavanke in Slovenia, Northern Limestone Alps in Austrian Tyrol, the German Basin (for example, in *Voltzia* sandstone). As already said, a revision of the genus *Voltzia* would be needed for comparison and determination of our conifers.

CONCLUSION

The first - preliminary and very short - review of the Slovenian Upper Cretaceous plants shows that in the Late Cretaceous very specific flora existed in the centre of Europe. When we speak about specificity of the flora we have in mind its composition - relations between different systematic groups in it, as well as systematic position of each plant.

According to its composition, the flora differs very much from the adjacent coeval floras and bears more resemblance to the Jurassic and Triassic floras of the re

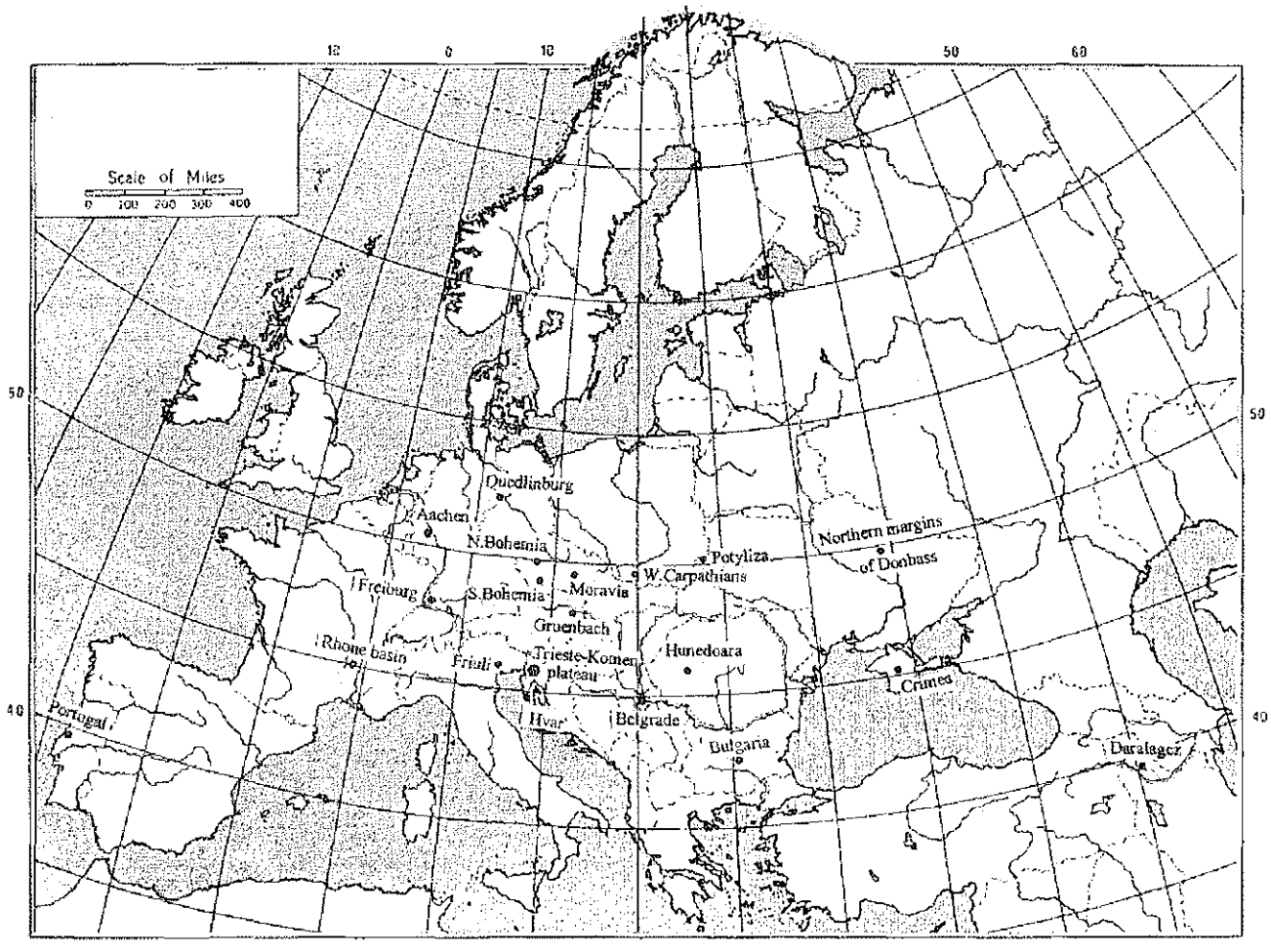

Fig. 5: Localities of the Upper Cretaceous plants in Europe and in the Transcaucasus.
Sl. 5: Nahajališča zgornjekrednih rastlin v Evropi in Zakavkazju.

gion. Sure, future investigations will discover more exact systematic relations of Slovenian plants. It is especially interesting for conifers. Conifers, from one hand, constitute the majority of studied plant assemblages. On another hand, they hint at the connection with old vegetation. Nevertheless, it is obvious that they differ enough from the Cretaceous plants known in Europe, North Africa and the Near East. And this conclusion does not depend on their belonging to one or another systematic group.

ACKNOWLEDGEMENTS

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We are indebted to the residents of Kazlje, Dobravlje, Križ and Tomaj that enabled our fieldwork on their land. We acknowledge our thanks to the curators Mrs. Katarina Krivic (Natural History Museum of Slovenia) and Dr. Ruggero Calligaris (Museo Civico di Storia Naturale di Trieste) for their assistance in the study of the specimens from both museal collections.

ZGORNJEKREDNA FLORA SLOVENIJE

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POVZETEK

O najdbah rastlinskih fosilov v ploščastih in laminiranih zgornjekrednih apnencih Tržaško-komenske planote je bilo doslej malo znanega. Kljub razmeroma številnim primerkom iz Komenskega apnenca, ki jih že desetletja hranita Prirodoslovni muzej Slovenije v Ljubljani in Museo Civico di Storia Naturale v Trstu, so rastlinski fosili v geološki literaturi ostali v senci številnih najdb fosilnih vretenčarjev, predvsem rib in reptilov, o katerih je pisal že Gorjanović-Kramberger (1895). Iz santonijsko-campanijskega tomajskega apnenca rastlinski fosili niso bili znani. Informativno so bili omenjeni le v reviji Annales, v članku o najdbi skata rodu Rhinobatos *(Jurkovšek & Kolar-Jurkovšek, 1995). Fosile maastrichtijskih rastlin Liburnijske formacije je deloma opisal Stache (1889).*

Zgornjekredna foslina flora Tržaško-komenske planote se od vseh poznanih zgornjekrednih rastlinskih združb razlikuje po prevladovanju iglavcev, medtem ko v drugih nahajališčih Evrope, Afrike in Bližnjega Vzhoda pripada bistveno večji delež kritosemenkam. V raziskani zgornjekredni fosilni flori se pojavljajo nekatere nove vrste in rodovi, ki v splošnem spominjajo na starejše tipe iglavcev.

Fosili so iz zbirke Prirodoslovnega muzeja Slovenije v Ljubljani, zbirke Museo Civico di Storia Naturale v Trstu in paleontološke zbirke Bogdana Jurkovška in Tee Kolar-Jurkovšek, ki je v skladu z veljavno zakonodajo registrirana pri Ministrstvu za kulturo Republike Slovenije in Prirodoslovnem muzeju Slovenije v Ljubljani.

Okrajšave:
PMS - Prirodoslovni muzej Slovenije / Natural History Museum of Slovenia, Ljubljana,
TS - Museo Civico di Storia Naturale di Trieste, Italija
BJ - Paleontološka zbirka Bogdana Jurkovška in Tee Kolar-Jurkovšek, Dol pri Ljubljani.

Kras lahko v ožjem tektonskem smislu opredelimo kot Tržaško-komensko planoto ali Komensko narivno grudo (Sl. 1), v širšem geotektonskem smislu pa Kras pripada obsežnim Zunanjim Dinaridom. Zanj so poleg plitvovodnih platformskih karbonatov značilni pojavi črnih ploščastih in laminiranih bituminoznih apnencev z rožencem, ki lokalno vsebujejo tudi fosile rastlin. Pojavljajo se znotraj različnih zgornjekrednih formacij od cenomanija do campanija. Na Formacijski geološki karti južnega dela Tržaško-komenske planote 1 : 50.000 (Jurkovšek et al., 1996) so te kamnine združene v členih tomajski in komenski apnenec. Starejši člen je komenski apnenec, ki pripada Povirski, Repenski in Sežanski formaciji, mlajši pa je santonijsko-campanijski tomajski apnenec Lipiške formacije (Sl. 2).

Zaradi splošne litološke podobnosti bituminoznih ploščastih in laminiranih apnencev z rožencem iz različnih formacij pri geološkem kartiranju severnega dela Tržaško-komenske planote danes upoštevamo predvsem tiste značilnosti, ki kažejo na različne načine in območja njihovega nastanka na karbonatni platformi.

Na osnovi raziskav sedimentacijskega okolja in mehanizmov nastanka recentnih z ogljikom bogatih morskih črnih skrilavcev sta Arthur in Sageman (1994) zaključila, da lahko te plasti nastajajo v petih večjih recentnih morskih okoljih:

1. globoki zaprti bazeni,
2. globoki bazeni ob robovih kontinentov,
3. kontinentalna pobočja, cona "upwellinga",
4. plitvi stratificirani bazeni,
5. priobalna medplimska okolja.

Šribar (1995) je menil, da so bila v primeru jugozahodne Slovenije zaradi položaja na karbonatni platformi za nastanek zgornjekrednih bituminoznih apnencev primerna le področja "upwellinga" in priobalni medplimski prostori.

Komenski apnenec iz okolice Komna so v novejšem času pogosto obravnavali med dokazi za drugi oceanski anoksični dogodek (OAE 2). Jenkyns (1991) je na osnovi primerjave razmer na Dinarsko-jadranski karbonatni platformi in razmer v širšem mediteranskem prostoru sklepal, da je med cenomanijem in turonijem obstajala razmeroma debela plast anoksične vode, ki je privedla v bazenu Umbria-Marche do nastanka plasti Bonarelli (Montanari et al., 1995). OAE 2 je sestavljalo več anoksičnih dogodkov, ki so poleg glavnega (plast Bonarelli)

povzročili nastanek še več tanjših z ogljikom bogatih plasti. Oceanski anoksični dogodki so vplivali na sedimentacijske razmere tudi na Dinarski karbonatni platformi jugozahodne Slovenije. Odločilni so bili predvsem za nastanek komenskega apnenca znotraj zgornjega dela cenomanijske Povirske formacije in cenomanijsko-turonijske Repenske formacije. Seveda so podobne anoksične razmere lahko nastale tudi v zaprtih lagunah, kjer je zaradi biološke produkcije in oksidacije prišlo do pomanjkanja kisika in nastanka z ogljikom bogatih plasti.

Še naprej ostaja deloma problematična natančna interpretacija nastanka tomajskega apnenca znotraj Lipiške formacije, saj je jasna povezava z evstatičnim dvigom morske gladine v tem delu Tetide nedorečena. Šribarju (1995) se zdi avtogeni nastanek anoksičnih razmer verjetnejši. O nekoliko globljem okolju nastanka teh plasti so na osnovi pojavljajočih se alodapičnih apnencev sklepali že Ogorelec in sodelavci (1987). V tomajskem apnencu, v nasprotju s komenskim, nismo nikjer zasledili znakov medplimskih razmer (Jurkovšek et al., *1996). Na dobro povezanost sedimentacijskega prostora z odprtim morjem kažejo pelagični mikro- in makrofosili, med katerimi prevladujejo amoniti. Summesberger in sodelavci (1996a, 1996b, 1999) so iz tomajskega apnenca opisali številne amonite z aptihi v bivalni kamrici in amonitne "roll marke", kar pomeni, da so v vodnem stolpcu nad dnom z anoksičnimi razmerami lahko živeli amoniti ter drugi nektonski in planktonski organizmi. V nekaterih nivojih je bilo ugotovljeno množično umiranje rib, ki ga povezujemo s premešanjem dobro stratificirane vode v laguni. Močan vpliv pelagiala v tomajskem apnencu lahko na osnovi dosedanjih spoznanj povežemo tudi z rastjo morske gladine oziroma t.i. drugo pelagično epizodo v zgornjem santoniju in campaniju, ki je svoj maksimum dosegla v campaniju (Haq* et al., *1987; Gušič & Jelaska, 1990; Kolar-Jurkovšek* et al., *1996). Bogata fosilna makroflora, ki je opazna v vseh raziskanih lokalitetah tomajskega apnenca, izvira iz kopna, ki je verjetno že v zgornjem santoniju pričelo nastajati južno od tomajske lagune (Pleničar & Jurkovšek, 1997a, 1997b).*

Organsko-kemični parametri komenskega in tomajskega apnenca so podobni, vendar je srednja vrednost organske materije (C_{org}=0,48%) v tomajskem apnencu v splošnem višja kot v komenskem apnencu, kar tomajski apnenec že uvršča na spodnjo mejo naftne potencialnosti (Ogorelec et al., *1996). V primerjavi s komenskim apnencem vsebujejo vzorci tomajskega apnenca več organske snovi vodnega porekla (alginita), medtem ko v komenskem apnencu prevladuje organska snov terestričnega izvora (ligninsko-huminski tip).*

Raziskane muzejske vzorce zgornjekredne fosilne flore, ki jih hranita Prirodoslovni muzej Slovenije v Ljubljani in Museo Civico di Storia Naturale v Trstu, smo na osnovi evidenčnih listov razvrstili v več horizontov komenskega apnenca in v tomajski apnenec (Sl. 2). Primerki iz Volčjega Gradu so bili najdeni v komenskem apnencu Povirske formacije in so srednje do zgornjecenomanijske starosti. Rastlinski fosili, najdeni v Pliskovici in Krajni vasi, izvirajo iz komenskega apnenca santonijskega dela Sežanske formacije. Vse primerke, vključno z vzorci iz zbirke BJ, ki so bili zbrani na prostoru Kazelj, Dobravelj, Šepulj in Križa, uvrščamo v zgornjesantonijski do campanijski tomajski apnenec Lipiške formacije. Vzorec iz gradbišča avtoceste med Divačo in Sežano je bil odvzet v maastrichtijskem delu Liburnijske formacije, neposredno nad tanko premoško plastjo.

Ključne besede: flora, zgornja kreda, Dinarska karbonatna plošča, Tržaško-komenska planota, Slovenija

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PLATE 1 - TABLA 1
Phlebopteris *sp.*
Tomaj Limestone, U. Santonian-L. Campanian
tomajski apnenec, zgornji santonij-spodnji campanij
Figs. - Sl. 1a, 1b, 1c: PMS 301, x1, x2, x2, Šepulje
Equisetites sp.
Figs. - Sl. 2a, 2b: PMS 312, x1, x2, Kazlje

PLATE 2 - TABLA 2
Brachyphyllum *sp. nov.*
Tomaj Limestone, U. Santonian-L. Campanian
tomajski apnenec, zgornji santonij-spodnji campanij
Fig. - Sl. 1: BJ 1753, x1, Križ
Fig. - Sl. 2: BJ 1968, x1, Križ
Fig. - Sl. 3: BJ 1384, x1, Dobravlje
Fig. - Sl. 4: BJ 1735, x 2, Križ
Fig. - Sl. 5: BJ 1967, x1, Križ
Fig. - Sl. 6: PMS 339, x1, Kazlje-Dobravlje

PLATE 3 - TABLA 3
Brachyphyllum *sp. nov.*
Tomaj Limestone, U. Santonian-L. Campanian
tomajski apnenec, zgornji santonij-spodnji campanij
Fig. - Sl. 1: PMS 328, x1, Avber
Fig. - Sl. 2: BJ 1734, x1, Kazlje
Fig. - Sl. 3: PMS 324, x1, Avber
Fig. - Sl. 4: PMS 293, x2, Dobravlje
Fig. - Sl. 5: BJ 1967, x2, Križ, (counterpart of the specimen on Pl. 2, fig. 5 - nasprotni odtis primerka na tab. 2, sl. 5)

PLATE 4 - TABLA 4
Pagiophyllum *sp. nov.*
Fig. 1: BJ 1654, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 1: BJ 1654, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij
Figs. 2a, 2b: BJ 1558, x1, x2, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 2a, 2b: BJ 1558, x1, x2, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij
Figs. 3a, 3b: BJ 1746, x1, x1, Križ; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 3a, 3b: BJ 1746, x1, x1, Križ; tomajski apnenec, zgornji santonij-spodnji campanij
Figs. 4a, 4b: BJ 1471, x1, x1, Divača-Sežana; Liburnian Formation, Maastrichtian
Sl. 4a, 4b: BJ 1471, x1, x1, Divača-Sežana; Liburnijska formacija, maastrichtij
Figs. 5a, 5b: BJ 1538, x1, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 5a, 5b: BJ 1538, x1, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij
Figs. 6a, 6b: BJ 1848, x1, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 6a, 6b: BJ 1848, x1, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij

PLATE 5 -TABLA 5
Pagiophyllum *sp. nov.*
Tomaj Limestone, U. Santonian-L. Campanian
tomajski apnenec, zgornji santonij-spodnji campanij
Fig. - Sl. 1: BJ 1658, x1, Dobravlje
Fig. - Sl. 2: PMS 336, x1, Kazlje-Dobravlje
Fig. - Sl. 3: BJ 1382, x1, Dobravlje

PLATE 6 - TABLA 6
Pagiophyllum *sp. nov.*
Tomaj Limestone, U. Santonian-L. Campanian
tomajski apnenec, zgornji santonij-spodnji campanij
Fig. - Sl. 1: BJ 1522, x1, Dobravlje
Figs. - Sl. 2a, 2b: BJ 1541, x1, x1, Kazlje

PLATE 7 - TABLA 7
Conifer gen. nov.
Komen Limestone, Cenomanian
komenski apnenec, cenomanij
Figs. - Sl. 1a, 1b, 1c: TS 7786, x0.4, x1, x1, Volčji grad

PLATE 8 - TABLA 8
Conifer gen. nov.
Komen Limestone, Cenomanian
komenski apnenec, cenomanij
Figs. - Sl. 1a, 1b, 1c: TS 7790, x0.4, x0.4, x1.3, Volčji grad

PLATE 9 - TABLA 9
Conifer gen. nov.
Tomaj Limestone, U. Santonian-L. Campanian
tomajski apnenec, zgornji santonij-spodnji campanij
Figs. - Sl. 1a, 1b, 1c: BJ 1971, x0.4, x1, x0.7, Križ

PLATE 10 - TABLA 10
Conifer gen. nov.
Komen Limestone, Cenomanian
komenski apnenec, cenomanij
Fig. - Sl. 1: TS 7785, x0.4; Fig. - Sl. 2: TS7786, x0.35; Fig. - Sl. 3: BJ1547, x1, Volčji grad

PLATE 11 - TABLA 11
Figs. - Sl. 1-6: Araucarites *? sp.*
Figs. 1a, 1b: BJ 1559a, x1, BJ 1559b, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 1a, 1b: BJ 1559a, x1, BJ 1559b, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij
Fig. 2: PMS 302, x1, Kazlje-Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 2: PMS 302, x1, Kazlje-Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij

Fig. 3: BJ 1516, x1, Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 3: BJ 1516, x1, Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij
Fig. 4: BJ 1513, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 4: BJ 1513, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij
Fig. 5: BJ 1745, x1, Križ; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 5: BJ 1745, x1, Križ; tomajski apnenec, zgornji santonij-spodnji campanij
Fig. 6: BJ 1548, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 6: BJ 1548, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij
Fig. 7: Conifer cone, BJ 1258, x1, Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 7: Storž iglavca, BJ 1258, x1, Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij
Figs. 8a, 8b, 9: Conifer scales, BJ 1561, x1, its counterpart, x1; BJ 1987, x1, Kazlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 8a, 8b, 9: Luske iglavca, BJ 1561, x1, nasprotni odtis, x1; BJ 1987, x1, Kazlje; tomajski apnenec, zgornji santonij-spodnji campanij
Figs. 10a, 10b: Conifer cone, BJ 1383, part and counterpart - x1, x2, Dobravlje; Tomaj Limestone, U. Santonian-L. Campanian
Sl. 10a, 10b: Storž iglavca, BJ 1383, nasprotna odtisa - x1, x2, Dobravlje; tomajski apnenec, zgornji santonij-spodnji campanij

PLATE 12 - TABLA 12

Figs. 1, 2, 3: Magnoliaephyllum *sp., BJ 1562, part and counterpart, x1; BJ 1563, x1; BJ 1847, x1; Kazlje, Tomaj Limestone, U. Santonian-L. Campanian*
Sl. 1, 2, 3: Magnoliaephyllum *sp., BJ 1562, nasprotna odtisa, x1; BJ 1563, x1; BJ 1847, x1; Kazlje, tomajski apnenec, zgornji santonij-spodnji campanij*
Figs. 4-8: Eucalyptus *sp., BJ 1744, x1, BJ 1988, x1, Križ; BJ 1986, x3, BJ1986, x3, Kazlje; BJ 1863, x1, Križ; Tomaj Limestone, U. Santonian-L. Campanian*
Sl. 4-8: Eucalyptus *sp., BJ 1744, x1, BJ 1988, x1, Križ; BJ 1986, x3, BJ1986, x3, Kazlje; BJ 1863, x1, Križ; tomajski apnenec, zgornji santonij-spodnji campanij*
Fig. 9: Eucalyptus *? sp., BJ 1701, x1, Kazlje, Tomaj Limestone, U. Santonian-L. Campanian*
Sl. 9: Eucalyptus *? sp., BJ 1701, x1, Kazlje, tomajski apnenec, zgornji santonij-spodnji campanij*
Fig. 10: Sassafras *sp., BJ 1560, x1, Kazlje, Tomaj Limestone, U. Santonian-L. Campanian*
Sl. 10: Sassafras *sp., BJ 1560, x1, Kazlje, tomajski apnenec, zgornji santonij-spodnji campanij*
Fig. 11: Fructification # 2, PMS 320, x1, Krajna vas, Komen Limestone, Santonian
Sl. 11: Fructification # 2, PMS 320, x1, Krajna vas, komenski apnenec, santonij
Fig. 12: Fructification # 1, BJ 1527, x1, Dobravlje, Tomaj Limestone, U. Santonian-L. Campanian
Sl. 12: Fructification # 1, BJ 1527, x1, Dobravlje, tomajski apnenec, zgornji santonij-spodnji campanij

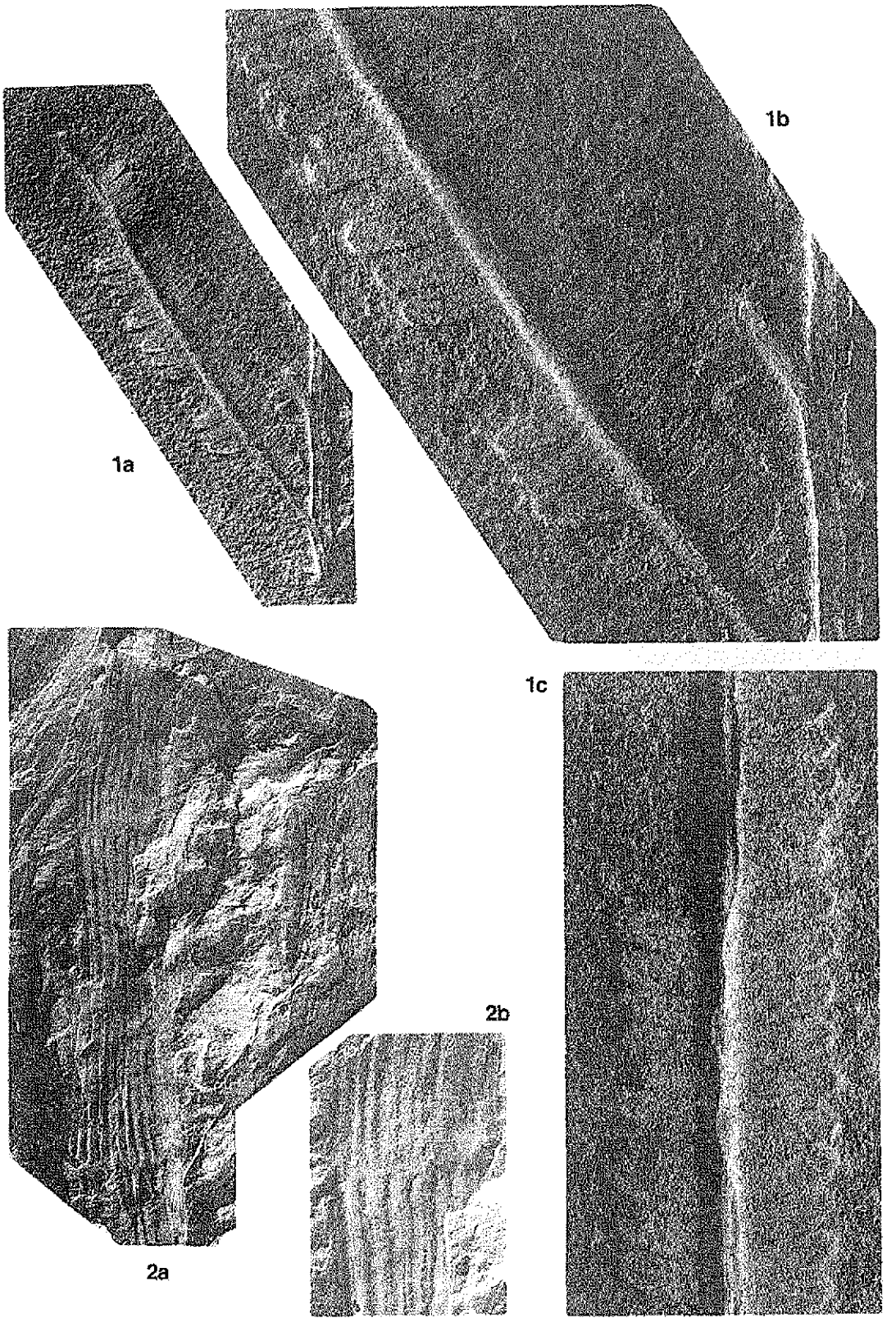


PLATE 1 - TABLA 1

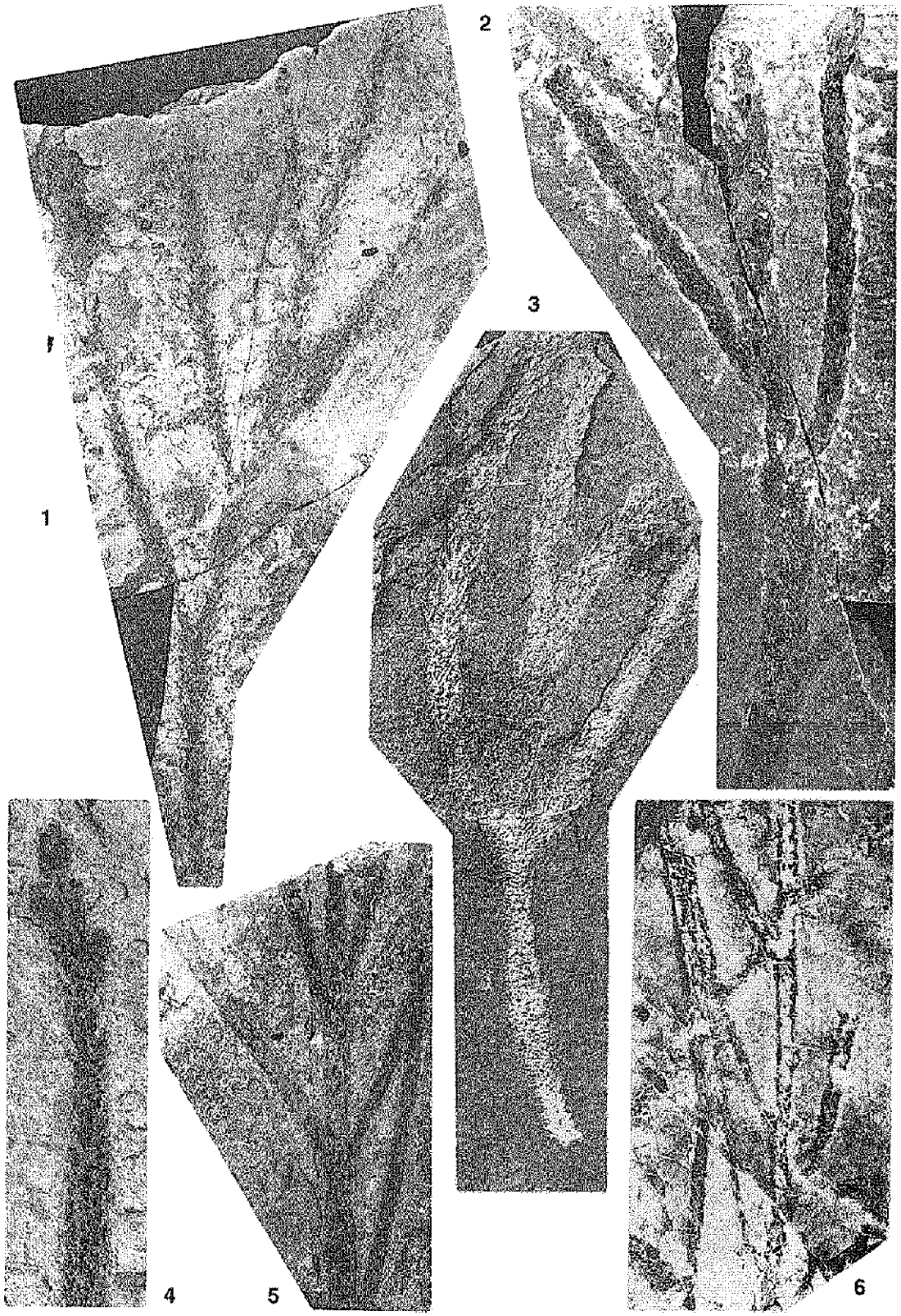


PLATE 2 - TABLA 2

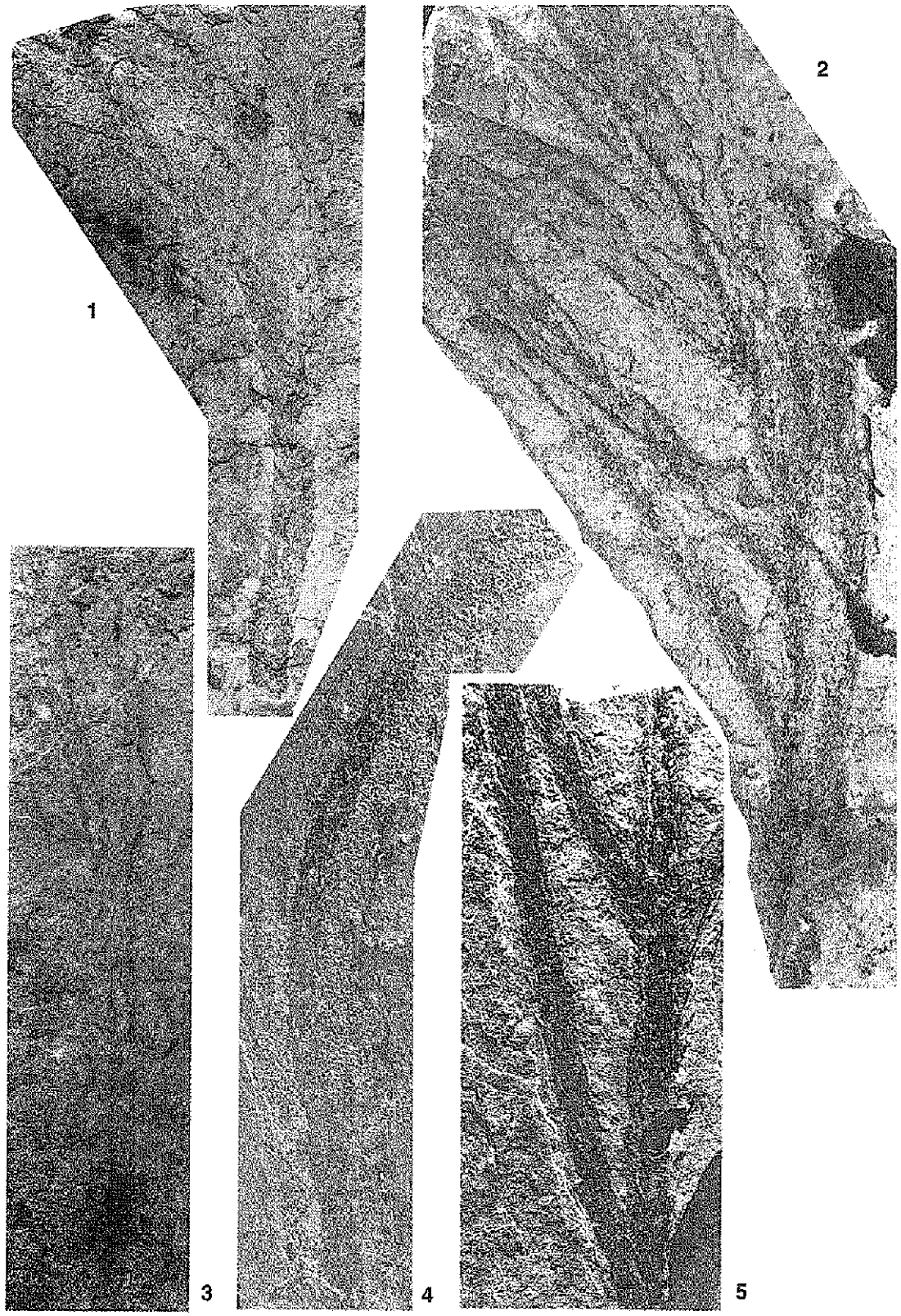


PLATE 3 - TABLA 3

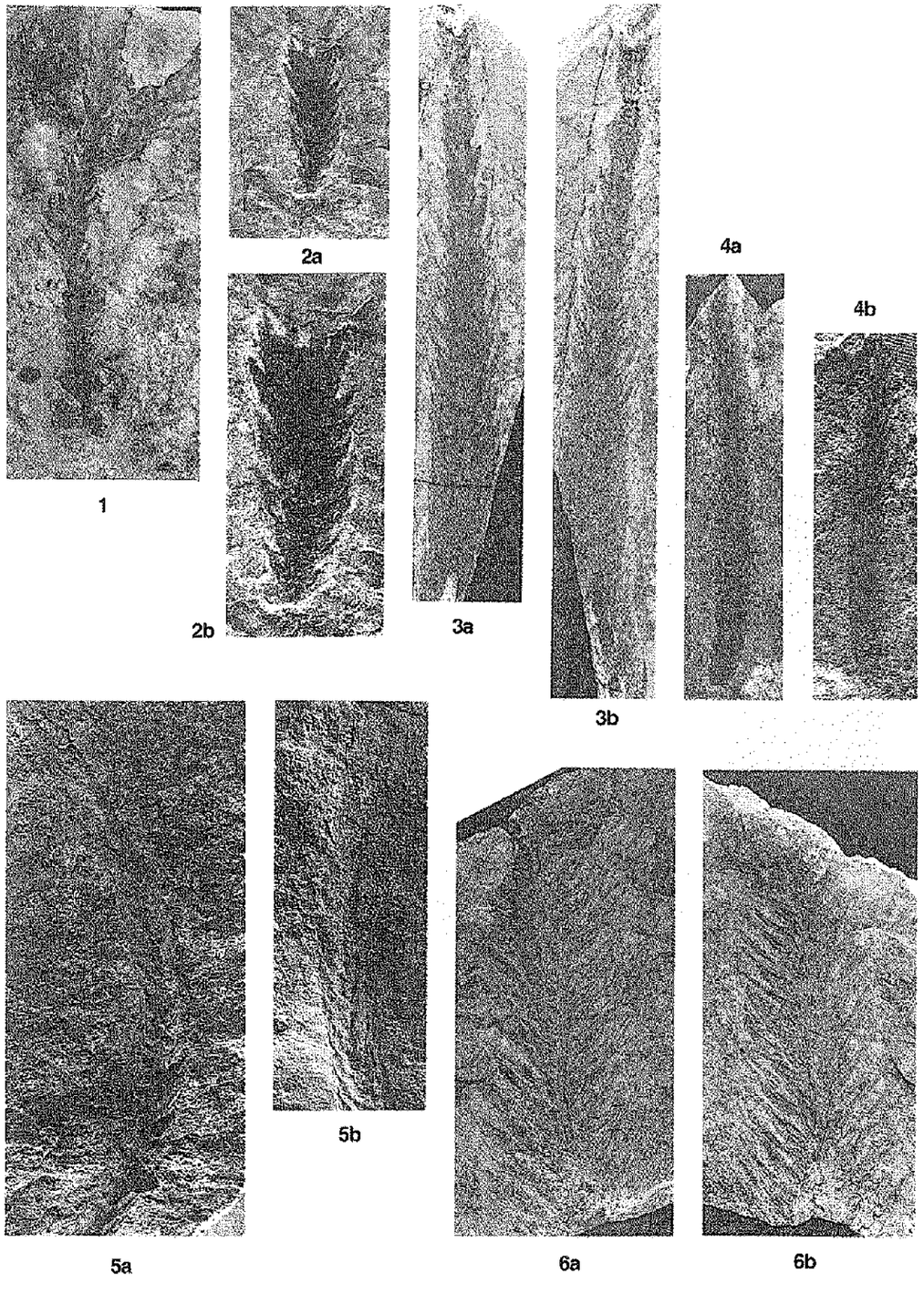
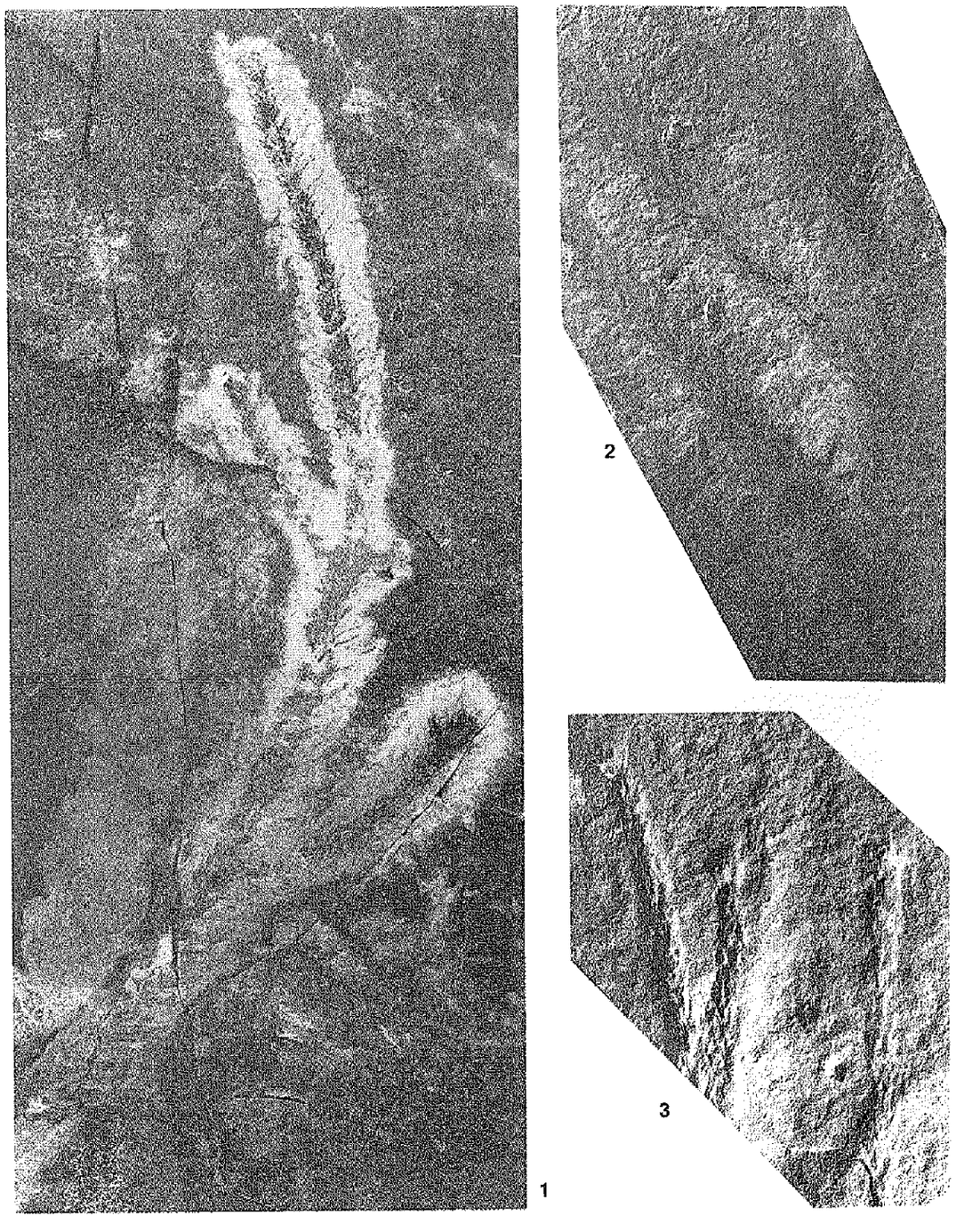


PLATE 4 - TABLA 4



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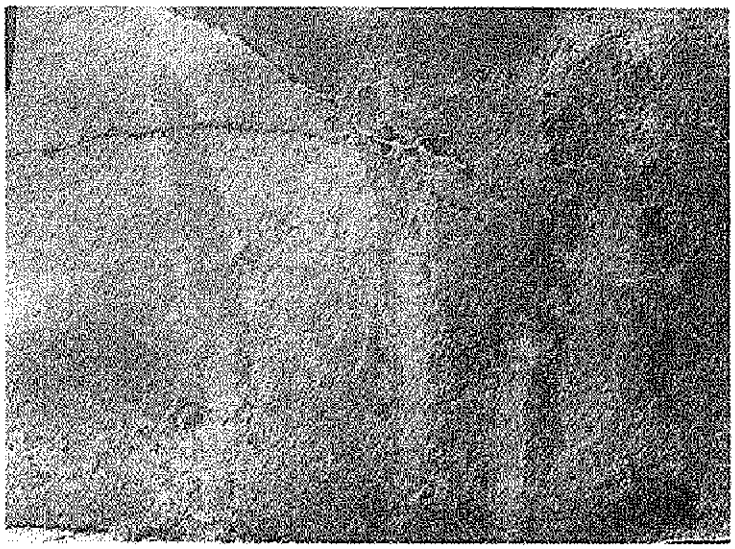

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2a

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PLATE 6 - TABLA 6

PLATE 7 - TABLA 7

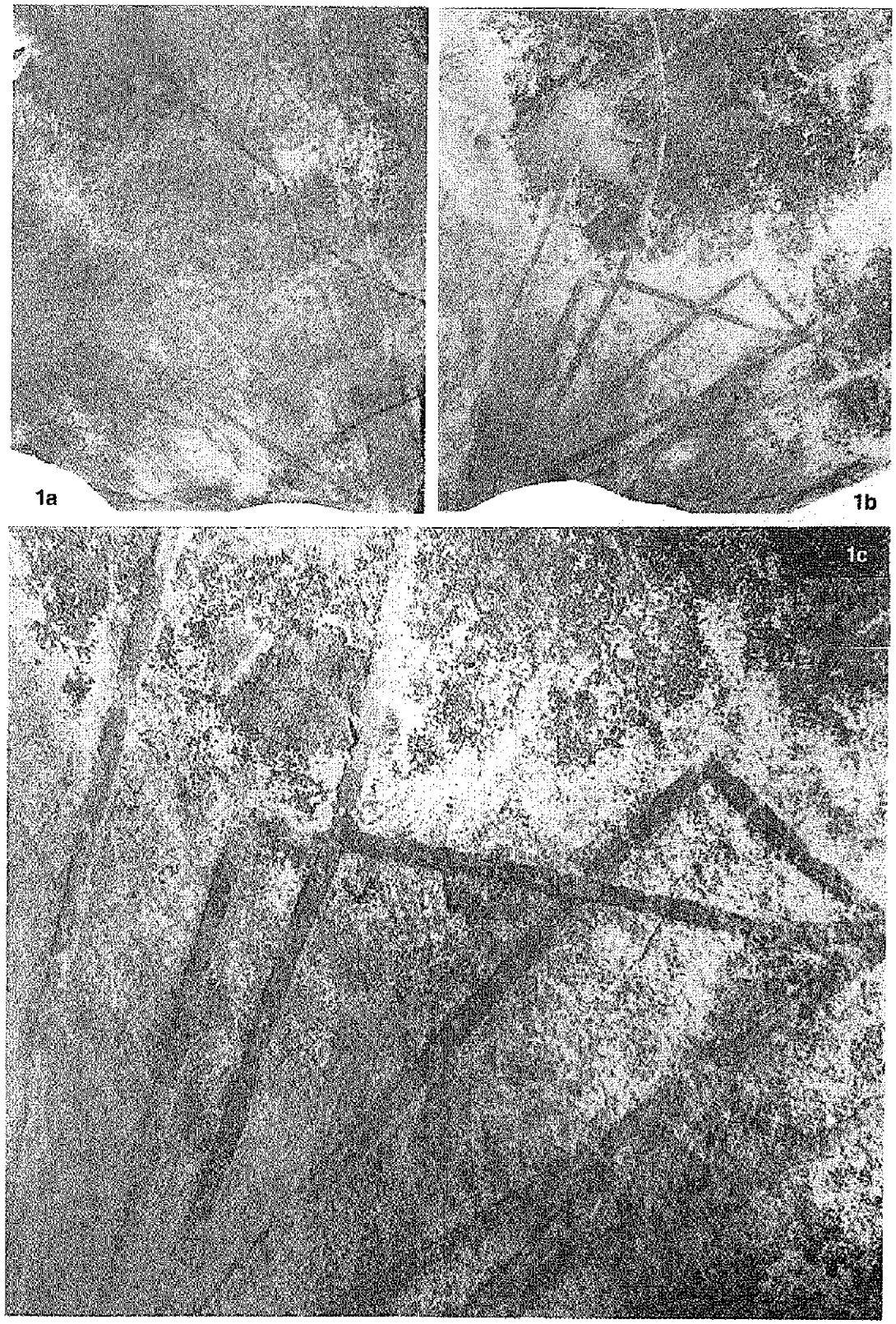

PLATE 8 - TABLA 8

PLATE 9 - TABLA 9

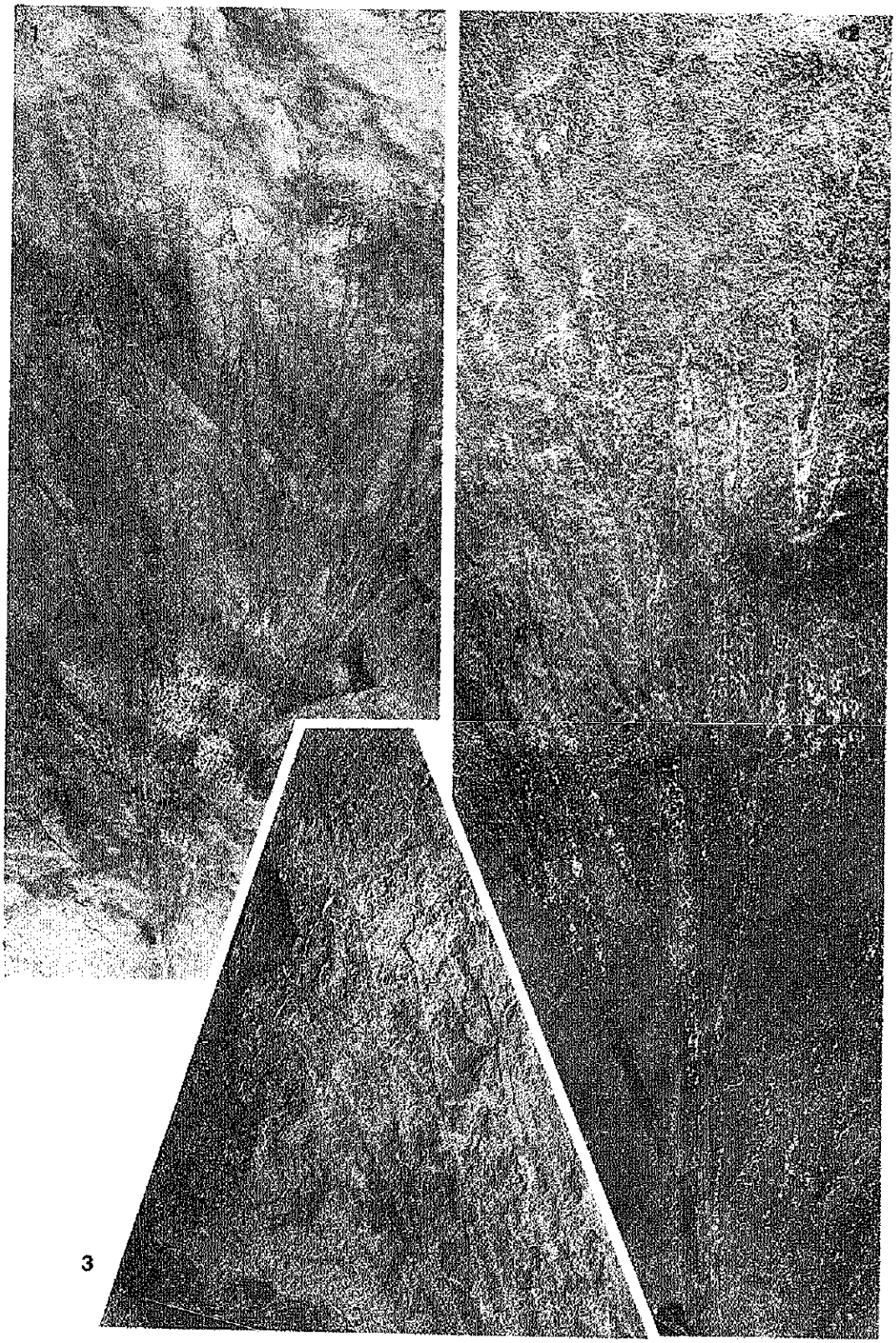

PLATE 10 - TABLA 10

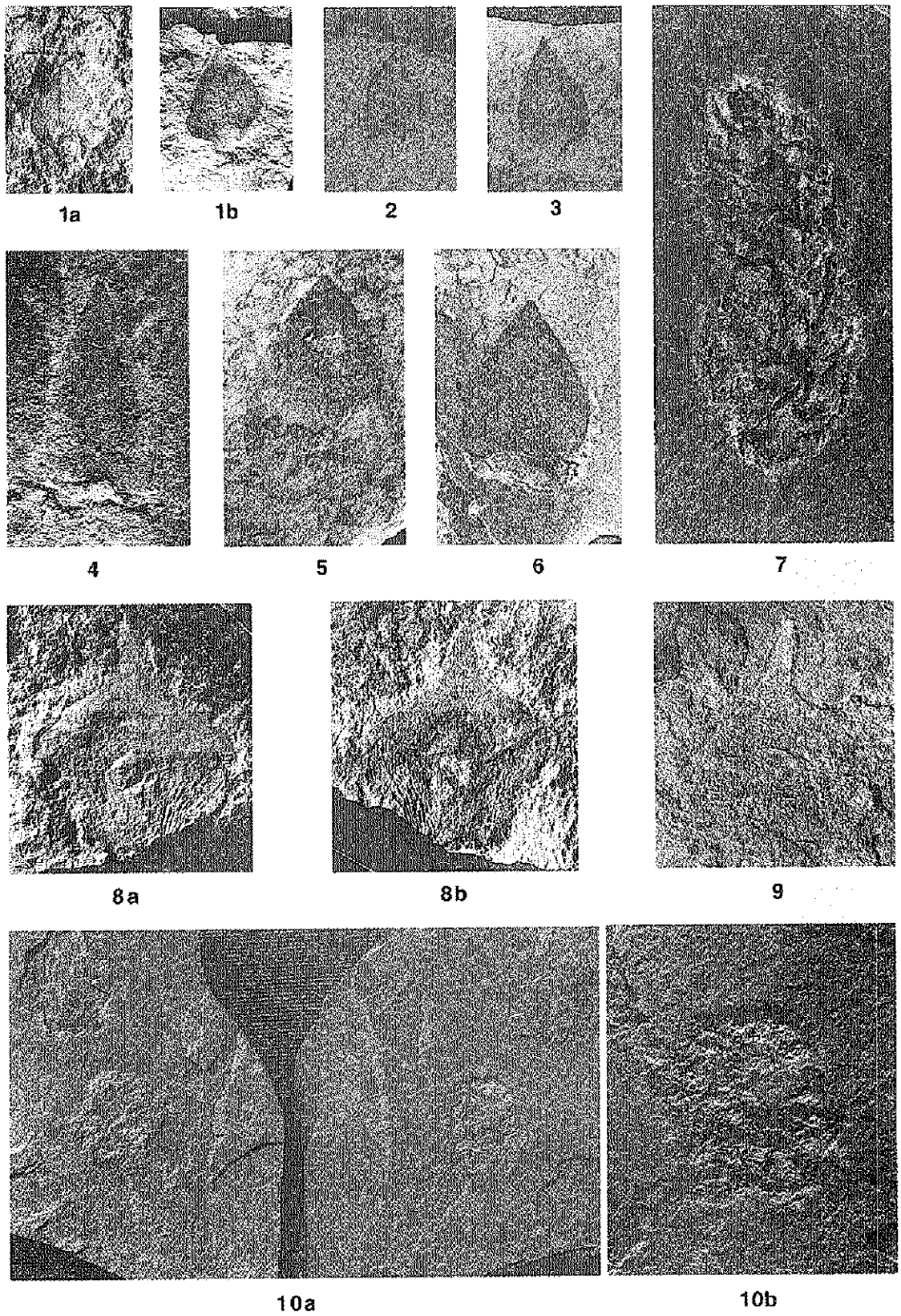

PLATE 11 - TABLA 11

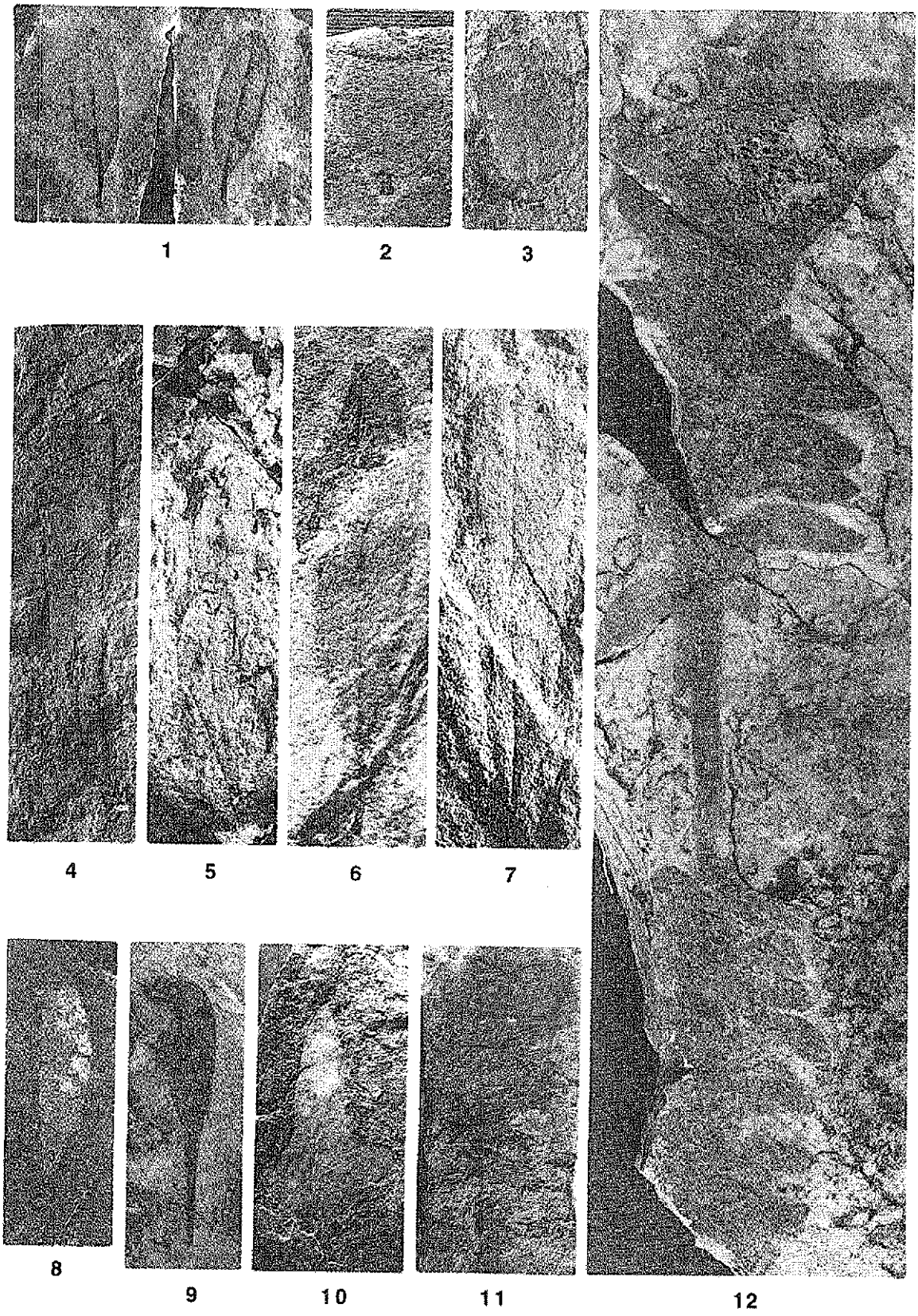

PLATE 12 - TABLA 12