GEOLOGICKÝ ZBORNÍK — GEOLOGICA CARPATHICA, 39, 5, BRATISLAVA, OCTOBER 1988, Pp. 523—537

JOZEF MICHALÍK* — VLASTIMIL KÁTLOVSKÝ* — ANTONÍN HLUŠTÍK**

PLANT REMAINS IN THE TOMANOVÁ FORMATION (UPPERMOST TRIASSIC, WEST CARPATHIANS): THEIR ORIGIN, COMPOSITION AND DIAGENETIC ALTERATION

(*Figs. 10, Tab. 1*)

Abstract: The paper supplements the results of earlier studies of the Tomanová Formation in the Červené vrchy Mts. of the Western Tatra (cf. Michalík et al., 1976). It analyses the composition, origin and preservation of plant remains in shale-sandstone beds, their relation to γ-activity values and radioactive element content. These facts supplement the reconstruction of the sedimentary environment of the Tomanová Formation: it was a product of continental sedimentation in isolated depressions where products leached out from weathering crusts in the wide surroundings were accumulated.

Резюме: Статья исходит из результатов ранних исследований томановской свиты Червеных Верхов Западных Татр (ср. Michalík et al., 1976). Авторы анализируют состав, происхождение и соблюдение растительных остатков в сланцевато-песчаниковых пластах, их отношение к значениям γ-активности и к содержанию радиоактивных элементов. Эти факты дополняют реконструкцию осадочной среды томановской свиты, которая является продуктом континентального осадконакопления в изолированных впадинах, где накапливались продукты, выщелоченные из кор выветривания широкой окрестности.

Introduction

In 1890, Raciborski described remains of Rhaetian plants from the Czerwone Źlebki, T. ı.aniar ki Twardy Upłaz and Tomanová dolina valley in the Západné Tatry Mts. Despite the stratigraphic and environmental importance of the flora described, this work has so far remained the only paleobotanic study. The petrography of the Tomanová Formation was studied by Gorek (1958), Kotański (1959), Radwański (1968) that presented several interpretations of the formation origin (see discussion in Michalík et al., 1976).

A more detailed study of the Tomanová Formation in the upper part of the Tichá dolina valley (Michalík et al., l.c.) resulted in the finding of traces of the bipedal dinosaur *Coelurosaurichnus tatricus* Michalík et Sýkora, knowledge of the composition of palynomorph spectrum and new sedimentological information. The attempts to discover dinosaur traces were undertaken also on the Polish territory: unfortunately in vain so far (pers. comm. J. Wieczorek). Classic macrofloral findings by M. Raciborski have not been supplemented for almost one hundred years (Reymanówna,

* RNDr. J. Michalík, CSc., RNDr. V. Kátlovský, CSc., Geological Institute of the Centre of Geoscience Research, Slovak Academy of Sciences, Dúbravská cesta 9, 814 73 Bratislava.

** RNDr. A. Hluštík, CSc., Šafaříkova 2528, 440 01 Louny.

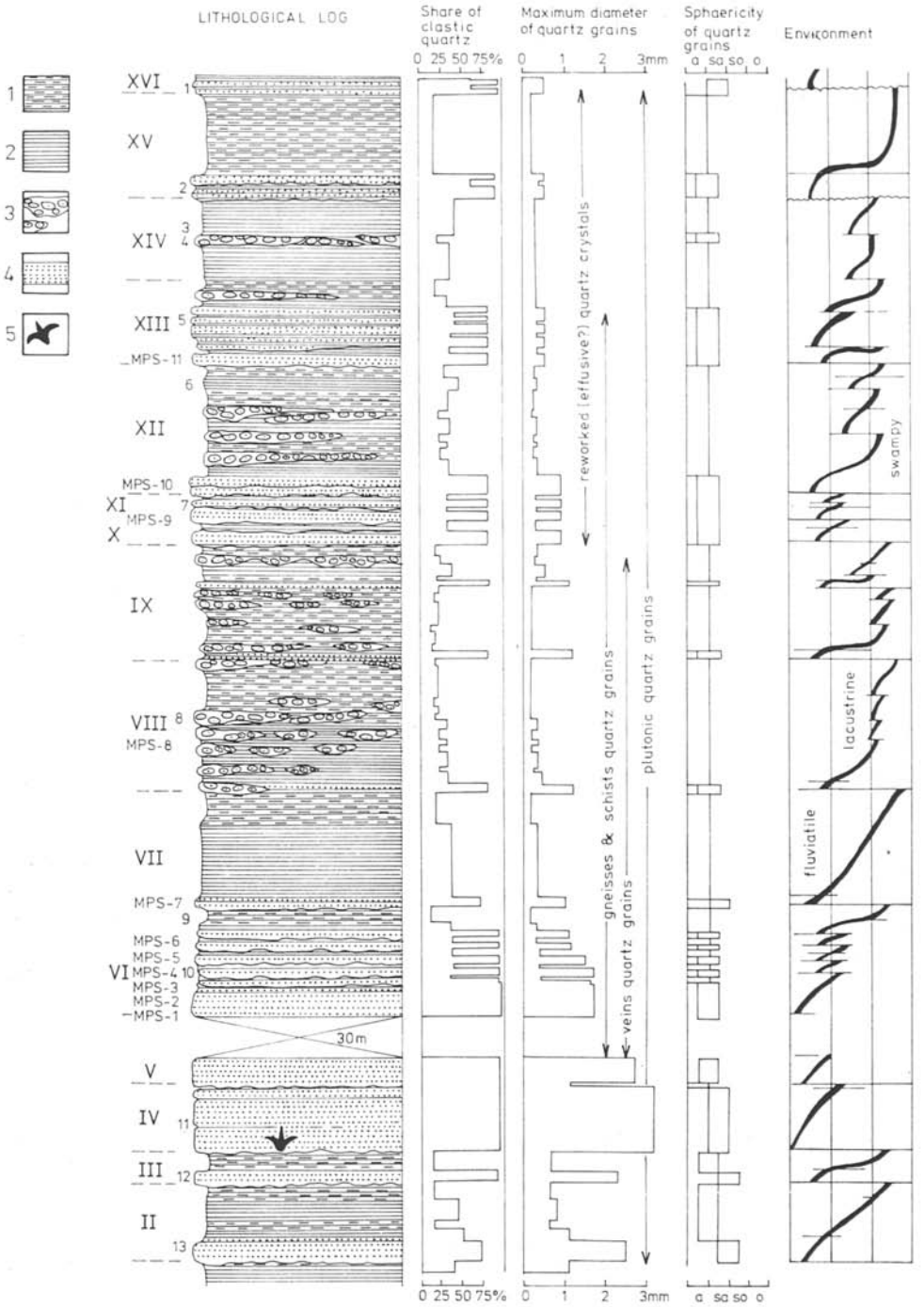

LITHOLOGICAL LOG
Share of clastic quartz
0 25 50 75%
Maximum diameter of quartz grains
0 1 2 3mm
Sphaericity of quartz grains
a sa so o
Environment
1
2
3
4
5
XVI
XV
XIV
XIII
XII
XI
X
IX
VIII
VII
VI
V
IV
III
II
MPS-11
MPS-10
MPS-9
MPS-8
MPS-7
MPS-6
MPS-5
MPS-4
MPS-3
MPS-2
MPS-1
30m
reworked (effusive?) quartz crystals
gneisses & schists quartz grains
veins quartz grains
plutonic quartz grains
swampy
lacustrine
fluviatile

Fig. 2. Quartzy sandstone bed — base of one cycle of the Tomanová Formation, locality Červený Úplaz (central part of Fig. 3). Photo J. Michalík.

1984). Only Planderová (in Michalík et al., l.c.) has described two microfloristic associations: black claystones contain predominantly the types *Taeniasporites, Protohaploxypinus* and a number of sporomorphs, while in the upper sandstone-shale part of the formation, pollen grains *Classopollis* and *Gliscopollis* prevail.

Fig. 1. Lithology of the section Červený Úplaz: sedimentation cycles, share of clastic quartz, maximum diametre of quartz grains, distribution of clastic quartz types, sphericity of quartz grains and interpretation of the environment where the individual beds originated.

Explanationary notes: Numbers with MPS index are related to the work Michalík et al. (1976), roman numbers designate individual cycles, arabic numbers without the index are samples for radiometric analysis. 1 — black claystone; 2 — dark-gray claystone; 3 — sphaerolitic Fe ore; 4 — sandstone; 5 — rhizom horizons; 6 — horizons with abundant plant remains; 7 — dinosaur traces. Orig. J. Michalík.

Fig. 3. Outcrop in the upper part of the Tomanová Formation, locality Červený Úplaz, Tichá dolina valley, Západné Tatry Mts. Arrow marks finding of coelurosaurid traces. Scale according to figures in the left part of the figure. Photo J. Michalík.

Lithology

The surveyed part of the formation is about 60 m thick (of which a half is represented by waste-covered, shrub-overgrown stretch above the bench with the dinosaur traces). The exposed rock sequence consists of sixteen more or less completely developed sedimentation cycles (Fig. 1).

The completely developed cycle is 250—300 cm thick. It usually begins with one or several light-coloured sandstone beds (Fig. 2). The basis of the cycle is usually erosional. The sandstone is quartzy, uneven-grained, gray (more clayey) in the upper parts of the beds, often laminated. The share of mono- as well as polycrystalline grains in the rock structure is 55—95 % (cf. Sýkora in Michalík et al., l.c.). Lydite fragments, grains of chlorite and other clay minerals, zircon, tourmaline, rutile, light-coloured mica grains are rare, chromite detritus occurs only exceptionally. Sandstone matrix is aleuritic--quartzy-chloritic, in upper parts argillitic-chloritic with a Fe-oxide admixture. The distribution of quartz grain types in the profile Červený Úplaz is variable. Monocrystalline types derived from plutonic rocks (Blatt — Christie, 1963) prevail in the lower cycles. In the upper cycles, grains originating from quartz veins along with polycrystalline grains characteristic for metamorphic rocks become more abundant (Fig. 1). Abundant small rounded quartz grains similar to effusive quartz crystals (Blatt — Christie, op. cit) appear in the uppermost part of the sequence. The grains are mostly imperfectly but distinctly rounded: subangular to suboval forms commonly prevail, but their contours often bear signs of corrosion. The grain size is variable: thicker beds near the base contain coarser grained material (up to 3 mm). Although finer grains are present in the upper parts of the beds, gradation signs are indistinct. Thinner beds in the upper part of the sequence are usually fine-grained (0.5 to 1 mm).

The contact of the sandstone beds with overlying claystones is gradual,

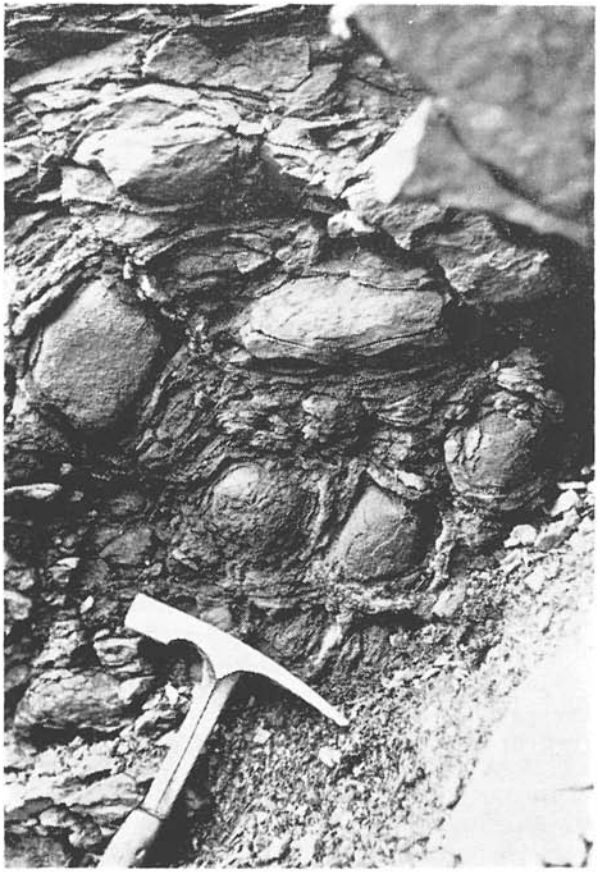


Fig. 4. Bed of sphaerolitic siderite „mud" iron ore, Červený Úplaz. Photo J. Michalík.

unsharp, represented by laminated clayey sandstones and silty claystones. Clastic quartz content exceeds 15—20 %. The claystone beds are thick, forming the major part of the sequence (Fig. 3). Unlike sandstone beds, quartz grains in claystones are finer (0.2—0.4 mm), angular, probably of eolian origin. The claystones consist of a mixture of clay minerals with a marked share of chlorite and kaolinite. In the uppermost part of partial cycles (commonly there are 4—5 of them within a more completely developed cycle of higher order), layers (5—30 cm) with siderite sphaerolites occur. The sphaerolites 0.7—2 mm large occur in nodules 25 cm in diameter (Fig. 4). In the siderite concretion cores there are quartz grains. The sphaerolites are cemented by chlorite, less frequently by pyrite. Authigenic quartz often occurs in fissures.

Plant fossils

Shale intercalations in the exposed part of the sequence contain abundant fine dispersed phytodetritus, fragments and more complete parts of plant tissues. On the sandstone bedding plains, remains of thick, sometimes up to 1 m long fragments of tree trunks and woody plant parts are common (Fig. 5). According to Raciborski, the sandstone and claystone beds contain remains of the following vascular plants:

Phyllothecaceae	*Schizoneura hoerensis* (HISS.) SCHIMP.
?Equisetaceae	*Equisetum chalubinskii* RACIBORSKI
	?Equisetum bunburyanum ZIGNO
?Dipteridaceae	*Clathropteris platyphylla* BROGNIART.
	Dictyophyllum aff. *dunkeri* NATHORST
?Osmundaceae	*Cladophlebis roessertii* (PRESSL in STERNBERG) SAPORTA
Pteridophyta inc. sed.	*Pecopteris lobata* (OLDH. et MORR.)
Stachyotaxaceae	*Palissya braueri* ENDLICHER
?Taxodiaceae s.l.	*Widdringtonites* sp.

Planderová (in Michalík et al., l.c.) has described the following forms of sporomorphs and palynomorphs from the Tomanová Formation:

Pteridophyta — *Camarozonosporites* sp., *Bianulisporites badius* PAUTSCH, *Cyathitides australis rimalis* BALME, *Cyathitides* fsp., *Dictyophyllitides harrisii* COUPER, *Distanulisporites punctus* KLAUS, *Distanulisporites tomanovae* PLANDEROVÁ, *Enzonalosporites* cf. *tenuis* KLAUS, *Eucommiidites* cf. *troedssonii* ERDTMAN, cf. *Infirmisporites fragilis* PAUTSCH, *Leiotriletes mesozoicus* (THIERG.) SCHULZ, *Maratiopsis hoerensis* (SCHIMP) THOMAS, *Retusotriletes mesozoicus* KLAUS, *Sporites* fsp., *Toroisporis auritorius* REINHARD, *Toroisporis mesozoicus* DÖRING, *?Triadispora* fsp.

Gymnospermae — *Classopollis torosus* (REISINGER) BALME, *Cycadopites follicularis* WILLSON et WEBSTE, *Gliscopollis meyeriana* (KLAUS) VENKATACHALA, *Monosulcites* cf. *minimus* (COOKSON) COUPER, *Ovalipollis ovalis* (KRUTZSCH) SCHEURING, *Praecirculina granifer* KLAUS, *Praecirculina tersa* NORRIS, *Protohaploxypinus subcarpathicus* PAUTSCH, *Taeniasporites* fsp.

The most abundant macrofloral remains present virtually in all rock types are equisetid internodes and other fragments. They are likely to represent autochthonous flora mouldered in the site of its life. Fans of the ferns *Cladophlebis* with the stalks *Widdringtonites* and *Palissya* that are likely to have been transported from distant places and unrepeatedly buried in a fine-grained sediment are the most complete but much less frequent findings.

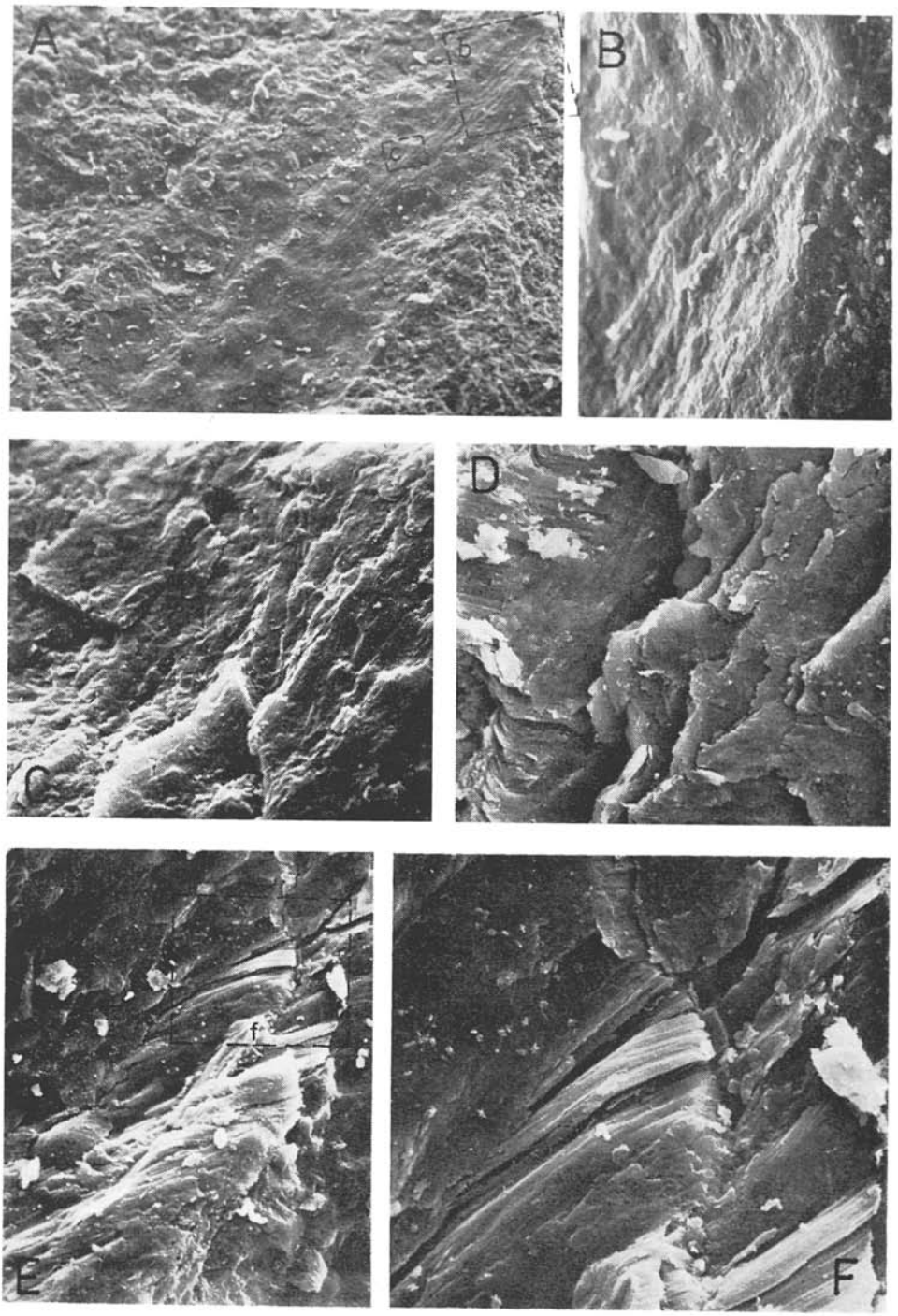
Thicker and thinner quartzy sandstone beds form basal members of the cycles. They are typically developed in the lower part of the profile where a layer with *Coelurosaurichnus* traces has been found in them. The beds contain no determinable plant remains except for thick pieces of carbonized woods (Fig. 5) and discontinuous irregular laminae of fine coal detritus. Only in the uppermost, frequently laminated layers of the beds, more complete fragments probably belonging among equisetids occur.

Sandy-clayey, claystone and ferruginous members of the cycles commonly

Fig. 5. Fragments of limonitized wood in the Tomanová Formation sandstones at the locality Červený Úplaz. Photo J. Michalík.

contain usually poorly preserved plant detritus. The best preserved plant remains are in black coal claystones which alternate with "mud ores" in the uppermost part of the cycles. A similar intercalation occurs e.g. in the lower part of the section between the beds 12 and 13 (Fig. 1). It contains abundant compressed and carbonized plant detritus. In the central part of the layer the amount of coal substance grows rapidly almost forming a thin coal seam 100—150 mm thick. The coal claystone contains very abundant subangular, partially graphitized wood fragments. They are mostly small (5—10 mm), although some carbonized woods attain as much as 120 mm. Among carbonized fragments, numerous internodes of fern stalks prevail (Fig. 6a—c). Nevertheless, bulk-maceration of the coal claystone has not yielded material suitable for cuticular analysis. This accumulation seems to have originated by a long-lasting piling up of gradually compressed, deformed and later partially graphitized equisetid stalks. Their preservation might have been allowed by fusinitization as early as before their deposition in the sediment (local fires of the vegetation ? — cf. Fig. 6e—f). The arrangement of the fragments shows no signs of sorting, orientated arrangement due to current, nor other arguments for their allochthonous origin. That is why the "coal claystone" is probably a preserved remnant of an original psammophilous biotope with dominant horsetail flora elements.

Although the uppermost part of the claystone layers is often eroded before the deposition of the basal part of the overlying cycle, remains of rhizom horizons are sometimes preserved in it. At least three such horizons can be observed in the upper part of the profile (Fig. 1, below beds 6, 9 and 11). They are


A
B
C
D
E
F

built up of small vertical and oblique cylindrical objects, sometimes irregularly thickened or even globular, in places ball-shaped with signs of branching. These conspicuous accumulation of small pyrite bodies up to 20 mm in diametre penetrate the sediment to a depth of a few centimetres. They can be interpreted as pyritized and secondarily limonitized remains of subaerial plant parts in situ, most likely rhizom remains. Radwanski (1968) interpreted them as traces of burrowing fauna. The supposition that they are underground vegetative organs comparable to rhizom system of equisetid plants is supported by the character of the fillings with prevailing limonitized plant material as well as by numerous equisetid remains of stalks, internodes and diafragms in the surrounding sediment (Fig. 7). Most fossils resemble axes of the genus *Equisetites* STERNBERG itself, some others more resemble the genera *Neocalamites* HALLE or *Schizoneura* SCHIMP. All the association and the mode of its occurrence indicate autochthonous flora in stagnant palustrine environments. In similar conditions, decomposition of organic tissues accompanied by sulphur and iron migration usually takes place (Berner, 1969; Slipchenko, 1981).

Coniferid remains present sporadically in the claystone members of the formation were a very important element of the flora studied. They include twigs similar to the genus *Pagiophyllum* as well as minor conical bodies and conical slices which resemble the genus *Palissya* ENDLICHER. It seems that new, more extensive collecting might bring more valuable data. Collecting material for his monography, Raciborski with the help of local inhabitants dug a virtual small quarry at the locality Czerwone Żlebki (Fig. 8). In contrast, all recent authors visited the fossiliferous localities in the Tomanová Formation only occasionally and spent only little time there.

The Tomanová Formation has its distant equivalents in other places of the West Carpathians. Age and facial equivalence of occurrences in the Považský Inovec Mts. has not been proved so far. Occurrences of wood fragments are known in the Carpathian Keuper in the Krížna unit of the Fatricum, but virtually all of them are only rare allochthonous fragments. Only in the Žľab pod Vidlou section (Havran unit of the Belianske Tatry Mts.), a sequence of sandstones, conglomerates and "coal claystones" occurs amidst the Carpathian Keuper Formation. Some of the beds contain coal fragments, carbonized plant detritus and fusinitized longitudinally striated stalks similar to equisetid ones. Fern remains are scarce. Under the base of one of the sandstone members there is even a layer with concretionary pseudomorphs similar to plant roots or rhizoms. Nevertheless, all this fossiliferous sequence represents a mere episode in the Carpathian Keuper sedimentation (Michalík et al., in prep.).

Fig. 6. Microstructures of plant remains from the Tomanová Formation, Červený Úplaz, photo I. Holický, SCAN BS-300 (GIÚ CGV SAV).
Explanatory notes: a - impression of equisetid blade, photo 3892, magn. 200×; b - dtto, detail, photo 3895, magn. 1000×; c - dtto, detail, photo 3891, magn. 4000×; d - clay mineral laths, the same sample, photo 3904, magn. 1000×; e - fusinitized plant remains, photo 3896, magn. 800×; f - dtto, cross-section, detail, photo 3897, magn. 2500×.

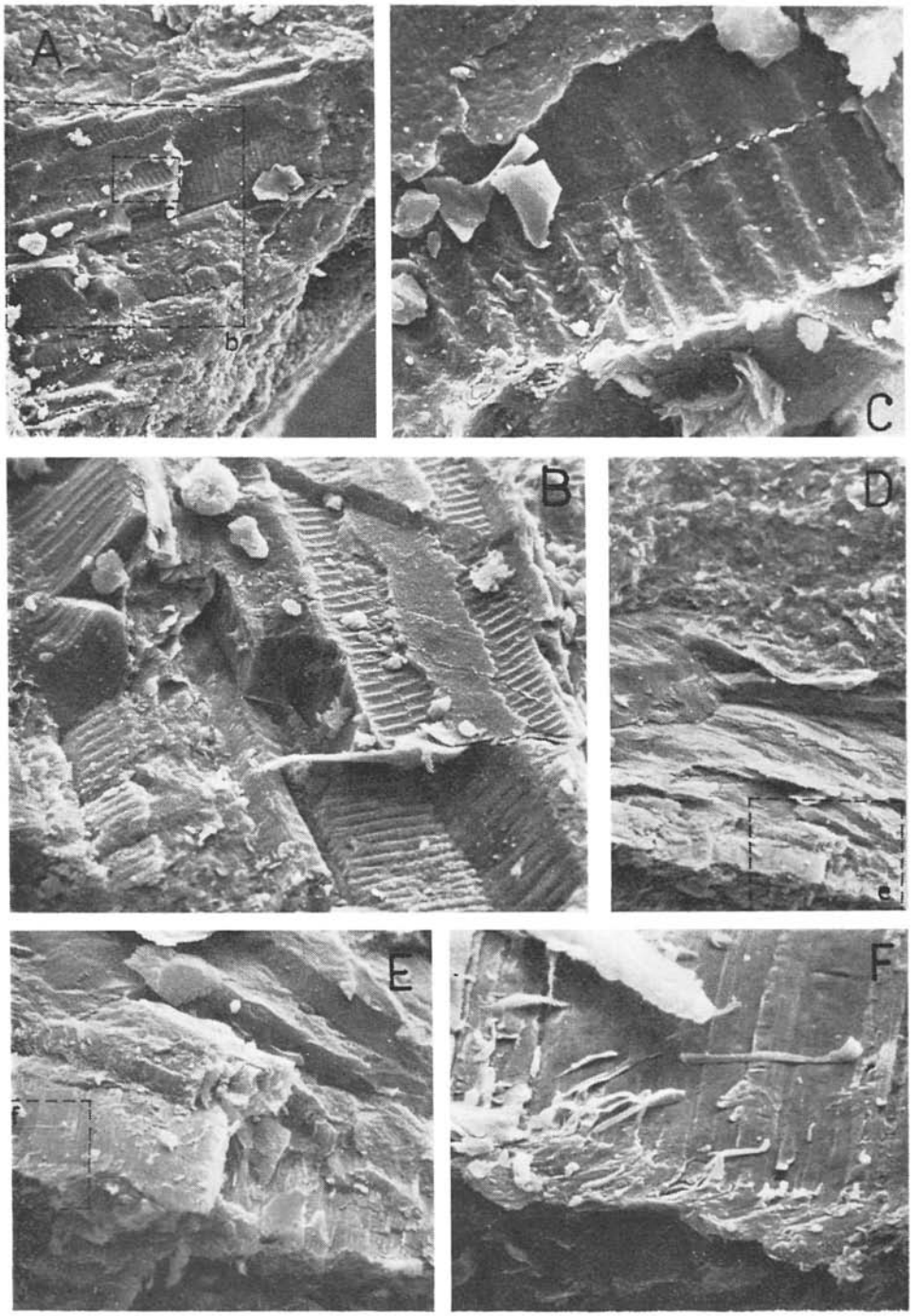

A
b
C
B
D
e
E
F

Fig. 8. Outcrop of the Carpathian Keuper (CK) and Tomanová Formation (TF) in the section Czerwone Źlebki, dolina Kościeliska valley, photo J. Michalík.

Radiometric characteristics

On the basis of natural radioactive element contents, two main rock types can be distinguished in the sequence described. The sandstones are characterized by total gamma-activity ranging from 2 to 5 ppm U_{ekv} and K below 0.1 %, i.e. below detectability value. Uranium content is 2 to 3 ppm and that of thorium 3 to 4 ppm.

On the other hand, the claystones have total gamma-activity 14 to 19 ppm U_{ekv}. The content of K is 0.3 to 0.7 %, uranium 5 to 6 ppm and thorium 20 to 25 ppm. From the radiometric viewpoint, sideritic "mud ores" are a transitional type between the two characterized types. The sandstone radioactivity probably results from radioactive admixtures in quartz grains with a smaller share of potassium in feldspar grains and/or elements of heavy accessory minerals (zircon, monazite). On the other hand, the claystone radioactivity is

Fig. 7. Microstructures of plant remains from the Tomanová Formation at the locality Červený Úplaz. Photo I. Holický (SCAN).
Explanatory notes: a - equisetid stalk, photo 3905, magn. 400×; b - ditto, detail (turn by 90°), photo 3907, magn. 1000×; c - ditto, detail, photo 3906, magn. 4000×; d - cross-section of carbonized plant remains, photo 3908, magn. 500×; e - ditto, detail, photo 3909, magn. 1700×; f - ditto, detail, photo 3910, magn. 6000×.

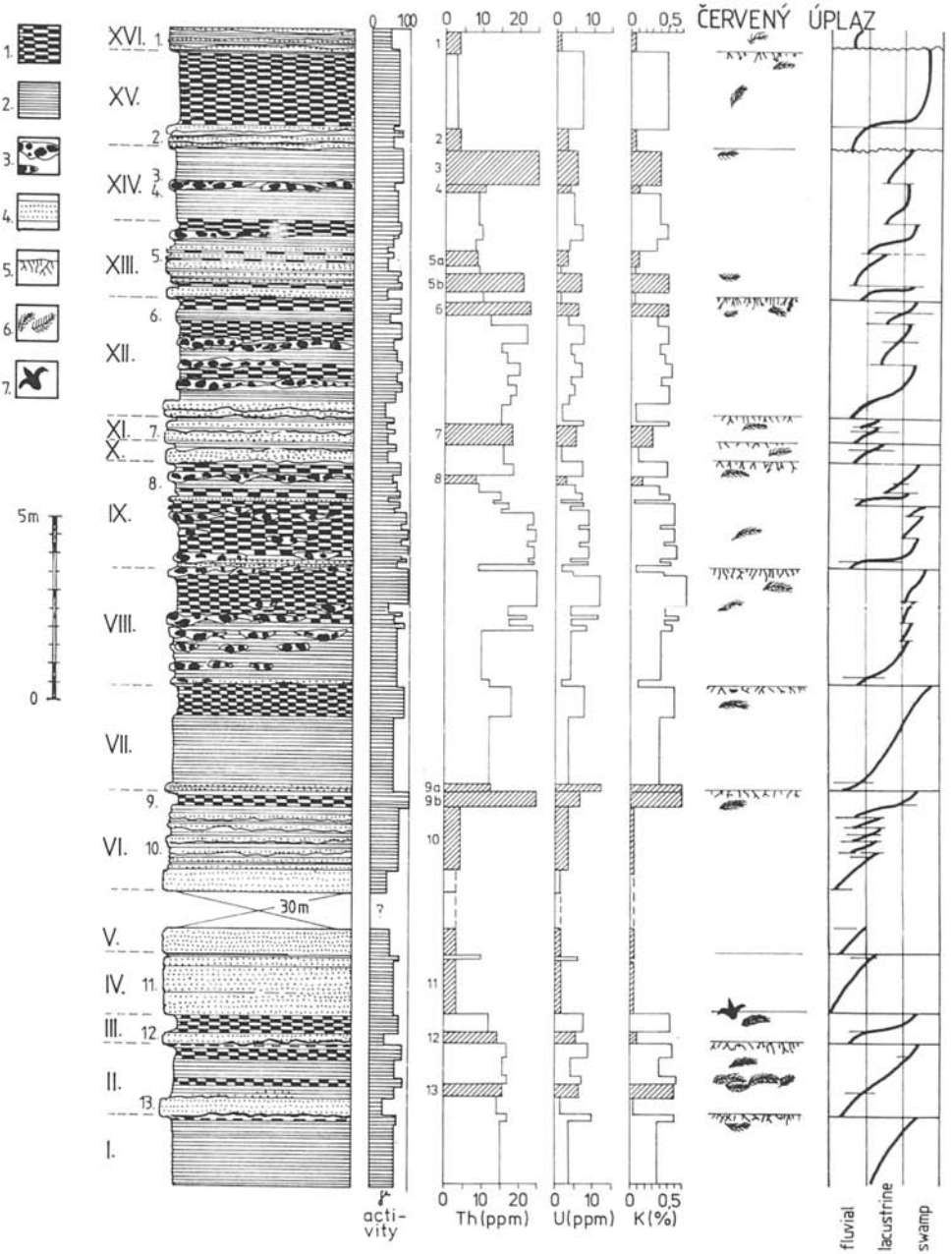


Fig. 9. Vertical distribution of radioactivity values in the section Červený Úplaz. *Explanatory notes:* o — activity, Th, U and K distributions. 1 — black claystones; 2 — dark-gray claystones; 3 — sphaerolitic iron ores; 4 — sandstones; 5 — rhizom horizons; 6 — horizons with abundant plant remains; 7 — dinosaur traces. Orig. J. Michalík.

Table 1

Contents of natural radioactive elements in horizons of the section across the Tomanová Formation Červený Úplaz (Červené vrchy Mts., Tichá dolina valley, Západné Tatry Mts.)

Sample designation (cf. Fig. 1)	Th content (in ppm)	U content (in ppm)	K content (in %)	Th/U ratio
1	03.9	01.0	00.05	03.9
2	03.7	02.9	00.05	01.3
3	25.0	05.4	00.4	04.6
4	10.6	03.2	00.1	03.3
5a	08.2	02.9	00.1	02.8
5b	20.8	06.4	00.5	03.2
6	22.6	05.7	00.5	03.9
7	18.0	05.1	00.3	03.5
8	08.0	02.5	00.15	03.2
9a	12.6	12.5	00.7	01.0
9b	24.8	06.5	00.7	03.8
10	04.3	03.6	00.05	01.2
11	03.6	01.8	00.05	02.0
12	14.5	05.6	00.1	02.6
13	20.4	06.3	00.6	03.2

rather due to sorbtion properties of clay minerals in the rock. The role of the admixture of small accessory mineral grains, however, cannot be ruled out. Potassium content is very low, illite is an unimportant constituent of the rock (Fig. 9).

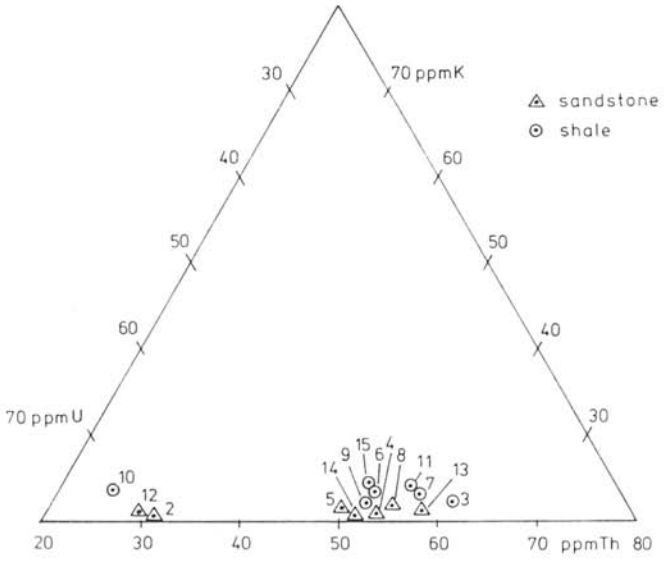


Fig. 10. Relation between Th, U and K contents in samples from the section Červený Úplaz, Tichá dolina valley, Západné Tatry Mts. Orig. V. Kátlovský.

Variations in Th content in the sandstones are probably due to accessory mineral concentrations in laminae and "nests", whereas differences in U content are caused by the variable content of clayey substance in the matrix. Claystones require other explanation: variations in their Th content might be due to accessory mineral contents, but changes in U content are probably related to the variable share of organic material in the rock (Fig. 10).

Conclusions

The marked cyclic arrangement of the described part of the formation proves rhythmically pulsating climate during the sedimentation of the Tomanová Formation. The composition of the cycles suggests rhythmic alternations of periods of abundant fluvial supply separated by arid ones. In the rain period, temporary lakes originated. As they gradually dried up their bottom became a swampy accumulation plain densely covered with ferns and horsetails (Michalík et al., 1976; Michalík, 1978, 1980a—b).

Although the results of the paleobotanic submitted previously study do not allow us to evaluate the taxonomic assignation of the present forms, they may be employed in paleoecological speculations. From the paleofloristic viewpoint, the flora is essentially of ancient, Triassic character (expressed by the dominance of equisetids and ferns), supplemented by Jurassic elements (gymnosperm *Classopollis*. *?Pagiophyllum* etc.). The dominance of ferns in this flora has paleogeographic reasons. The sedimentation area of the Tomanová Formation represented a humid undrained depression - a sort of oasis in a relatively dry to arid region. In more humid periods, it offered a suitable biotope for pteridophytous and other psammophilous as well as palustrinous flora. These periods occurred periodically and supplied the basin with water for relatively long periods of slow aridization. The described flora thus represented a sporadic vegetation cover in the vicinity of temporary lakes, swamps and deltas in a bolson-like area formed on a temporarily emerged segment of the Alpine-Carpathian shelf.

Fairly high thorium and uranium contents is a common sign of the whole sequence of the Tomanová Formation.

Along with other sedimentological and paleontological evidence they indicate a small, relatively isolated undrained sedimentation area, not too far away from the sediment source area.

Acknowledgement: We are obliged to RNDr. E. Planderová, CSc. and RNDr. M. Sýkora, CSc. for their inspiring remarks and RNDr. J. Mikleová for help. For re-drawing the figures we thank Mrs. M. Ružová.

Translated by L. Böhmer

REFERENCES

BERNER, R. A., 1969: Migration of iron and sulphur within anaerobic sediments during early diagenesis. Amer. J. Sci. (New Haven), 267, pp. 19—42.

BLATT, H. — CHRISTIE, J. M., 1963: Undulatory extinction in quartz of igneous and metamorphic rocks and its significance on provenance studies of sedimentary rocks. Journ. sed. Petrology (Tulsa), 33, 3, pp. 559—579.

GOREK, A., 1958: Geologické pomery skupiny Červených vrchov, Tomanovej a Tichej doliny. Geol. Sbor. Slov. Akad. Vied (Bratislava), 9, 2, pp. 203—240.

KOTAŃSKI, Z., 1959: Stratigraphy, sedimentology and palaeogeography of the high-tatric Triassic in the Tatra Mts. Acta geol. Pol. (Warszawa), 9, 2, pp. 113—145.
MICHALÍK, J. — PLANDEROVÁ, E. — SÝKORA, M., 1976: To the stratigraphic and paleogeographic position of the Tomanová Formation in the Uppermost Triassic of the West Carpathians. Geol. Zbor. Geol. carpath. (Bratislava), 27, 2, pp. 299—318.
MICHALÍK, J., 1978: To the paleogeographic, paleotectonic and paleoclimatic development of the West Carpathian area in the Uppermost Triassic. In: Vozár, J. (ed.): Paleogeographic development of West Carpathian Mts. Geol. Inst. of D. Štúr, Bratislava, pp. 189—211.
MICHALÍK, J., 1980a: A paleoenvironmental and paleoecological analysis of the West Carpathian part of the northern Tethyan nearshore region in the latest Triassic time. Riv. Ital. Paleont. Stratigr. (Milano), 85, 3—4, pp. 1047—1064.
MICHALÍK, J., 1980b: Why the "problem of Rhaeto-Norian" in the West Carpathians. Geol. Práce, Spr. (Bratislava), 74, pp. 189—204.
MICHALÍK, J. — KÁTLOVSKÝ, V. — SÝKORA, M. in prep.: Upper Triassic and Lower Jurassic sedimentary development in marginal Fatric area (Havran Nappe, Tatra Mts., Western Carpathians).
RACIBORSKI, M., 1980: Flora retycka w Tatrach. Rozpr. Wydz. mat.-przyr. Pol. Akad. Umiejęt. (Kraków), 21, 2, 1, pp. 243—260.
RADWAŃSKI, A., 1968: Studium petrograficzne i sedymentologiczne retyku wierchowego Tatr. Stud. geol. Pol. (Warszawa), 25, pp. 1—146.
REYMANÓWNA, M., 1984: Flora retycka z Czerwonych Żlebków. In: Paleontologia mezoziku Tatr. Materialy 8. konf. paleontologow PTG, Zakopane 1984, pp. 12—13.
SLIPCHENKO, G. V., 1981: O dvukh geneticheskikh tipakh oolitovykh zheleznikh rud Lissakovskogo mestorozhdeniya (severniy Kazakhstan). Geol. Zhurn. (Moscow), 41, 6, pp. 53—61.

Manuscript received December 5, 1987.