Upper Permian - Lower Triassic evaporites in the Western Carpathians (Slovakia)

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Abstract. The Upper Permian - Lower Triassic Western Carpathians evaporite basins formed in a semiarid climate, generally in non-marine and marine depositional setting. The origin and time/space distribution of marine evaporite basins was connected with transgression, which reflected the beginning of Alpine orogenic cycle. All these marine evaporite basins were rimmed by shallow shelves that became covered by sulphate and in more rapidly deepening part by chloride precipitation. Sedimentary structures indicate that part of the anhydrite and even halite sediments was deposited through the action of gravity currents. Semiarid flash floods were the major suppliers of siliciclastic sediments. Non-marine evaporites (carbonates, sulphates, albitolites) originated in endorheic basins and alkaline lakes as well as by groundwater precipitation.

Key words: Western Carpathians, Upper Permian/Lower Triassic, evaporites, S isotope composition

Introduction

On the territory of the Western Carpathians Upper Permian - Lower Triassic evaporites are found in several tectonic units (Fig. 1). They, however, differ from one another not only in their stratigraphic position, but mainly in structural features and the depositional setting, partly also in mineral composition. In sedimentological analysis of these sequences the main problem is their occurrence in the complicated Alpine structure when extension and original shape of sedimentation basins were reduced to a considerable extent with Alpine orogeny. Moreover, evaporite formations are not cropping out and for this reason they can be studied on the basis of materials obtained from borehole profiles or mine workings only.

From the genetic point of view, the Upper Permian - Lower Triassic evaporites were formed in three fundamental types of sedimentation environment - continental lakes; - groundwater precipitations; - subtropical marine bays and lagoons (Fig. 2). These fundamental genetic types of evaporites were practically established in all main Alpine tectonic units of the Central and Inner Western Carpathians; i.e. in the Tatricum, Veporicum, Zemplinicum, Hronicum, Northern and Southern Gemericum, Turnaicum and Silicicum. Of course, in each of them not all three types are found together or not each of them is represented in more significant amount. As to the amount and variety of development most significant occurrences are in the Northern Gemericum and in units of the Turnaicum and Silicicum.

Geological setting

In Alpine nappe edifice of the Western Carpathians Upper Permian - Lower Triassic evaporite formations are represented in the inner structural zone, which is mainly formed by a complex of pre-Gosau nappe units. A part of them, besides identical Mesozoic formations, also contains an own crystalline basement, the second group of nappes mainly consists of Mesozoic sequences, at most with relics of tectonically reduced Carboniferous-Permian formations in their lower part.

The lowermost tectonic unit, Tatricum, contains medium - to high-grade crystalline complexes associated with deep-seated migmatites and magmatites, which were covered by Permian continental sediments with angular unconformity. Lower Triassic sediments of the Mesozoic cycle are lying parallely disconformably on both structure stages. An identical geological situation is in the Northern Veporicum, the main differences from the Tatric unit are in lithofacial development of the Mesozoic sequences. (Maheľ 1986, Biely et al., 1996). The superficial, Krížna nappe, as the home area of which the unit of the Northern Veporicum is considered, does not contain sediments older than the Lower Triassic (with the exception of the

Tectonic sketch of the Slovak part of Western Carpathians (after Biely et al. 1996)

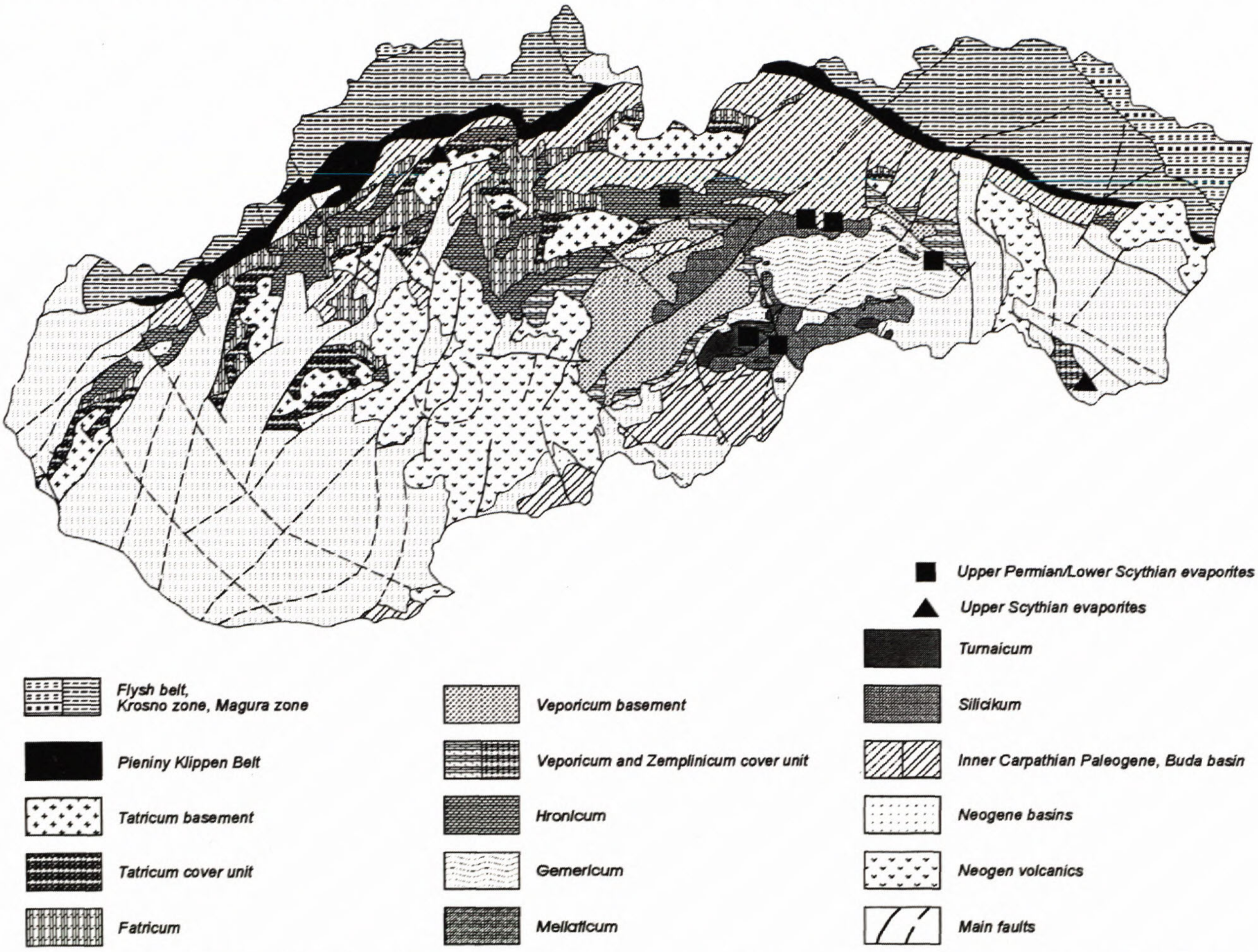

Fig. 1 Distribution of the Upper Permian - Lower Triassic evaporite formations on the territory of the Central and Inner Western Carpathians. Based on the geological map of the Slovakia 1 : 500 000 (Biely et al., 1996)

		CENTRAL WESTERN CARPATHIANS						INNER WESTERN CARPATHIANS			
main paleo-Alpine Western Carpathians units		T	NV	SV	Z	H	NG	SG	M	TU	S
depositional setting											
Upper Permian - Lower Scythian	non-marine: groundwater precipitation	■			■	■	■	■		■	
	endorheic basin					■	■			■	
	alkaline lake						■	■			
	paralic sebkha						■			■	
	marine: lagoon, restricted sea, connected with sebkha						■				
	wide shelf marginal closed sea									■	■
Upper Scythian	marine: lagoon and restricted sea connected with sebkha	■			■						
primary precipitation		sulphates + carbonates					carb. sulph.+ chlor.	carb.	sulphates + carbonates		
Permian/Lower Triassic boundary		disconformity <------------------------------>					gradual		continuation		

N <--S
direction of marine transgression

Fig. 2 Scheme of sedimentary evolution of the Western Carpathians Upper Permian - Lower Triassic evaporite basins.
Explanation to symbols: T - Tatricum; NV - Northern Veporicum; SV - Southern Veporicum; Z - Zemplinicum; H - Hronicum; NG - Northern Gemericum; SG - Southern Gemericum; M - Meliaticum; TU - Turnaicum; S - Silicicum

occurrence of Permian sediments at a small area in the Starohorské vrchy Mts.). From the point of view of the crystalline basement, but also Triassic development, with the Tatricum and Northern Veporicum units also the Zemplinicum unit (Vozárová, 1991), originally delimited as an independent tectonic unit in the southern part of the East Slovakian lowland, is identical (Slávik, 1976). In it only the stratigraphic range of the Late Variscan envelope, which is represented by the continental Upper Carboniferous and Permian in the Zemplinicum, is different. The Mesozoic cycle starts again with Lower Triassic sediments, which are separated from Variscan post-orogenic sediments by a hiatus and parallel disconformity.

A different type of the crystalline basement and also envelope sequences has the unit of the Southern Veporicum. Crystalline complexes are represented by medium - to low-grade metamorphosed complexes, which are highly Alpine-reworked and penetrated by Alpine granitoids. The Late Paleozoic envelope of the Southern Veporicum is represented again by the Upper Carboniferous and Permian rocks, which are parallely disconformably covered by Lower Triassic clastics.

The whole group of the above mentioned basement nappes including the Krížna nappe is overthrusted by the Hronicum nappes (Subtatric nappes sensu Andrusov, 1968). They belong to rootless nappes, mainly consisting of Mesozoic sequences, which are underlain by remnants of Upper Carboniferous-Permian sediments reduced tectonically, preserved in places only.

The southernmost nappe units, in which the crystalline basement is preserved, are the Northern and Southern Gemericum. Rock sequences of the basement of the Northern Gemericum are composed of high-grade and low-grade metamorphosed complexes of oceanic and/or lower crust affinity, mutual tectonic contact of which is overstepped by Westphalian conglomerates. Syn- and post-orogenic Variscan formations are represented by Lower Carboniferous flysch, Westphalian marine and continental, Permian molasse. Characteristic of this tectonic unit is the Upper Permian - Lower Scythian evaporite formation, which is continuously linked to Upper Scythian carbonate-siliciclastic sediments. The basement of the South Gemeride unit consists of low-grade metamorphosed Early Paleozoic flysch, which is covered with angular unconformity by continental Permian sediments, continuously replaced by lagoonal near-shore Lower Triassic sediments.

The nappe units of the Turnaicum and Silicicum mainly consist of Mesozoic sequences, only in a partly of the Turnaicum the Middle Carboniferous flysch formation is preserved at its base. After a stratigraphic hiatus this is covered by continental sediments with angular unconformity and by lagoonal - evaporite formations of Upper Permian age continuously evolved from them.

Depositional setting

Groundwater precipitations

Minerals forming by precipitation from groundwaters mainly occur as crusts or pedogenic nodules. They were associated with relatively little yielding (poor) regime of groundwaters under continental, semiarid climatic conditions. Calcite nodules and calcretes (often pink-coloured from the present Fe pigment) are known from Permian sediments in the Hronicum (Malužiná Formation), Northern Gemericum (Petrova hora and Novoveská Huta Formations) and Turnaicum (Brusník Formation). Distinct cyclic fluvial sediments, with intermittently developed discharge lakes in the flood plain, contain besides calcite nodules also Fe-dolomite concretions, testifying to slightly reductional conditions at the floor of shallow, stagnant reservoirs. In the Permian of the Hronicum also horizons of caliche or cohesive crusts (calcite, dolomite) are known, attaining several dcm to 1 m on an average, laterally linked to calcretes scattered in surrounding sandy and clayey sediments.

Continental sebkhas (endorheic basins)

Evaporite sediments belong here, which are formed by precipitation in closed basins, accumulation and evaporation of fluvial inundation waters in semiarid areas. This type of environment is represented by small gypsum lenticles established in upper parts of megacycles of the Permian sequence in the Hronicum (Ďurovič, 1971, Novotný & Badár, 1971). They usually contain clayey admixture associated with a variable amount of grains of aleuritic and sandy size. This type of continental evaporites is bordered by horizons of gypsum and/or carbonate sandstones.

Alkaline lakes

Sediments of alkaline lakes were interpreted in Permian sediments of the Northern and Southern Gemericum (Čurlík et al., 1984, Vozárová & Vozár, 1988). They are represented by horizontally laminated, fine grained sediments, originally claystones, aleurolites, less fine grained sandstones with carbonate cement and a high content of authigenic to anchimetamorphic albite. We suppose that albite formed by subsequent alteration of zeolites, which were linked genetically with decomposition of acid volcanoclastic material in highly alkalic environment of lakes. With these sediments horizons enriched in Ca and Ca-Mg carbonates are associated laterally, also with sediments having higher content of siliceous cement.

Paralic sebkhas and subtropical marine environments

They are evaporite sediments linked genetically with the environment of supratidal flat, connected with marine environment spatially and in time, with separated lagoons, bays or shallower or deeper parts of shallow sea basins.

Upper Permian - Lower Scythian horizon: The largest accumulations of such evaporite sediments are preserved amidst Upper Permian - Lower Scythian sediments of the Northern Gemeric (NG), Turnaic (T) and Silicic (S) units. All these occurrences of evaporites (NG - Novoveská Huta Formation, S and T - Perkupa Formation) belong to transgressive formations, reflecting the transgressive phase of salinity. In the Northern Gemericum and Turnaicum evaporite sediments occur amidst a sequence, which starts with continental red-beds and terminates with deposits of open sea. In the Silicicum unit the substratum of the evaporite formation on the territory of Slovakia is not documented. The main evaporite minerals are sulphates, associated with less amount of dolomite, which occurs underlying the whole evaporite formation or also at the base of partial cycles inside the evaporite formation. In the Northern Gemericum, besides that, in the frame of evaporite breccias halite and in mineralogical amounts also potassium salts - sylvite and carnallite are present (Ďurkovičová in Maheľ & Vozár 1973).

Two fundamental sedimentation models are characteristic of this sedimentation area: 1. Clastic facies of red-beds type prograding into arid sabkha-lagoonal and near-barrier environments, with intermittent connection to open sea; 2. Evaporite aride coasts linked to a mobile, highly subsidentially sinking basin, with well developed slope and basin facies.

Northern Gemericum: In this zone evaporite facies were established in mine workings (Rudňany, Poráč, Gretľa, Novoveská Huta, latest Markuška - Šafárka) and were attested in numerous boreholes in the areas of Spišská Nová Ves, Krompachy and Košická Belá. The variegated red-beds and evaporite sequences of the Northern Gemericum are part of the Novoveská Huta Formation. The age of the evaporite horizon was established as Upper Permian - Lower Triassic however, not later than the Smithian as proved on the basis of its occurrence underlying the zone with *Claraia clarai* already in the sense of older data from boreholes SM-1 and SM-2 (Maheľ & Vozár, 1971) and also confirmed again by newer stratigraphic data of Salaj (in Vozárová et al. 1993) from borehole RHV-25 on the basis of microfauna *Meandrospira cheni* (Ho) and *Mendrospira pusilla* (Ho). Characteristic of lithological development of the Novoveská Huta Formation is a clastic basal sequence, which is developed regionally. This horizon consisting of sediments of psephitic and psammitic grade (Strážany Member), is typical in relatively mature detritus with prevalence of quartz grains (60-70 % and in places also more) and relatively abundant intraformational clasts, mainly of volcanics coming from the underlying, Petrova hora Formation. These areal sheet floods of alluvial sediments at profiles alternate with deposits of continental sabkha and/or alkalic lakes (last documented by horizons of carbonatic sandstones and aleurolites alternated with layers of albitolites).

Overlying basal clastic sediments evaporite horizons are developed, containing also wedges of red-beds type clastic continental sediments, indicating on the whole a marginal position of evaporite facies sedimentation in the zone, of paralic sabkha and lagoon. The precondition of great facial differentiation in the frame of evaporite sediments is the existence of an areally extensive supratidal flat and lagoon, which was gradually linked to marine environment. The layers of evaporites, several tens of metres thick (also in order of hundreds of metres and more as a consequence of tectonic boudinage) alternate with greengreyish or variegated clastic sediments. In evaporite sediments are in places well preserved sedimentary structures, mainly horizontal lamination, nodular structures, ripplemarks and an amount of structures proving redeposition of evaporite precipitates by gravity currents and slumps and/or cohesive flows similar to turbidity currents. A part of horizons of resedimented evaporites are beds of graded-bedded and massive anhydritearenites, pebbly anhydritestones (also described by Karoli 1993) and also halite breccia (described from borehole SM-1; Maheľ & Vozár, 1973).

Pebbly anhydritestones have matrix supported structure and most probably represent high density debris flow deposits. Thickness of beds most often attains 1 to 2 m, rarely more. The detritus in them consists of fragments of light- and dark-grey dolomites, grey dolomitic shales, green, grey, very scarcely red claystones and siltstones, rarely fine-grained sandstones and also fragments of fine-grained acid volcanoclastics. Clastic grains of psamitic grade are formed by quartz, feldspar and clastic micas. The size of psephitic grains varies from 2 to 35 mm, only a small part attains 50 mm to 70 mm. They are angular and/or subangular. The matrix is formed by grained anhydrite with admixture of originally clayey fraction, in which diagenetic new forms of albite, dolomite, scarcely of quartz are scattered.

Anhydritearenites are associated with pebbly anhydritestones and also non-evaporite sediments, mainly with dolomitic shales and clayey aleurolites. These form thin beds of massive, indistinctly horizontally laminated, rarely graded-bedded structures. The clasts of psammitic grade are concentrated in laminae or are of chaotic distribution within the bed, less often ordered graded positively.

Halite breccias are composed of greyishwhite or slightly pinkish halite, in which subangular, less angular fragments of greenishgrey claystones and shales are enclosed. The fragments of shales are most often of ellipsoidal, oval shape. In horizons with content of halite are often marks of dissolution and recepicitation. Halite breccias, however, may be considered as primary, with regard to the fact that at profiles they are alternating with laminae or thin beds of claystones. Mahel' & Vozár, (1973) mention the content of halite in breccias in the extent of 40 to 90 %. In fragments of claystones contents of sulphate and halite are mentioned in the extent of 10 to 30 % and carbonates up to 15 %. Ďurkovičová (in Mahel' & Vozár 1973) also identified in this horizon sylvite, in concentrations of 6,5 and 8,5 %.

Besides the above mentioned types of evaporite sediments thin layers of light-grey, crystalline anhydrites, in places with fine laminae of yellowishgrey dolomite are associated in these horizons. Dolomites, which in places occur with anhydrites are mostly fine-grained, of dolmicrite character, without fauna and with gypsum crystals locally only. Yellowishgrey fine-grained dolomites of cellular structure, with galls of greenishgrey or red shales, which are found in the upper part of and overlying the anhydrite horizon, were described at the new evaporite deposit Markušovce - Šafárka (Jančura & Šašvári, in this volume).

Besides primary evaporites several generations of epigenetic sulphates are present, which are a reflection of dissolution and mobilization of primary evaporite minerals as a consequence of post-sedimentary diagenetic to anchimetamorphic alterations and mainly of tectonic reworking of evaporite facies along a system of faults and/or subvertical tectonic zones (plastic deformation and polyphase dissolution and recrystallization in the system of circulating fluids).

Turnaicum and Silicicum: Upper Permian - Lower Scythian evaporites of the Turnaic and Silicic units are of equal lithological character. They were described under the uniform term Perkupa Formation (Mello et al., 1996) with the main occurrences in the Slovak Karst and northern Hungary in the Aggtelek Karst near the locality Perkupa (Kovács et al., 1989). In the Turnaic unit on the territory of Slovakia to this formation evaporites from borehole DRŽ-1 studied in detail lithologically by Karoli (in Mello et al. 1994), may be ranged. Underlying the classical Werfen Formation of the Silica nappe, evaporites are known from many boreholes in the area of Rožňava (G-1, G-1/2), Gemerská Ves (Š-7 to 49; VŠ-1), Bohúňovo (VB-20; SA-2 to 8; SA-12 to 16; VPS-4 to 12) and further (Bystrický & ORAVCOVÁ 1962; Dianiška et al., 1984 and others).

Primary facies of evaporites of the Perkupa Formation similarly as in the Northern Gemericum include clastic facies of evaporites - pebbly anhydritestones (described by Karoli, 1993 as anhydriterudites) and anhydritearenites. On the contrary to the Northern Gemeric Novoveská Huta Formation, however, in pebbly anhydritestones among clasts, fragments of shales of violet and/or red colour, even fragments of sandstones are not found. Besides grey and greenishgrey claystones and aleurolites among fragments dark-grey to black dolomites, fine-laminated dolomites, in irregular horizons scattered fragments of acid volcanoclastics and in small amount fragments of fine-laminated anhydrites are present. The content of clasts in pebbly anhydritestones is not exceeding 40 %. Thick beds of these paraconglomerates have a massive and/or slightly graded-bedded structure. The roudness of clasts is mostly subangular. The matrix is anhydrite, highly gypsified.

In anhydritearenites clastic grains are formed by anhydrite, dolomite and dolomite shales. Grains of authigenic quartz and feldspars are scarce. The structure of anhydritearenites is massive or horizontally laminated. Lamination is caused by fine laminae of greenishgrey clays and/or yellow and yellowishgrey and black dolomites, alternating with thick layers of anhydritearenites. A part of evaporite horizons are layers of fine laminated sediments, in which laminae of anhydrite and light-coloured and dark dolomite are alternating.

Upper Scythian horizon (Röt): Evaporites of this stratigraphic range were recorded by borehole MGF-1 in the Malá Fatra Mts. (Vozárová & Vozár, 1986). The evaporite horizon is evolving gradually from a variegated, siliciclastic formation, characteristic of the Lower Scythian of the Tatric unit in the Western Carpathians (Lužná Formation). In the basal part (about 30 m) this consists of a horizon with cyclical alternation of fine-grained oligomict conglomerates, quartz arenites and subarkoses and/or wackes of adequate mineral composition. The middle part (40-50 m) is formed by a complex of thin- and medium-bedded (thicknesses 5-20 cm) light-violetishgrey and violet sandstones and shales, into which thin interbeds of oligomict conglomerates are wedging in. From structural features ripplemarks, horizontal lamination, load casts, bioturbation structures and erosional wash-outs at the base of coarse clastic layers are typical in these sediments. The associated shales contain nodules and concretions of carbonates.

In the upper part of the Lužná Formation in borehole MGF-1 layers of marly shales and intramicrites were established, in which a poorly preserved foraminifer microfauna was found, determined by dr. Salaj as the species *Glomospirella* sp. With regard to the small size they are generally considered by the author as Lower Triassic. The layers of intramicrite and dolosparite alternate first with violet and greenishgrey shales and aleurolites and in overlying direction are gradually replaced by a horizon of anhydrite breccias (thickness 30 m). The breccias with supporting matrix structure contain fragments of dolomite and claystones, which are cemented by anhydrite, in places secondary-gypsified anhydrite matrix. Besides that small amounts of baryte and new forms of quartz and albite were established. Overlying the anhydrite breccias, a horizon of black shales with interbeds of anhydrite, gypsum and argillaceous dolomite occure. The remaining part of the evaporite formation is reduced tectonically at the borehole profile.

The similar sedimentary environment is assumed for the Upper Scythian anhydrites of the Zemplinicum (borehole near Ladmovce vill.).

Isotopic composition of anhydrites

Isotopic composition of O and S was studied in anhydrites of the Turnaic unit in borehole DRŽ-1 and particularly only isotopic composition of S in anhydrites of the Northern Gemeric, Turnaic and Silicic units as well as in Upper Scythian evaporites in the Tatric unit in the Malá Fatra Mts. (Fig. 3).

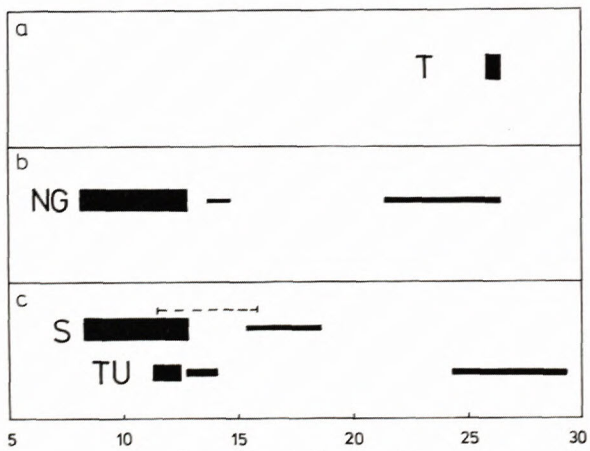

Fig. 3 Spread of isotope sulphur data for anhydrite from the Upper Scythian of the Tatric Unit (a.), the Upper Permian - Lower Scythian of the Northern Gemeric unit (b.) and the Turnaic and Silicic units (c.). Thickness of lines corresponds to frequency of data. Dashed line (diagram a.) belongs to isotope sulphur data for pyrite.

The results of isotopic analyses of S in the Turnaic unit (borehole DRŽ-1; Ďurkovičová & Repčok in Mello et al., 1994) point to the occurrence of two groups of anhydrites, with different content of S heavy isotope. The majority of samples have $\delta^{34}S$ values within the range of 11.4 to 12.3 ‰ (from the total amount of 19 samples 11). In four samples somewhat higher values were recorded - within the range of 12.8 and 14.1 $\delta^{34}S$ ‰. Extremely high values were established in further four samples - within the range of 24.4 to 29.3 $\delta^{34}S$ ‰. S isotopic analysis document the marine origin of evaporites, the contents of heavy sulphur isotope correspond to composition of marine evaporites from the time section of the Upper Permian - lowermost Triassic (NIELSEN 1965, Holser et al., 1977, Claypool et al., 1980). Ďurkovičová & Repčok (l.c.) interpreted samples with extremely high content of sulphur heavy isotope in two ways: they either correspond to conditions of precipitation in a stratigraphically younger period (Upper Scythian = Röt) and were tectonically folded in the whole complex or their isotopic composition was influenced by activity of sulphate - reducing bacteria. We tend to the latter interpretation, because horizons of these anhydrites are not only reduced in thickness, but also secondary contain magnesite and a high amount of organic substance. Isotopic composition of sulphate ion oxygen was established at the borehole DRŽ-1 profile only in 7 samples and varies within the range of 10.6 to 14.9 ‰ $\delta^{18}O$, indicating considerable variability. All these values, however, correspond to or are little different from the diapason Upper Permian - Lower Triassic at the age curve of oxygen isotopic composition of marine evaporites (Claypool et al. 1980).

In the Silicic unit, in the area of Strelnice in the Slovak Karst, Kantor (1972) established S isotopic composition from anhydrites. Isotopic composition of S from the bulk of anhydrites (26 samples) in borehole G-26 is relatively homogeneous. It varies within the range of $\delta^{34}S$ from 8.3 to 12.8 ‰, corresponding to the values mentioned for Upper Permian marine evaporites. Only three samples escape from the mentioned range ($\delta^{34}S$ = 15.5 and 18.6 ‰). Kantor (l.c.) interprets this enrichment of anhydrites in sulphur heavy isotope by the activity of sulphate reducing bacteria. The author confirmed his statement by data of sulphur isotopes composition from associated pyrites, in which $\delta^{34}S$ values varied within the range of 11.5 to 15.9 ‰ (Fig. 3).

Most isotope analyses of S were performed at anhydrite occurrences in the Northern Gemericum (worked out comprehensively by Kantor et al., 1982). From borehole SM-1 13 samples were elaborated, with isotope values $\delta^{34}S$ varying within the range of 10.1 to 12.7 ‰. These values, highly enriched in light sulphur, are comparable with data mentioned from the Zechstein in Western Europe. In borehole SM-2, situated in the equal area (loc. Smižany), from 21 samples the majority are also showing low contents of heavy sulphur - $\delta^{34}S$ within the range of 9.1 to 12.7 ‰. Four samples contained higher $\delta^{34}S$ values, within the range of 14.3 to 14.7 ‰. Even 7 samples from the given complex, however, displayed extreme enrichment in isotopes of heavy sulphur, with $\delta^{34}S$ values within the range of 21.4 to 26.6 ‰. Kantor compared these anhydrites with extreme contents of heavy sulphur with Upper Scythian marine evaporites (saline Röt in western Europe). This interpretation corresponds to the geological situation of Mahel' & Vozár

(1971, 1973), according to which the evaporite horizon occurs in the frame of a complicated fold/upthrust structure, in the core of which Middle Triassic carbonates are preserved. In the deposit area of Tolstein and Grétla, south of Spišská Nová Ves, 14 samples from mine workings and further 18 samples from boreholes in the area of the locality Teplička (borehole Š-866, SB-4) were analysed. From 14 samples coming from mine working in 8 samples $\delta^{34}S$ contents varied within the range of 10.1 to 11.4 ‰, with values lower in two samples (8.7 and 7.8 ‰) and, vice versa, higher in further two samples (13.7 and 14.3 ‰). Only in one layer extremely high contents of heavy sulphur were found ($\delta^{34}S$ = 26.1 ‰). Thus the overwhelming majority of samples are characterized by low contents of heavy sulphur isotope, what is typical of marine evaporites of Upper Permian age. The values around 13 to 14 ‰ $\delta^{34}S$ most likely correspond to younger, Lower Triassic horizons of the evaporite formation. The sample with extreme contents of heavy sulphur isotope, according to data of Kantor (l.c.), was taken in close proximity of tectonic borders of the deposit, what could be influenced by this fact. All other anhydrite samples, obtained from the mentioned boreholes, have $\delta^{34}S$ contents in the extent of 9.2 to 10.7 ‰ (11 samples) or 9.6 to 12.5 ‰ (7 samples), fully corresponding to marine evaporites of Upper Permian/ Lower Scythian age. Similarly also $\delta^{34}S$ values from anhydrites obtained from boreholes in the area of Rudňany (borehole RG-3) and Biele vody (borehole SB-10) are varying in this extent. From 11 samples $\delta^{34}S$ values in the extent of 8.1 to 12.8 ‰ were obtained.

From Upper Scythian evaporites of the envelope group in the Malá Fatra Mts. (borehole MFG-1; Kantor, 1988) 3 samples were analysed, which are characterized by relatively stable isotope composition. Values of $\delta^{34}S$ are varying within the range of 25.82 to 26.33 ‰ and correspond to the grades of enrichment in heavy sulphur by marine sulphate from the time section of the upper part of the Lower Triassic, in the sense of data according to the time scale of Claypool et al. (1980) as well as data from the germanic Röt (Nielsen 1965) and from some localities in Austria (Pak, 1974; Klaus & Pak, 1974).

Discussion and conclusion

In the Central and Inner Western Carpathians, in the Upper Permian - Lower Triassic interval evaporite sediments of different genesis, as well as chemical and isotope composition and of course, also different as to the amount of occurrence and their economic importance occur. In the Central Western Carpathians only evaporites of non-marine origin formed in the Upper Permian and Lower Scythian, either as groundwater precipitates or as deposits of endorheic basins and alkalic lakes.

In equal time interval marine evaporites originated in Inner Western Carpathians. From the point of view of the lithological character and spatial linking to the associated non-evaporite sequences in lateral as well as vertical direction a genesis in two subenvironments may be taken into consideration.

i) The evaporites, which originated in separated lagoons or marginal parts of the sea and were associated with deposits of paralic sabkha or in the fore shore part with deposits of semiarid playa and alluvial fans on the one hand and with open sea on the other hand. A representative of this environment are evaporite sediments of the Northern Gemericum. The proximity of semiarid continental flat is well documented by interlayers of red beds type sediments or redeposited fragments of variegated shales, sandstones or ash rhyolite tuffs directly in evaporite clastic sediments. The prevalence of redeposited evaporites (anhydritearenites, pebbly anhydritestones), their structural features and distinct cyclity or intercalations of continental detritus document considerable synsedimentary tectonic activity and repeated subsidence of the sedimentation basin. Laminated and graded anhydritearenites have sedimentary structures characteristic of transport in turbidity flows and debris flow, structureless, thick beds deposited earliest as grain flow (so interpreted by Karoli, 1993) or fluxoturbidites. The matrix supported conglomerates correspond to deposits of high-density debris flow, which in parts with distinct content of continental detritus were influenced by storm activity. The existence of these sediments is conditioned by a bathymetrically considerably dissected, also generally shallow-water, unequally subsiding marine sedimentation basin. Bathymetric unequality resulted from tectonic breaking of sedimentation basin floor by faults of different activity in space and time. Alternation of relatively shallower and deeper parts is also documented by occurrences of halite-claystone breccias. We suppose that they originated in an area near to the depocentre, from highly saturated, subtropical salt brines in relatively calm periods, interrupted by rushes of rain freshwater, as represented by interbeds of claystones and also admixture of clay in halite. Precipitation of a small amount of sylvite associated sporadically with halite could have been brought forth by overlapping of salt brines with rain waters, making possible oxidation of organic compounds, which reduce solubility of sylvite in salt brine (Steinike, 1962). In times of higher tectonic activity claystone-halite sediments were redeposited into relatively deeper parts of the depocentre. The original admixture of clay in places gives halite a grey colour. A part of salt breccias is linked genetically to post-depositional leaching and consequently to plastic deformation and pressing of claystone material in the halite matrix (evaporite solution breccia). The marginal deposition, under conditions of paralic sabkha, is documented by nodular anhydrites.

ii) Evaporites, which originated in marine basin with wide shelf of extensive surface. Evaporite sequences of the Turňa and Silica nappe units belong here. According to Karoli (1993) these sediments may be interpreted as a result of intense precipitation on platform and their subsequent destruction at water level and contingent re-deposition into relatively deeper and in places more reductional parts of the original basin. The sediments have sedimentary structures indicating redeposition in an environment of thin non-cohesive currents as also testified by missing or only little represented clay in anhydrite matrix. When compared with the preceding type, the continental source area provided essentially less amount of siliciclastic detritus, wedges of continental red-beds are completely missing.

Upper Scythian evaporites belong to marine evaporites of the first type, originating at a coast dissected tectonically, with hypersaline lagoon, linked to paralic sabkha in direction to the continent.

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